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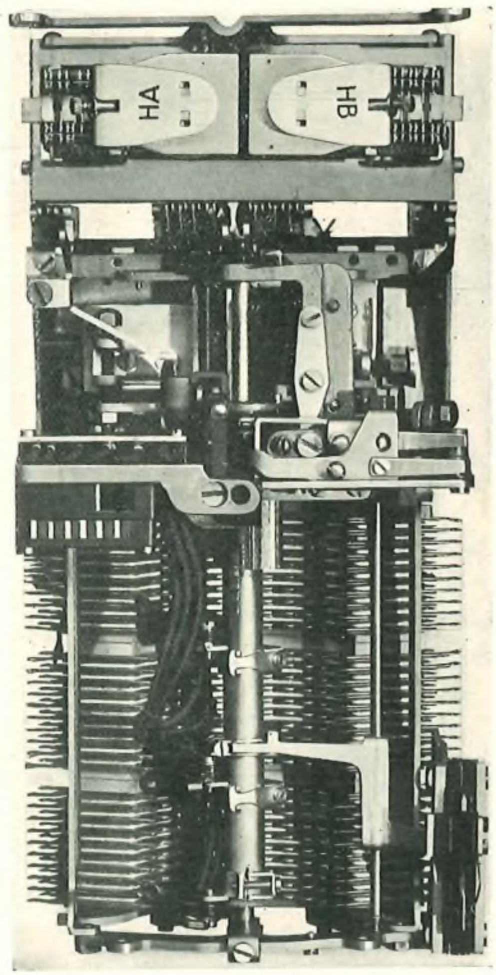

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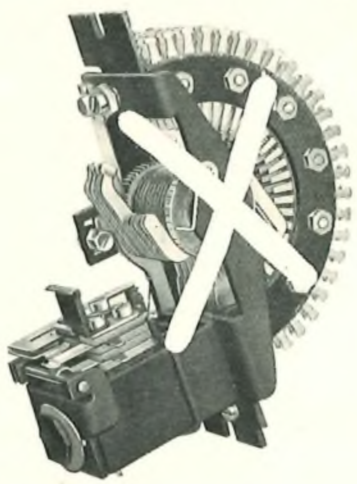

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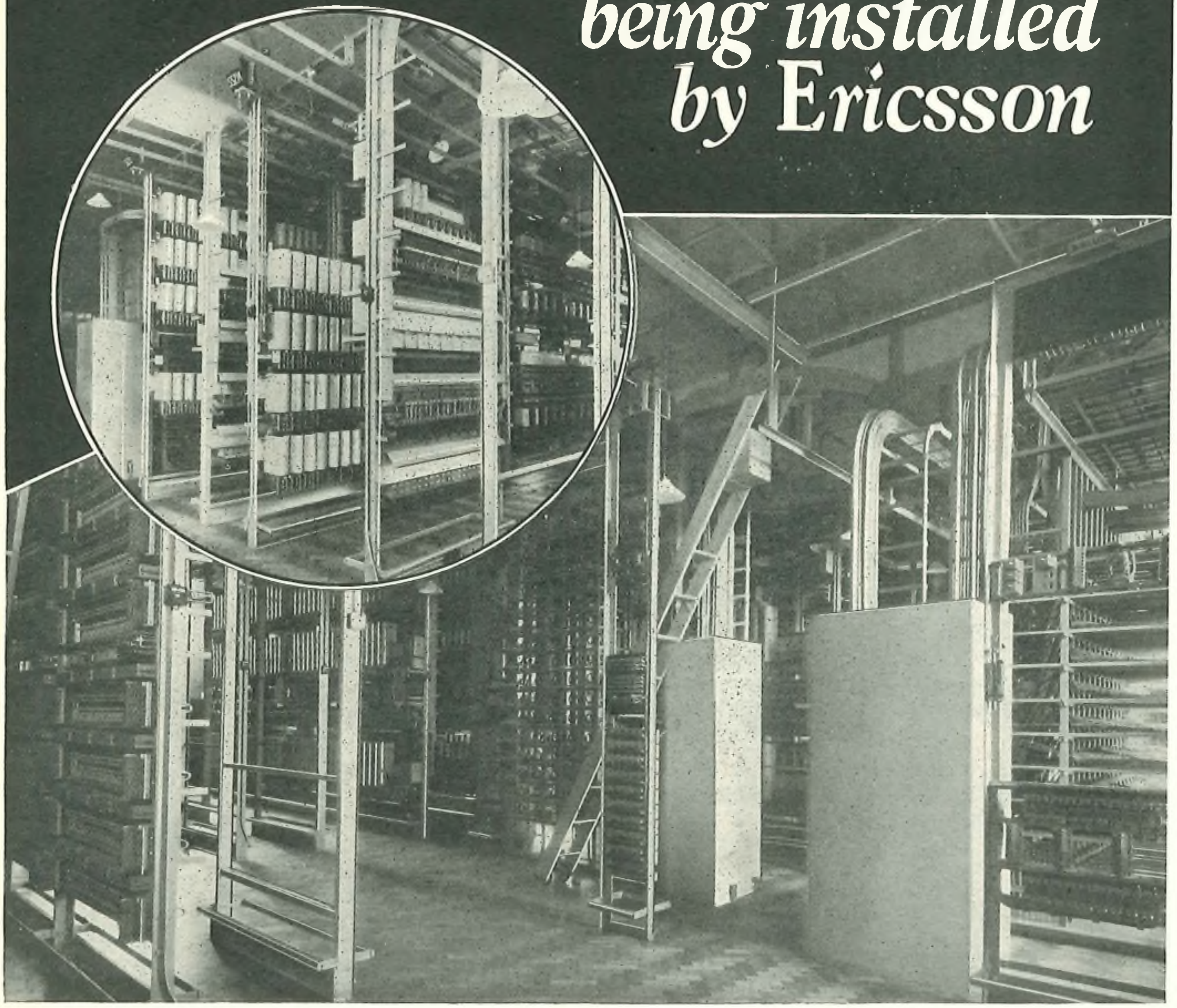

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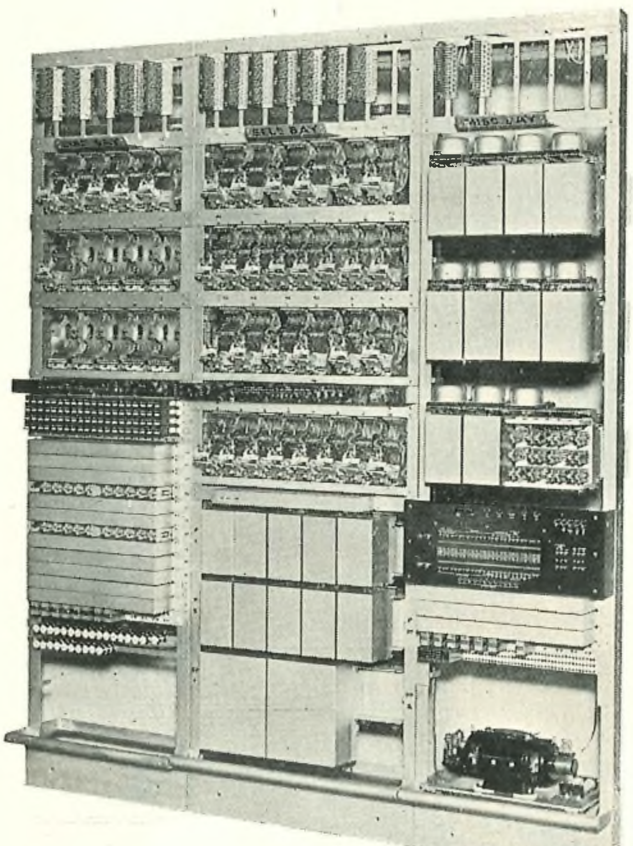

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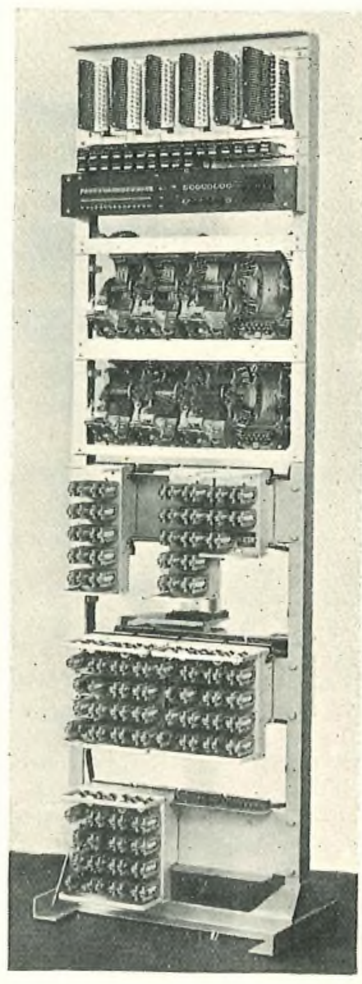

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THE Post Office Electrical Engineers' Journal

The New Inland Telegraph Service

C. J. MERCER, M.I.E.E., Mem.I.R.E.

A COMPREHENSIVE system of underground telegraph cables, carrying the telegraph circuits connecting the largest towns of the country, was constructed during the first decade of the present century and has been extended from time to time in conjunction with developments of the corresponding main line telephone system. These cables have formed the backbone of the telegraph service, and their beneficial effect upon its stability will be realized by a scrutiny of Fig. 1, which is a plan of the system as it existed up to a few months ago. The circuits carried in these cables were worked by the direct current methods which have been in nearly exclusive use during the century or so in which the electric telegraph has had its existence. Until recently it appeared likely that these cables and these methods would continue to be so used more or less indefinitely, but a rival to the direct current telegraph has arisen in the various multi-channel voice-frequency systems which have been greatly improved in recent years and have slowly but surely made headway against the entrenched position of their predecessor. It is a repetition of the story of the electric power industry, in which the advantages of alternating current from the transmission standpoint have resulted in direct current being ousted from its premier place.

Multi-channel voice-frequency telegraphs are by no means a new development. As far back as 1900, M. Mercadier, the French telegraph engineer, invented a 12-channel voice-frequency system for operation on a telephone loop, and his method was actually tried in this country, but was not proceeded with because it caused interference with neighbouring telephone circuits owing to the high power input to line which was necessary at a time when valve repeaters and amplifiers were unknown.

A further incentive to the introduction of alternating current methods in telegraph practice has been the necessity for co-ordinating the line plant of the telegraph and telephone services in order to secure the advantages and economies of a system which could be used for either service. The voice frequency telegraph which, as the name implies, makes use of the same band of frequencies as telephone speech, has provided the link by which the " com-

FIG. 1.—MAIN UNDERGROUND TELEGRAPH ROUTES; DUCTS AND CABLE COMPLETED AT 31 MARCH, 1933.

plete co-ordination " long desired but hitherto unattainable has been achieved.

The use of alternating currents of voice frequency interrupted in accordance with a suitable code such as the Morse or Teleprinter codes provides a means of telegraph signalling which is almost without distance limit as in the case of telephony. The restrictions imposed on direct current telegraphy by the CR law which states that for a cable of given capacity C per mile and resistance R per mile the maximum speed obtainable is inversely proportional to CR and therefore to the square of the length of the circuit now disappears or rather it re-appears in a form which can be compensated by the use of valve repeaters.

As so often happens when big changes are concerned, the final pressure came from without. It was the necessities of the telephone service which forced the telegraph service to change its methods. The introduction of the " on demand " trunk service appeared likely to be hampered by a shortage of main underground cable lines on certain routes and, in a period of intense national economy, it would have been difficult to obtain the capital for the necessary extensions. It was possible to recondition the telegraph cables to render them suitable for the telephone service, but the financial success of such a scheme obviously depended upon the telegraphs being worked by methods which would result in economies of line plant to an extent sufficient to justify the expenditure involved in reconditioning the cables and of furnishing the telegraph system with the equipment to enable it to be operated with a smaller number of conductors side by side with the telephones. The solution of the problem was found in the adoption of the system which has been developed and manufactured in Great Britain by Messrs. Standard Telephones and Cables, Ltd. It is an eighteen channel system, using 18 tones, and is operated upon four-wire repeatered telephone circuits, identical in all respects and fully inter-changeable with the lines used for the telephone trunk service. The " go " and " return " loops of the circuit each carry eighteen channels, giving the equivalent of that number of full duplex circuits. A description of the system was given in Vol. 25 of this Journal (pages 8 to 16) to which the reader is referred. The present article will, however, describe some of the accessory equipment which has been designed in the Post Office Engineering Department for use in conjunction with the multi-channel system.

The scope of the scheme will be evident from Fig. 2 which shows the number and type of telegraph conductors which would be released under the complete voice frequency proposals embracing the Northern, Western, Eastern and South Eastern cable systems. The Northern and Scottish portions of this scheme have been authorized and are under construction, being due for completion at the end of the current year. Fig. 3 indicates the centres included and the number of multi-channel circuits to be set up. The number of channel ends to be provided for at each centre under this instalment is as follows :—

London ...	234	Derby	36
Birmingham ...	120	Bristol	30
Leeds	180	Cardiff	18
Grimsby ...	24	Glasgow ...	102
Hull	30	Edinburgh ...	60
Liverpool ...	84	Dundee ...	12
Manchester ...	132	Aberdeen ...	24
Newcastle ...	48	Belfast ...	18
		Milford Haven...	6

The new telegraph line system has been designed to provide adequate facilities for crossing and extending channels for special events and for making up circuits by alternative routes in emergency. It comprises links between London and the large towns and, in addition, cross-country links between provincial centres, each centre being at an angle of one or more triangles of communication so as to secure freedom from complete isolation by the breakdown of one link in the network. In cases where the method of triangular routing is not practicable, it will be especially necessary to ensure that reserve circuits are carried by a different cable route from the working circuit.

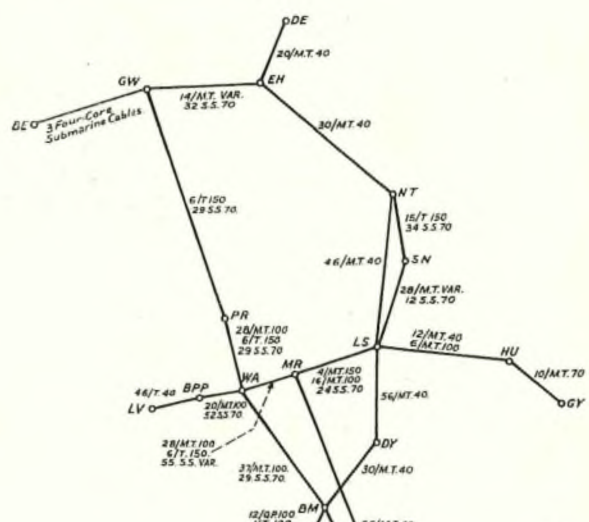


FIG. 2.—NUMBER AND TYPE OF TELEGRAPH CONDUCTORS RELEASED FOR TELEPHONE SERVICE.

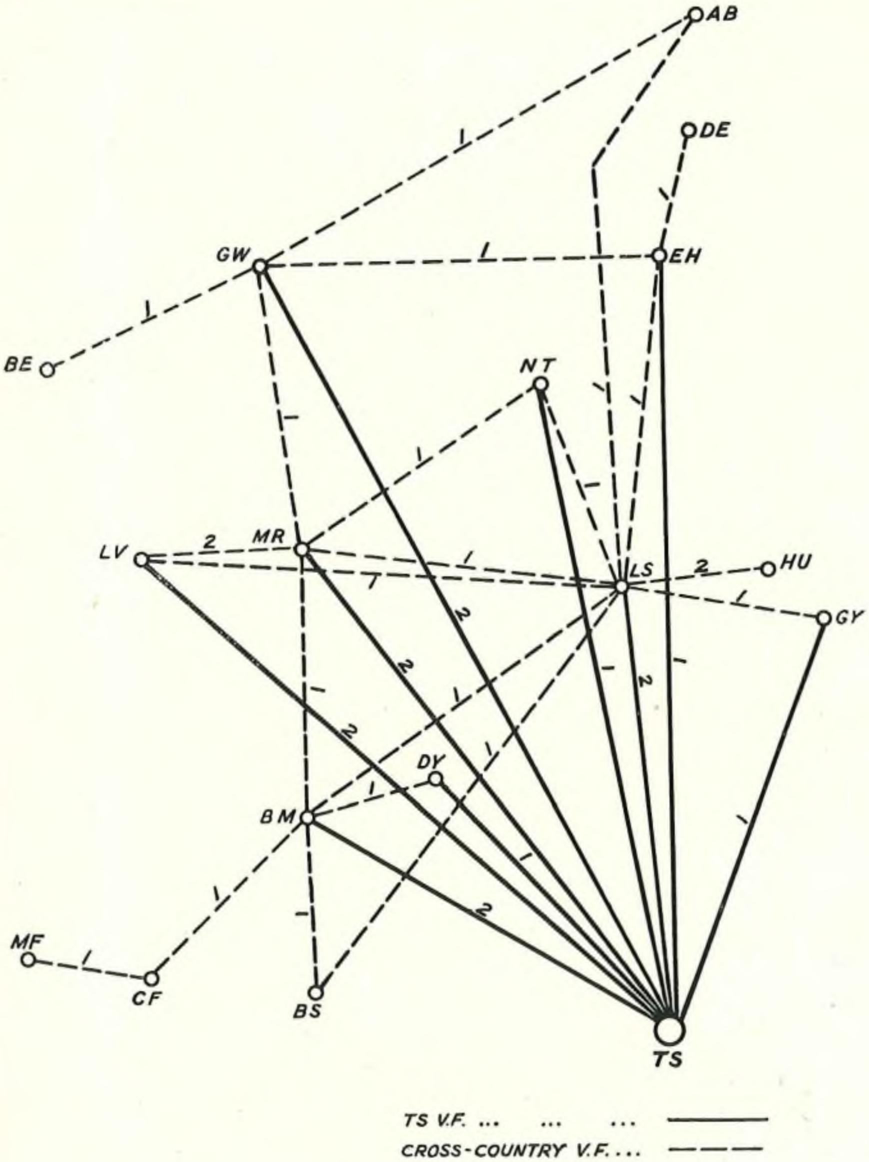


FIG. 3.—4-WIRE V.F. CIRCUITS, NORTHERN AND SCOTTISH SCHEMES.

The provision of adequate reserve facilities for the replacement of faulty lines is of prime importance in a system where the failure of one line may involve the isolation of one or more important telegraph offices. The reserve lines of the combined telegraph and telephone line network will be pooled, and, in the case of certain named reserve wires, the telegraphs will have the right of priority in use. The failure of a multi-channel line will be treated as a major breakdown, and all the operations involved in replacing it have been organized with the object of reducing the duration of stoppage to a minimum. In addition to the reserve wires, engineering spare wires will be made available for use in emergency by either service by connecting them to a special patching board to be provided at the principal trunk exchanges.

The terminal equipment of voice frequency systems will usually be installed at telephone repeater stations or in exchange apparatus rooms, in proximity to the telephone trunk terminations. The interchangeability of lines for telephone and telegraph purposes, and the pooling of reserve lines, make the association of importance. The maintenance of this equipment will be undertaken by the repeater or apparatus room staff. It will be appreciated that the V.F. termination is equivalent to the terminal repeater in a telephone system, and the same conditions for line-up and control of circuits are applicable. The only apparatus of telegraph type fitted at the termination are the transmitting relay, which applies to line the particular frequency of the channel with which it is associated, and the receiving relay, in the plate circuit of the final valve, which transmits local direct current signals to operate the receiving telegraph instrument. The adjustment of these relays has been reduced to a routine operation by the employment of relay test sets, and it is inadvisable to attempt adjustment by any other method. Diagrams of the sending and receiving circuits are given in Figs. **4** and **5**.

In addition to the apparatus described in the article already referred to, all necessary testing apparatus has been incorporated in a Test Bay which has been designed in accordance with the Department's requirements. The following facilities are provided, one bay being installed at each main V.F. terminal :—

(*a*) A distortion measuring set, consisting of a test transmitter, for the production of perfect signals for transmission to the channel under test, and a test receiver. The receiver incorporates a cathode ray tube which produces radial flashes on a graduated screen whenever the anode is momentarily raised to a high potential by a received signal and thus gives a direct reading of the " time " distortion in the channel.

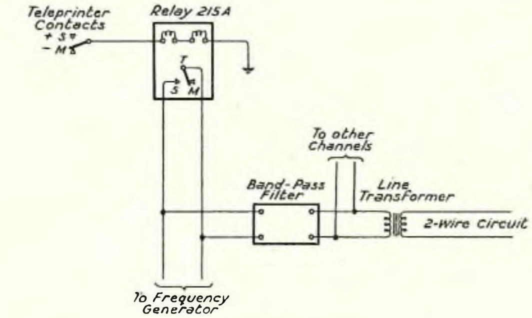


FIG. 4.—SENDING CIRCUIT.

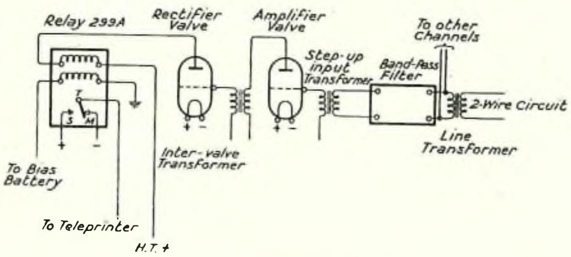


FIG. 5.—RECEIVING CIRCUIT.

(*b*) Test supplies of the 18 carrier frequencies are teed off from the generator bay at a fixed level of 10 microwatts and brought out to jacks on the test bay.

(*c*) A key type attenuator is provided for the measurement of line levels, the range being from 1 db. up to a maximum of 63 db. in 1 db. steps.

(*d*) Facilities are provided for measuring the interference between SEND and RECEIVE lines. Operation of an "Interference measure" key provides two alternative circuits whereby, using the rectified current as a criterion of equality, the attenuator may be adjusted to the same value as the interference and the latter thus read directly.

(*e*) A detector panel is incorporated, having a relay (normally operated) included in the rectified current output. A channel, on which an intermittent fault is suspected, when patched into this detector will cause the relay to fall back, bringing in the line-fail and main alarms when the rectified current drops to $\frac{1}{3}$ of its normal value.

(*f*) Facilities are provided whereby the distant station can be called on a pre-determined channel by interrupting the tone normally sent out. The arrangement is essentially the same as in (*e*) above and brings in the call lamps on the jack field and test bay at the distant station. This also serves as an indication of a line failure.

At the Telegraph Instrument Room the channel leads from the V.F. terminal equipment, *i.e.*, from the V.F. transmitting and receiving relays, are brought to a Control Board as simplex "go" and "return" lines. The Control Board for V.F. systems is the equivalent of the Test Board used with physical line systems. It provides the Commercial Staff with facilities for testing, crossing, and making up special circuits, part time private wires, etc., utilizing voice frequency channels. It consists primarily of a jack field with connexion strips for terminating the necessary cables. A panel containing two "Combiner Units" and three "Speaker Signalling Sets," which will be described later, is fitted above the jack field. The Control Board proper is made up in bays, each of which accommodates five V.F. "systems" of a maximum of eighteen channels each. A "system," for this purpose, comprises the channels associated with a four-wire telephone circuit, whether fully equipped for eighteen channels or partially for six or twelve. In the latter event, the spare jacks, up to the full number of eighteen, are kept plugged up to ensure uniformity of connexion of "systems," and to avoid changes when the number of channels in a system is increased. The "go" and "return" leads of channels are each taken through three jacks at the Control Board, and thence are extended to the teleprinter or other type of apparatus at the instrument table in the operating galleries, to the panel of a physical line extension of a V.F. channel, or to another V.F. channel, if the circuit concerned is made up by extending a channel in one system to a channel in another. These jacks are labelled "Test," "V.F." and "Extension" respectively. A schematic diagram of the Control Board connexions of a channel is given in Fig. 6. In the case illustrated, two leads to P.W. lines are joined to the "V.F." jacks. These connexions are only made in the special case of a channel allocated for use as a part time private wire. The part time circuit is completed when required by the insertion

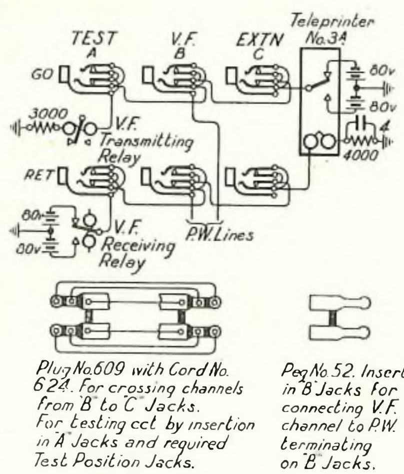


FIG. 6.—CONTROL BOARD: SCHEMATIC CONNEXIONS OF ONE CHANNEL.

of the double peg, which extends the channel to the renter's office without other switching or cross connexion on the board. The "test" jacks enable a channel to be extended to a portable or fixed Testing Position, or to a Speaker Signalling Set, without breaking down communication between the terminals. The "V.F." and "Extension" jacks are normally used for crossing channels, but in the event of the "V.F." jack being in use for another purpose, as in the case of the private wire referred to above, the "test" jack may be used instead. These jacks are also used for coupling channels, the "go" jack of one channel being connected to the "return" jack of the other and vice versa.

The first row of jacks on each bay of the Control Board is set aside for the provision of Interbay Junctions which will obviate the use of long cords across the front of the board. The Control Board is made up of strips of 20 jacks, and six channels are connected to each strip; the two end jacks being thus free are made use of to provide a system of miscellaneous Transfer Circuits to fixed test positions, or to spare jacks on concentrators, for access to any teleprinter position or to any apparatus panel on a physical circuit, *via* the Test Board (to which all physical lines coming into the office are connected), and to the Test Board itself. Examples of the use of the three last named transfer circuits are shown in Fig. 7.

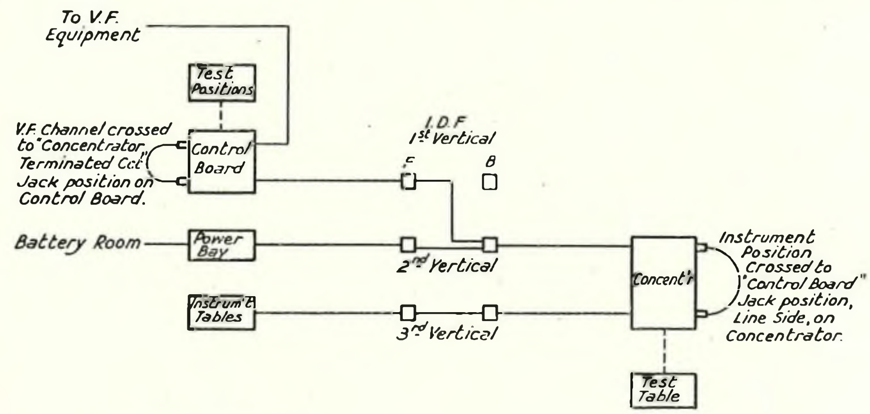


FIG. 7A.—SPARE V.F. CHANNEL EXTENDED *via* CONCENTRATOR TO ANY INSTRUMENT POSITION.

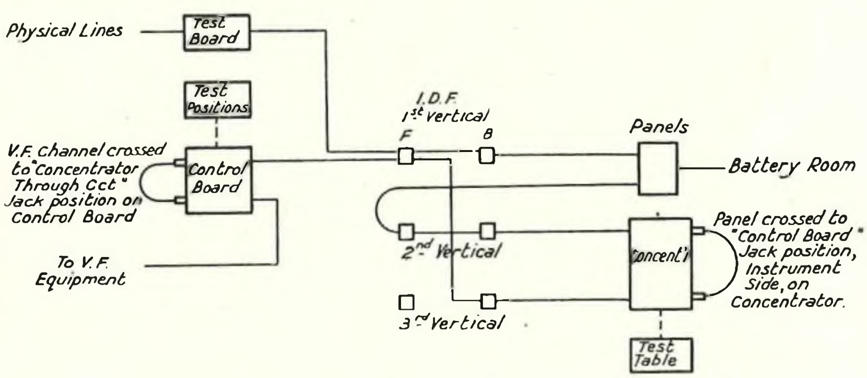


FIG. 7B.—SPARE V.F. CHANNEL EXTENDED *via* CONCENTRATOR AND ANY PANEL TO PHYSICAL LINES.

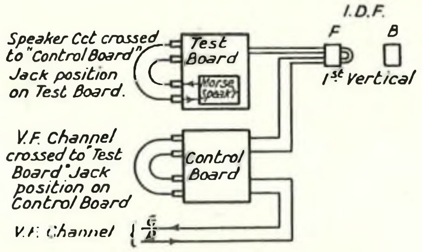


FIG. 7C.—V.F. CHANNEL COUPLED TO TEST BOARD MORSE SPEAKER CIRCUIT.

Reference has previously been made to the panel containing Combiner Unit and Speaker Set equipment. The complete connexions of this panel are given in Fig. 8.

The Combiner Unit makes use of a multiple coil relay for the purpose of grouping V.F. channels to form YQ circuits. The essential requirement of this circuit is that signals from any line in the combination shall be repeated to all other lines. The unit provides for the connexion of a maximum of four channels. The "return" of each channel is joined to one of the six coils of the relay (Relay Standard, HN.) Two coils are joined in series and to a battery to produce an electrical bias. The direction of the current in the bias winding is opposite to that received from the V.F. receiving relay, when normal or negative. With all circuits connected, and currents correctly adjusted, the relay has a bias due to the preponderance of current in the "return" lines of the channels. A reversal of current in any "return" line causes the relay to operate. The "go" lines of the channels are bunched and connected to the tongue of the relay. Signals are thus transmitted from any channel to all the other channels, and a local record is obtained.

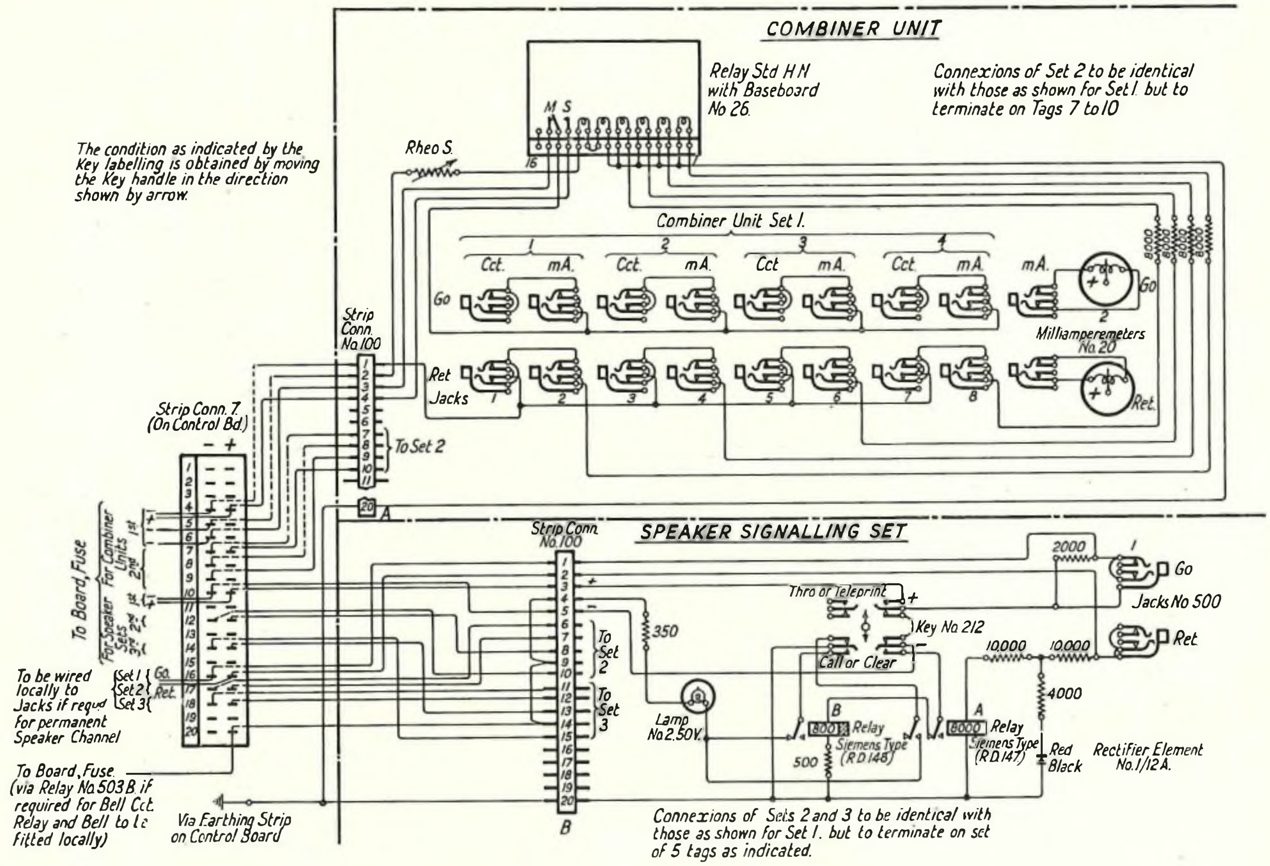


Fig. 8.—Wiring and External Connexions of Panel comprising Two Combiner Units and Three Speaker Signalling Sets.

It may not be necessary at all times to group the maximum number of circuits, and, in order to maintain correct conditions in the relay coils, the inner contacts of the return jack are connected to negative thus simulating the condition normally presented by an idle channel of any grouped system.

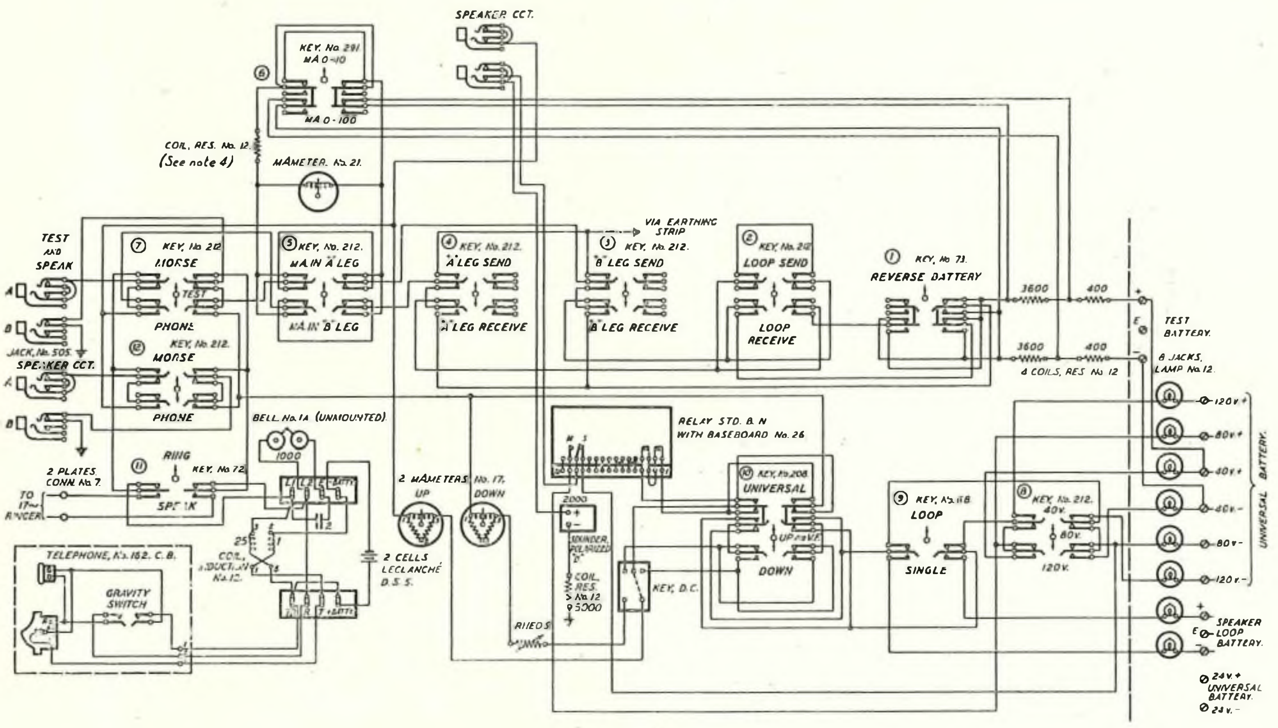
The working adjustments are as follows :—The Relay HN should first be set neutral on the Relay Test Panel, the gap being adjusted to 2 mils. The currents on the respective return legs will be equal and of the order of 10 mA either from the inner springs of the jack or from the contacts of the receiving relay when the YQ circuit is set up. The correct adjustment of the Rheostat S in the bias winding circuit is determined by inserting a disconnecting plug in any one of the return line jacks and adjusting the Rheostat S until the relay is again neutral. The disconnecting plug should then be withdrawn and the channels forming the YQ circuit connected. The " Go " of the V.F. channels should be connected to the " Go " jacks of the Combiner Unit and similarly with the Return legs.

Milliamperemeters terminated on jacks together with corresponding milliamperemeter jacks in each circuit are provided to enable the conditions to be tested.

The satisfactory operation of the unit depends upon equal currents passing through the respective line windings of the relay. Where four V.F. channels are combined this condition must necessarily obtain since the voltage on the V.F. receiving relay is always 80. In the event of a circuit other than a V.F. channel forming part of the combination, care should be taken to ensure that the current through the particular winding is the same as that through the remaining line windings.

Fixed and portable Test Positions are provided mounted on steel tables. The two types are similar in make-up. They comprise a Teleprinter 3A, and a testing unit which enables the test teleprinter to be (a) connected in shunt with the circuit teleprinter, (b) connected to the V.F. channel, and (c) connected to the circuit teleprinter.

To enable testing officers at V.F. offices to communicate with each other, certain channels are named for use as speakers and are kept connected. The method of operation of the Speaker set (Fig. 8) is as follows : The V.F. channel named as speaker is extended from the " go " and " return " test jacks of the channel to the corresponding jacks of a speaking set. Calling, clearing, etc., are effected by means of a key of telephone type which, in the normal position at each end, applies negative voltage to the V.F. transmitting relay, and thus to the calling and clearing relay, A, of the set. In this condition the direction of the current is such that the rectifier element, joined with resistances across the coils, shunts sufficient current to render the relay inoperative. When the signalling key at either end is moved to the " call " position, the " through or teleprint " position. In this position a slugged relay, B, is introduced into the circuit to avoid flickering signals due to the operation of the A relay by the teleprinter signals, and to ensure that a calling signal is received even if the distant teleprinter is left plugged in with the key in the " through or teleprint " position. The operation of the slugged relay is such that it prevents the lamp from glowing except on receipt of a prolonged signal. Two channels may be coupled to provide a through speaker circuit and the calling and clearing arrangements will remain effective throughout. These con-



NOTES :—1. Numbers encircled indicate the positions (from right or left) of the keys as mounted on the panel.
2. The encircled diagonal lines indicate connexion plates mounted on a strip at the base of the rack.
3. The condition as indicated by the key labelling is obtained by moving the key handle in the direction shown by the arrow.
4. The resistance, including its connecting leads, to be equal to 1/9th of the resistance of the milliamperemeter with its connexion leads. The meter should record on the 0-100 mA scale, with the shunt in circuit, correct to 1% (Value approximately 1 1/9 ohms).

FIG. 9.—TELEGRAPH TEST BOARD FOR PHYSICAL LINES ; TESTING CIRCUIT.

direction of current is reversed and the relay at the distant end is operated, lighting the calling lamp or ringing a bell. On receipt of the calling signal, a teleprinter is plugged into the " V.F." jack of the speaker channel. The visual calling is effective even if the teleprinter is already plugged in, owing to the resistance of 2,000 ohms, joined across the sleeve and outer spring of the speaker jack, being in series with the transmitter tongue and leaving the V.F. transmitting relay and distant signal under control by the key. The teleprinters are ready for communication when the keys are thrown to the nexions are set up at the intermediate office by plugs and cords between the " V.F." jacks of the channels concerned, the " go " of one channel being connected to the " return " of the other and the signalling key being left in the " through or teleprint " position. On completion of the call, the terminal offices, by moving their keys to the " call or clear " position, cause the lamps at the intermediate and distant offices to glow. The intermediate office will take down the connexion and restore the keys to normal on receipt of clearing signals from both ends.

The multi-channel system is, for the present at any rate, restricted to the main cable routes, and there are many circuits between telegraph offices which have to be made up partly by voice frequency channels and partly by physical lines. Such extensions from the V.F. system may be worked as two-line simplex or ordinary single-wire duplex, for which the auxiliary equipment is generally assembled on panels. The extension lines are taken through the Test Board for physical lines to the panel equipment, and thence are connected to the voice frequency channel through the Control Board. A new type of Test Board to accommodate 140 lines and to line up with the Control Board has been designed for this purpose. In addition to the usual line jack field, the board is provided with Morse and telephone speaker sets in combination with a testing set in which the connexions are set up by telephone-type keys. Fig. **9** is a schematic diagram of the complete set. It will be seen that it is an adaptation of telephone methods to telegraph requirements. The external connexions of the set are made through two sets of jacks which enable independent use to be obtained of the speaker and testing portions of the set when necessary. The telegraph speaker may be worked from an independent loop battery or from any of the universal battery voltages, changes being readily made by the operation of keys. Connexions to the Control Board are provided to enable the Morse speaker to be extended over any V.F. channel by means of cord connexions. The test keys provide facilities for sending and receiving currents and for the approximate measurement of resistances by calibration with the readings of the milliamperemeter.

The connexions of the Fuse Board and Power Bay which has been designed for installation at V.F. offices are shown in Fig. **10**. Power for operating V.F. extensions, both internal and external, which has been standardized at 80 volts, is distributed through this board. Protective resistances of 120 ohms in the apparatus battery leads, made up in units of ten resistances, are also assembled here, as well as, for convenience, the shunted condenser networks in the local teleprinter circuits. Fuses rated to operate at 5 amperes are inserted in the main power leads and are mounted on a panel of the Power Bay.

The multi-channel voice frequency system and the accessories to its use which have been described may appear, at first sight, to have increased the complexity of telegraph technique. Actually the reverse is the case. The operation of the service has been simplified to a degree that no previous changes in method have been able to achieve. The stage has been reached when a telephone circuit, as used for a single conversation, is capable of carrying 36 telegraph messages simultaneously without being worked to its full capacity. By sacrificing simplicity the voice frequency channels could be worked as triple or even quadruple multiplex circuits. This huge traffic carrying capacity is combined with a degree of flexibility in the make-up and use of channels which was unattainable under the old order. Difficulties incidental to varying power requirements, duplex balancing, and telegraph repeating have disappeared. On the other hand adjustments have been reduced to a routine basis. All the indications are that the stability of the service will be greatly improved, and instrument room supervising officers, instead of being harassed by technical difficulties, will be able to devote their attention wholly to traffic requirements. The first step in this direction was taken with the installation of the panel equipment, and the immense improvements which have been

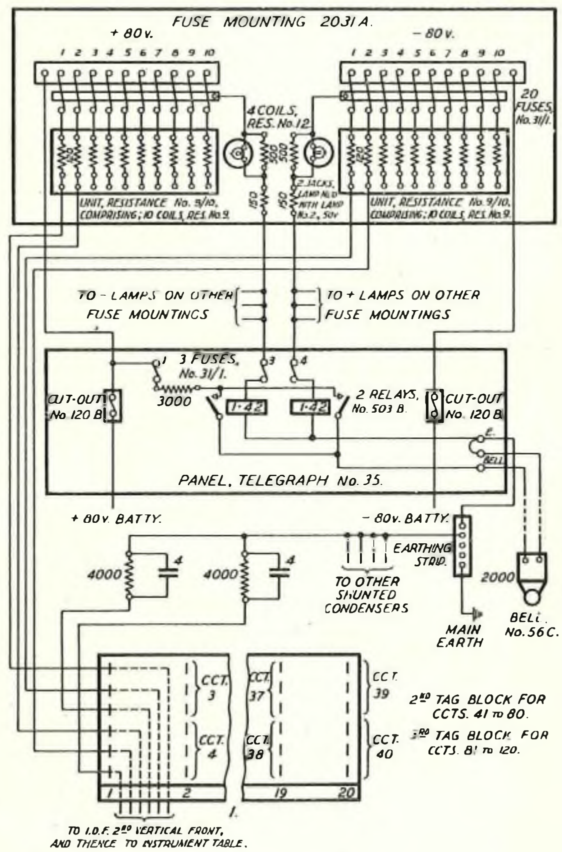


Fig. 10.—Fuse Board and Power Panel.

made recently in the lay-out of instrument rooms, combined with the provision of efficient internal circulation by means of conveyors. The further developments described in this article have greatly restricted the use of panel equipment, but although not required under the multi-channel scheme it will remain in service for some time on physical extensions from that scheme and on minor circuits. It is probable, however, that these circuits will also be operated in the future by alternating current methods, as local telegraph lines become merged with telephone line plant. Developments in this direction are already under consideration.

Regenerative Repeater for Teleprinter (Start-Stop) Systems

E. H. JOLLEY, A.M.I.E.E. and J. A. S. MARTIN, A.M.I.E.E.

Introduction.

IN telegraphy a regenerative repeater is one which accepts distorted signals and re-transmits them essentially free from distortion. Such repeaters are well known in cable telegraphy work, but they are costly and complicated, and are only justified on long and expensive circuits.

The almost universal adoption of teleprinters for communication on public and private services has opened a field for a regenerative repeater suitable for " Start-Stop " working. If such a repeater is of simple construction, cheap and easy to maintain; then the advantages derived from its use could be secured on many circuits which would otherwise have to be operated with a smaller margin of efficiency.

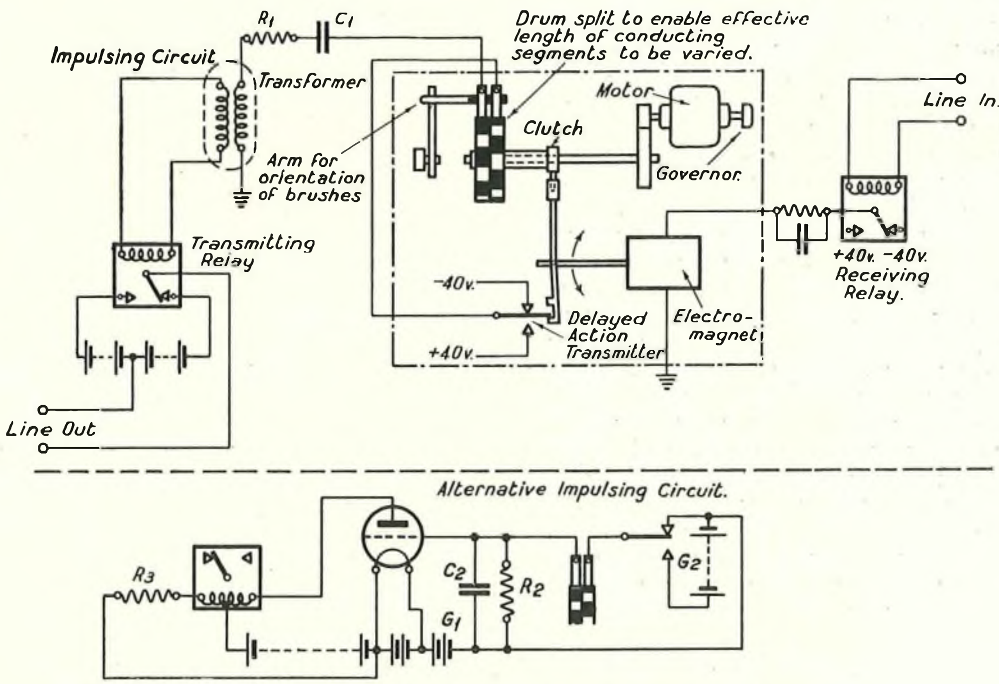


FIG. 1.—SCHEMATIC DIAGRAM OF REGENERATIVE REPEATER.

In general the regenerative repeaters at present in use involve a storage feature necessitating the employment of a number of relays as well as receiving and transmitting distributors. In the repeater described in this article, storage is avoided and the place of the distributors is taken by a simple segmented drum. Only one relay is required in addition to the usual receiving relay and therefore the repeater is of a very simple character.

General Principles.

In long distance telegraph transmission, when the signal is represented by elements of different length, such as in start-stop systems, the different elements become distorted with respect to time (as for example the length of an element may be increased or decreased) due to distortion introduced by the line and by interference from outside sources. Distortion may also be produced in the case of duplex circuits owing to imperfection of the balance.

The object of the regenerative repeater is to provide a means whereby the distorted signals can be received and regenerated or restored to their proper form. The regenerated signals may be re-transmitted over a further line section in cases where, without regeneration, the cumulative distortion of the two sections would have rendered satisfactory operation impracticable. Also when the distortion of the signals received at the end of a circuit is such as to cause imperfect registration of the characters, the signals can be regenerated and perfect operation secured provided the regenerative repeater is made to accept a greater degree of distortion than is possible with the particular receiving mechanism.

Description of the Repeater.

The general arrangement of the repeater is given in Fig. 1. The device consists essentially of a motor geared to a shaft so that the shaft runs at a speed somewhat higher than that of the teleprinter transmitter. The speed of the motor is accurately controlled by an electric governor. A segmented drum is driven from the shaft through a clutch, the clutch being controlled by the operation of the armature of an electro-magnet. Where a number of repeaters are installed at the same place the separate drums can be driven from a common motor. The drum is divided into seven conducting and seven non-conducting segments alternately, and is split into two parts so that the ratio of the length of the conducting to the non-conducting segments may be varied as desired.

Two brushes bear on the surface of the drum so that during the revolution of the drum a conducting path is provided at certain intervals.

Referring to Fig. 1, the signals received from the line are passed by the receiving relay to the electro-magnet of the regenerative repeater. The receiving relay can be of any of the usual types and distortion correcting networks and vibrating circuits may be used.

On the receipt of the start signal which precedes each character the electro-magnet is actuated and allows the clutch to engage and the drum is allowed to make one revolution. The clutch is disengaged when the electro-magnet is operated by the stop signal which follows each character.

In addition the electro-magnet through the medium of a link operates a delayed action transmitter. The function of this transmitter is to repeat the received signals, but with a definite time lag. These signals are passed to the drum and the delay thus introduced compensates for the lag which occurs between the operation of the line receiving relay and the actual engagement of the clutch. It should be noted that the transmitter does not operate until the completion of the stroke of the electro-magnet armature. By virtue of the fact that the transmitter is not rigidly connected to the armature extension, any chatter that occurs at the receiving relay contacts is eliminated. The elimination of chatter is an essential requirement in this particular method of regeneration. The transmitter is electrically connected through the brushes and drum to a special circuit which impulses the transmitting relay.

The result of the rotation of the drum is that the delayed action transmitter is only connected to the impulsing circuit when the brushes are passing over a conducting segment, therefore, only a limited portion of the received signal is utilized for the preparation of the regenerated signals. The shorter the length of the conducting segment with respect to the non-conducting, the greater the amount of time distortion permissible in the incoming signals.

The type of impulse generated is shown in Fig. 2 where the top line is the impulse into the transmitting relay and the bottom line is the signal from the delayed action transmitter. In order that the most favourable part of the signal may be used for the purpose of generating the impulses, the brushes are capable of being orientated with respect to the conducting segments. The transmitting relay is operated each time an impulse is generated. As the time between the impulses is fixed by the speed of rotation of the drum and the distance between the conducting segments, the signals given out from the transmitting relay are essentially free of distortion.

If arrangements are not made to prevent it, an impulse is generated every time the brushes pass over a conducting segment. This would cause chattering of the transmitting relay and it is, therefore, essential that an impulse is only generated when the polarity of the received signal is reversed. For instance, the oscillogram reproduced in Fig. 2 shows a letter blank signal from a Teleprinter 3A. The signal commences with a positive unit for the start element followed by two further positive units, then the third unit which is negative, two more positive units, and finally 1.5 units negative for the stop. It will be seen that the impulses are only generated during the start, third, fourth and stop elements, *i.e.*, when the polarity of the signal is reversed. The obliteration of unwanted impulses has been secured by each of the two means described in the following paragraphs.

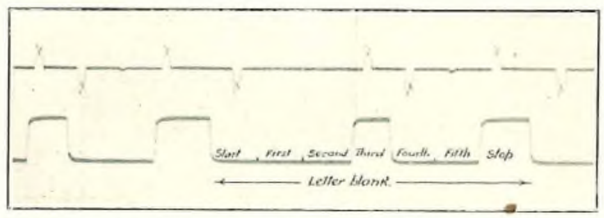


FIG. 2.—OSCILLOGRAM OF SIGNAL GIVEN OUT BY DELAYED ACTION TRANSMITTER AND CORRESPONDING IMPULSES.

Condenser Impulsing Circuit.

In this method an impulsing circuit consisting of a condenser (C_1), resistance (R_1) and the primary of a transformer in series is used (See Fig. 1). The constants of this circuit are so arranged that whenever the polarity of the battery on the delayed action transmitter is reversed, a damped oscillatory charge is set up, the duration of the first pulse being equal to the time taken for the brush to pass over a conducting segment. The damping is made suitably great so that the condenser is practically charged to the potential of the battery during the first pulse. The result of this is that, although the brushes may pass over conducting segments, no current flows into the impulsing circuit except when the polarity is reversed. It is necessary that the current in the impulsing circuit be zero at the instant that the brushes leave a conducting segment, so that sparking does not occur. Normal spark quench devices are not permissible in this particular case. In addition, if the time of the first pulse of the oscillatory charge is less than the time length of the segment, a reversal of current occurs in the impulsing circuit which causes a momentary break at the contact of the transmitting relay. It is, therefore, important that the constants of the impulsing circuit should be fixed with respect to the length of the conducting segments, in order that pure impulses are generated and perfect operation of the transmitting relay secured *via* the secondary of the transformer. With this method of impulsing, it is possible to arrange that the conducting segments have an effective time length of approximately 3 milliseconds. This corresponds to a permissible distortion of 43% at the delayed action transmitter. On account of the regenerative effect secured in the local circuit containing the electromagnet, this corresponds to about 47% at the receiving relay. In practice, owing to the variable lag in the engagement of the start-stop clutch, the amount of permissible distortion is about 3% less than the calculated figure. This circuit involves the use of a strongly polarized relay such as a Creed or A.E.C. telegraph relay, which remains steady on either contact without the necessity for a holding current.

The impulses generated and the output signals of the transmitting relay are shown in Fig. 3. The second peak on each impulse is due to the change of flux in the relay when the armature moves over.

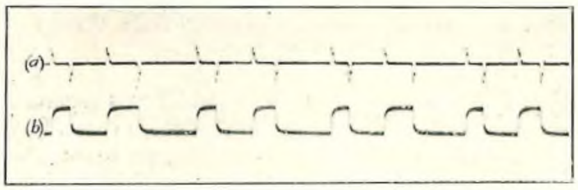


FIG. 3.—(*a*) IMPULSES INTO TRANSMITTING RELAY WITH 3-MILLISECOND SEGMENTS ON DRUM.
(*b*) OUTPUT FROM TONGUE OF TRANSMITTING RELAY.

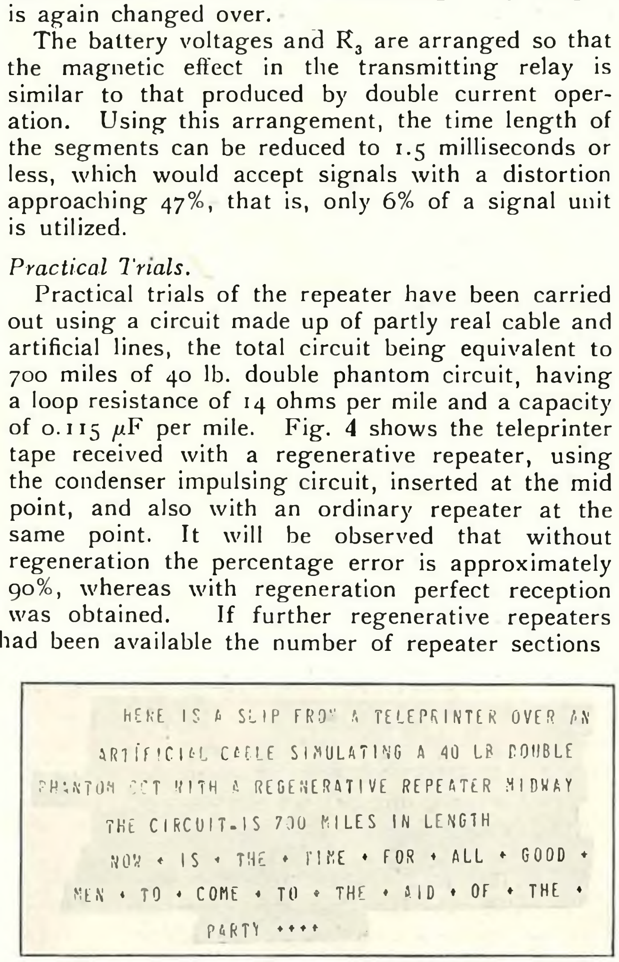
Valve Impulsing Circuit.

In this method, in order to permit the use of a shorter segment and so accept a greater degree of distortion, as well as to use an ordinary polarized relay such as a relay Standard BN, or 299 AN, a thermionic valve is used. The circuit is given at the bottom of Fig. 1. The arrangement is such that during a period of rest, that is when the brushes are resting on a non-conducting segment and no signals are being transmitted, there is no potential across condenser C_2. The grid battery G_1 is adjusted so that in this condition the biassing current of the relay via R_3 holds the tongue of the transmitting relay in the required position. On receipt of a start signal, the tongue of the delayed action transmitter moves over so that the positive pole of battery G_2 is connected to one of the brushes. At the same time the drum commences to revolve and when the brushes pass over the first conducting segment a momentary current is passed to charge condenser C_2 to the voltage of battery G_2. Under this condition the potential of the grid is raised and the valve becomes conductive, the value of the current being such that the tongue of the transmitting relay is moved over to the opposite contact. The resistance of the grid leak R_2 is made great enough to prevent any appreciable discharge of C_2 during the periods in which the brushes are passing over a non-conducting segment. When, during the transmission of the remainder of the signal, the polarity is reversed, the tongue of the delayed action transmitter moves on to the negative side of the battery G_2 and during the next instant at which the brushes pass on to a conducting segment, condenser C_2 is short circuited, the valve becomes non conductive, and the transmitting relay tongue is again changed over.

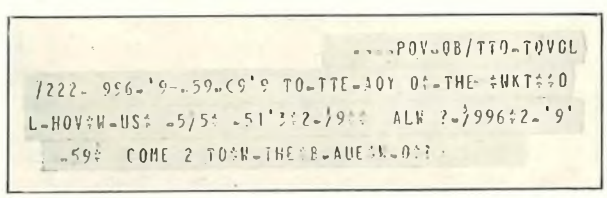
The battery voltages and R_3 are arranged so that the magnetic effect in the transmitting relay is similar to that produced by double current operation. Using this arrangement, the time length of the segments can be reduced to 1.5 milliseconds or less, which would accept signals with a distortion approaching 47%, that is, only 6% of a signal unit is utilized.

Practical Trials.

Practical trials of the repeater have been carried out using a circuit made up of partly real cable and artificial lines, the total circuit being equivalent to 700 miles of 40 lb. double phantom circuit, having a loop resistance of 14 ohms per mile and a capacity of 0.115 μF per mile. Fig. 4 shows the teleprinter tape received with a regenerative repeater, using the condenser impulsing circuit, inserted at the mid point, and also with an ordinary repeater at the same point. It will be observed that without regeneration the percentage error is approximately 90%, whereas with regeneration perfect reception was obtained. If further regenerative repeaters had been available the number of repeater sections



(*a*) With Regeneration.



(*b*) Without Regeneration.

The words sent out from the teleprinter were "Now—is—the—etc." and the received slip was as shown.

FIG. 4.—SPECIMEN OF TELEPRINTER SLIP RECEIVED OVER 700 MILES OF A 40-LB. DOUBLE PHANTOM CIRCUIT, WITH AND WITHOUT REGENERATION OF THE SIGNALS MIDWAY.

could have been materially increased. It was observed that the signals at the end of the first section did not give entirely perfect reception on the teleprinter, although the regenerator was capable of accepting these signals and repeating them a further 350 miles.

Similar trials were made with the first repeater section made up of a 400 miles double phantom circuit between London—Leeds and London, looped back at Leeds. This circuit was made up of 40 lb. conductors between London and Derby and 20 lb. conductors between Derby and Leeds (KR. 345,000 ohms μF). The second repeater section was made up of artificial cable as before.

Oscillograms of typical signals are given in Figs. **5** and **6**. It will be seen from Fig. **6** that the regenerated signal (*b*) is actually more perfect than the original transmitted signal, which shows evidence of bounce at the teleprinter contacts. Table 1 gives typical values of the distortion.

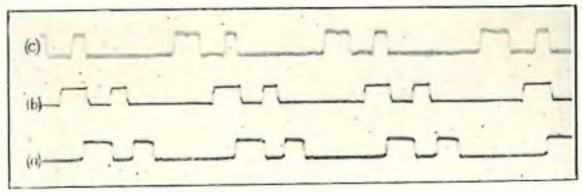
TABLE 1.

DISTORTION MEASUREMENTS.

Signal	Sent from Teleprinter Contacts	Received at End of first Section	Regenerated Signal	Received at end of Second Section	
				Without Regn.	*With Regn.*
" = "	5%	30%	2%	33%	17·5%
Letter Space.	5%	23·5%	2·5%	36%	19·5%

Further trials of the regenerative repeater were made during the setting up of a duplex teleprinter circuit composited on the Jersey—Compass Cove single core telephone cable. For this purpose the circuit was set up so that Jersey transmitted to Exeter. At Exeter the received signals were regenerated and transmitted into an Exeter-London double phantom circuit and repeated back on a London-Exeter double phantom circuit to Exeter giving perfect reception at Exeter, under duplex conditions in the Exeter-Jersey section. A further advantage of the regenerative repeater was evidenced by the fact that the value of the first condenser section in the duplex balance at Exeter could be varied by 30% without impairing the accuracy of reception, *via* London. This clearly demonstrates that imperfections of duplex balances can be compensated for by the use of the regenerative repeater on account of the large amount of distortion that it will accept.

Experiments made with the valve impulsing circuit proved that in this case even a larger amount of distortion could be accepted due to the fact that shorter conducting segments could be used on the drum.

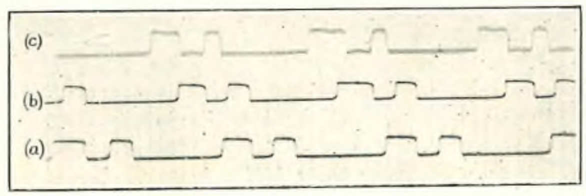


(*a*) Signal transmitted into first repeater section from transfitting contacts of Teleprinter.

(*b*) Signal received at end of first section and transmitted into second section.

(*c*) Signal received at end of second section.

FIG. **5**.—TESTS ON 700-MILE DOUBLE PHANTOM CIRCUIT WITHOUT REGENERATION.



(*a*) Signal transmitted into first repeater section from transmitting contacts of Teleprinter.

(*b*) Signal transmitted into second section.

(*c*) Signal received at end of second section.

FIG. **6**.—TESTS ON 700-MILE DOUBLE PHANTOM CIRCUIT WITH REGENERATION.

Fig. **7** shows an experimental model of a regenerative repeater, suitable for a duplex circuit, made by the Automatic Electric Co. On the particular line over which this model was tested, signals having a distortion of 45 per cent. were received and transmitted correctly. With this amount of distortion, direct Teleprinter reception was impossible, showing that the repeater was capable of accepting more distortion than a Teleprinter.

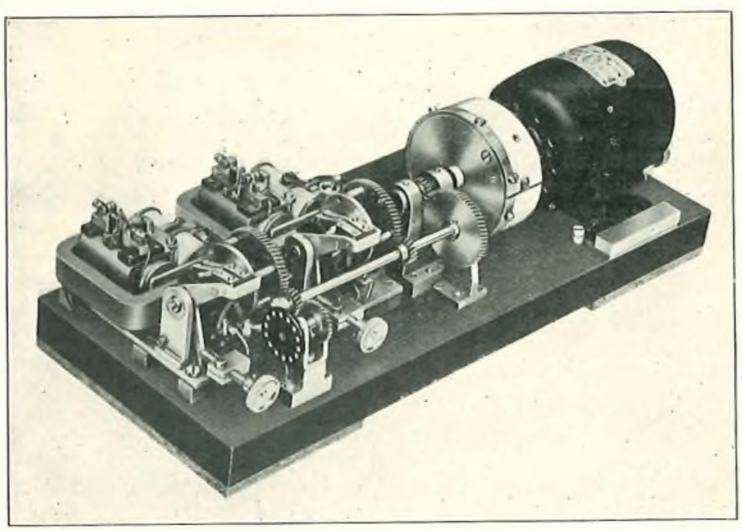


FIG. **7**.—EXPERIMENTAL MODEL OF A REGENERATIVE REPEATER, SUITABLE FOR A DUPLEX TELEPRINTER CIRCUIT, MADE BY THE AUTOMATIC ELECTRIC CO.

Two Aids in the Study of Telephone Transmission

A. K. Robinson, A.M.I.E.E.

THERE is no doubt that some knowledge of alternating currents and transmission theory is becoming more and more important as the science of electrical communication advances. Unfortunately very little of any real use can be done without mathematics, and only too often the first chapter of a text-book dissuades the private student from proceeding any further.

It is thought that this is probably due more to the unfamiliarity of the ideas involved than to any aspects, but that is a process requiring labour, time and patience.

A further point is that even when the student is reasonably familiar with the mathematical elements, the process of conversion from one form to the other, and the evaluation of expressions like sinh $(a + j\beta)$, are so tedious that he is very much tempted simply to read the proofs and the worked examples without bothering to try examples for himself.

The two aids described below are fundamentally

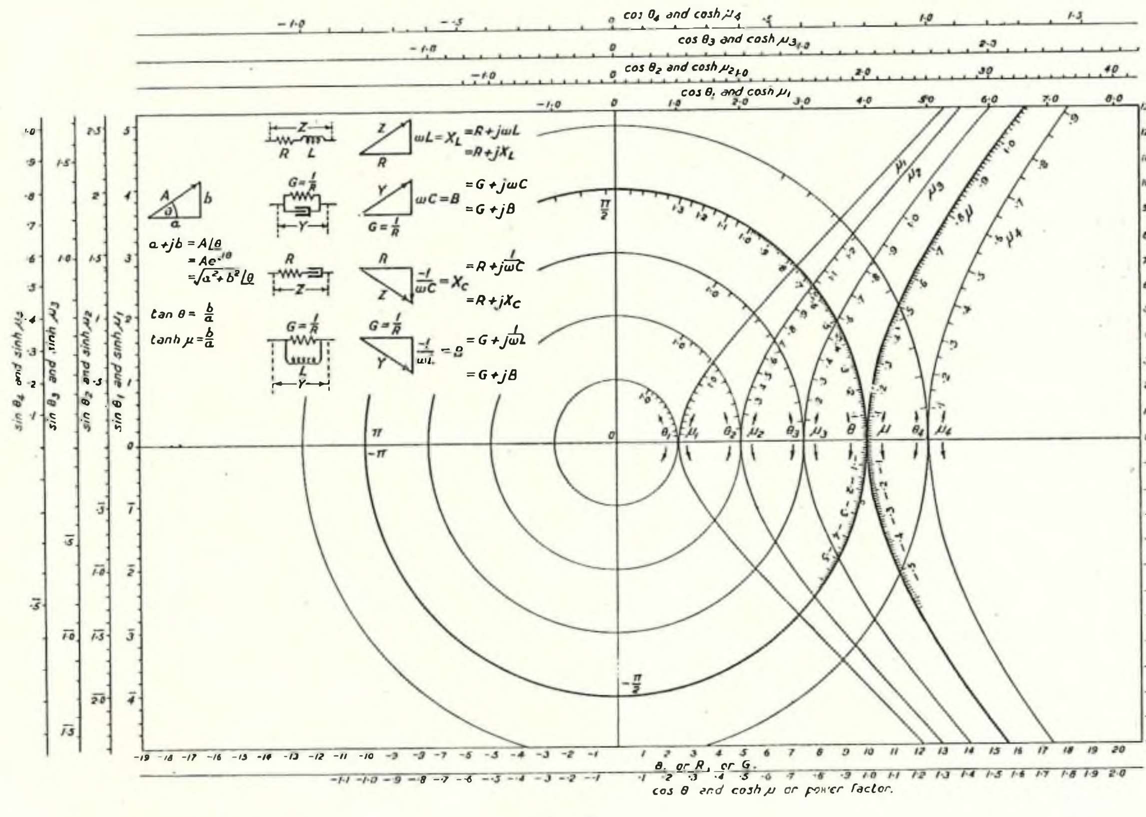


Fig. 1.

inherent complexity in those ideas, and this unfamiliarity must be overcome as a first step. For instance, the fact that

$$a + jb,\ \sqrt{a^2 + b^2}(\cos\theta + j\sin\theta),\ \sqrt{a^2 + b^2}\cdot e^{j\theta},$$

$$\sqrt{a^2 + b^2}\,\underline{/\theta},\ \sqrt{a^2 + b^2}\ \tan^{-1}\frac{b}{a}\ ,\ \text{and } Ae^{j\theta}$$

are merely different ways of representing the same vector should be so familiar as to require no thought if transmission literature is to be read without undue labour, and that depends upon the firm appreciation of the exact relations between the three values a, b, and A, and the angle θ. Familiarity is best obtained, of course, by working numerous examples from all designed to save time and labour. They are not particularly novel, though so far as is known the second has not previously been published, but they may be of interest: and the student who cares to construct them will find that the work involved is not their least valuable feature. Once they have been constructed and used for a few examples, the essential facts will not be quickly forgotten.

(1) This is merely a slight elaboration of the ordinary calculating board, used chiefly for conversion between the various forms of expression representing a vector. The size is not really important, but a convenient size is that of the standard graph sheet 40 cm. × 25 cm., ruled in cm. and mm. squares.

Horizontal and vertical axes are drawn as centre lines and a circle of 10 cm. radius described about the point o, as shown in Fig. **1**. On this scale 1 cm. along the circumference represents 0.1 radian, so a scale of radians can be marked off along the circumference, in cm's and half cms., and subdivided into hundredths of a radian (*i.e.*, millimetres on the circumference) by estimation. A scale of degrees can be added if desired, by using a protractor, but it is useful to get into the habit of thinking in radians. This scale of angles gives, of course, the value of θ. The horizontal and vertical scales are marked off in cms.

A rotating arm is constructed, as shown in Fig. **2**, of fairly stout card, with a scale of centimetres,

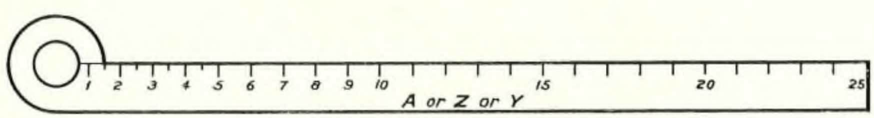


Fig. **2**.

24 cms. long, made of a strip of the graph paper. It is pivoted at o by means of a short flatheaded drawing pin passed through from underneath. Circular washers of stout card should be gummed firmly to each side of both the graph sheet and the rotating arm.

For any point on the graph the horizontal scale represents a, the vertical represents b, and the rotating scale represents A, but they can also represent other quantities. If the horizontal is R and the vertical is X $\left(\text{X being } \omega L - \frac{1}{\omega C}\right)$ in a series circuit, the rotating scale gives the value of the impedance Z, where θ is the angle of lag or lead. For parallel circuits, if the horizontal is the conductance G $\left(\frac{1}{R}\right)$ and the vertical is the susceptance B $\left(= \omega C - \frac{1}{\omega L}\right)$, the rotating scale gives the value of the admittance Y.

In addition to the circle a hyperbola marked with the hyperbolic angle μ, is drawn using the same origin. The best way to draw hyperbolas from memory is to draw from the origin o lines at 45° and −45°, as shown in Fig. **3**, and remember that all rectangles such as those shown, bounded by the two 45° lines and touching the hyperbola are of equal area; and that if the distance OA is 1 unit (as it always is for our purpose) the area of each of these rectangles is ½ (in square units). Thus, if the length of a rectangle be doubled, the width is halved, and so on, and hyperbolas can in this way be drawn very rapidly. As, however, scale values are required in this case, a schedule is given so that any hyperbolas required up to a value of 2.6 hyperbolic radians can be plotted. The values are given in steps of .05 radian and can be subdivided into hundredths of a radian by estimation. Just as the radius of the circle is taken as unity for marking off circular radians, so is the distance OA unity for the plotting of the hyperbola; the same origin being used for each, they both start from the same point on the horizontal axis. To the same scale (1 Unit = 10 cms.) the horizontal measurement represents either cos θ or cosh μ according to whether it is less than one or more than one, and the vertical measurement represents sin θ and sinh μ; so scales can be marked off horizontally and vertically to give the values of those functions. Also, since the power factor of an A.C. circuit = cos θ, the same horizontal scale gives power factors where the angle of lag or lead is θ.

The scales so far given are the important ones, but in addition other circles and hyperbolas are plotted on scales of 2.5 cms., 5 cms., 7.5 cms., and 12.5 cms. and some of the values indicated, corresponding horizontal and vertical scales for cos and cosh, sin, and sinh values being provided. They are quite optional, of course, and it may be considered preferable to add only two, on say 2.5 cm. and 15 cm. scales, to avoid confusion. The object of them is to provide higher values of hyperbolic angles and also to emphasise the fact that the use of different scales does not affect the value of the readings in either the circle or the hyperbola in spite of the fact that in the latter case there may appear to be a difference in the shape of the curves.

A few simple diagrams and formulæ are given on the left of the graph as a convenient reference in using the scales.

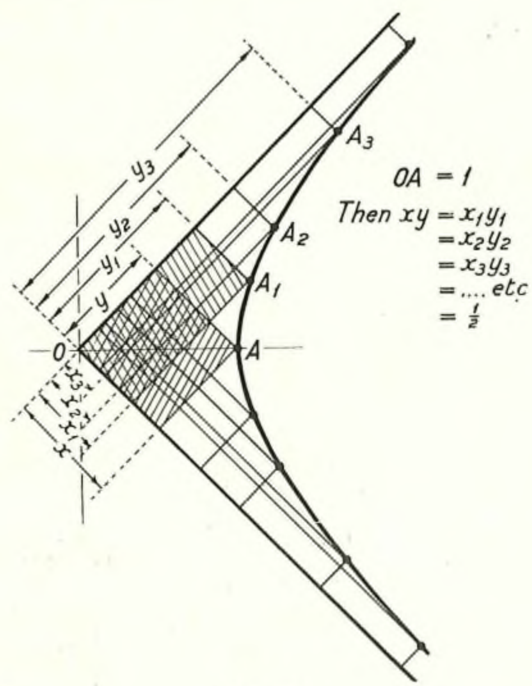


Fig. **3**.

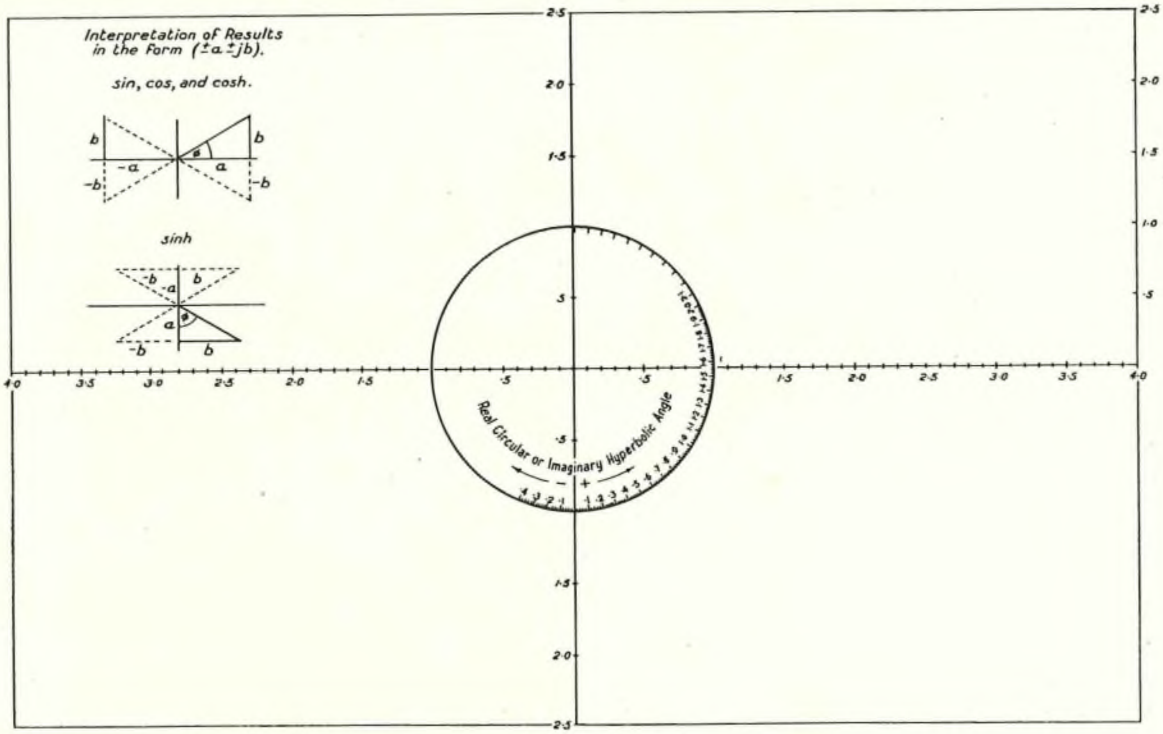


FIG. 4.

(2) This is a simple method of obtaining the values of sin $(\pm \alpha \pm j\beta)$, cos $(\pm \alpha \pm j\beta)$, sinh $(\pm \alpha \pm j\beta)$ and cosh $(\pm \alpha \pm j\beta)$ without drawing or calculation. It is based on Kenelly's method,[1] which has the disadvantage of requiring a separate construction for every value.

The essentials consist of a sheet of graph paper 40 × 25 cm. with a circular scale marked on it, as shown in Fig. 4, and a rotating hyperbola constructed of fairly stout card, as shown in Fig. 5. The value of the hyperbolic angle is shown on the hyperbola itself and also on the base line, where it is plotted according to the cosh value, *i.e.*, it is merely the projection on to the base line of the point on the hyperbola itself.

The method of use is similar in every case. The hyperbola is rotated until an arrow indicates either α (for circular functions) or β (for hyperbolic functions) on the circular scale. Then if B and B_1 (in Fig. 6) are the points representing the other components of the angle (*i.e.*, β, for circular functions

[1] A. E. Kennelly, "Application of Hyperbolic Functions to Electrical Engineering Problems."

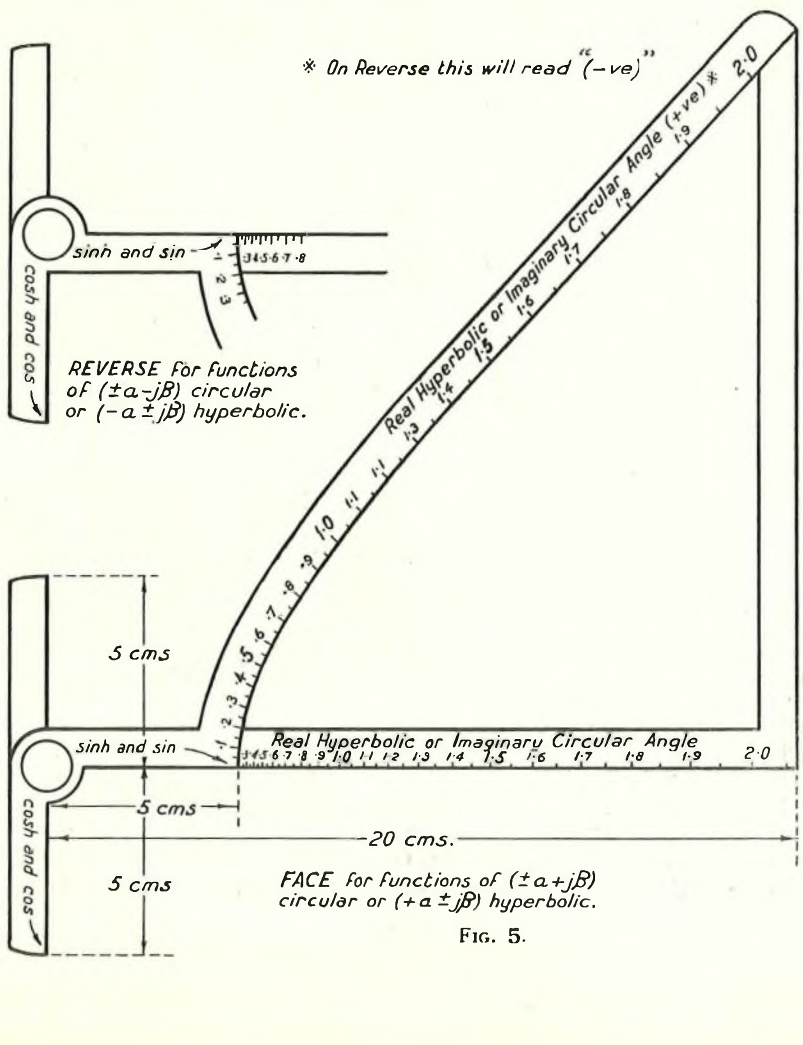
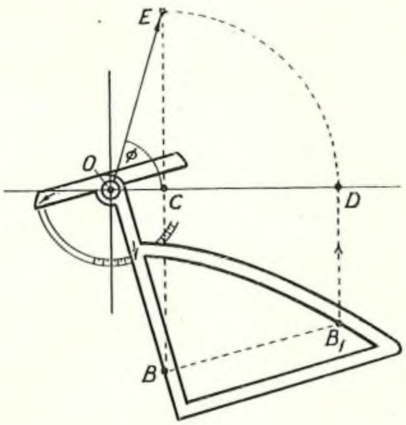


FIG. 5.



General Method of use (for all four functions). The positions of the points B and B_1 are determined by the values of α and β. Projected to the horizontal axis, they give the points C and D. OC is the real component of the required function and CD the imaginary component, except in the case of sinh, when OC is imaginary and CD is real.

Fig. 6.

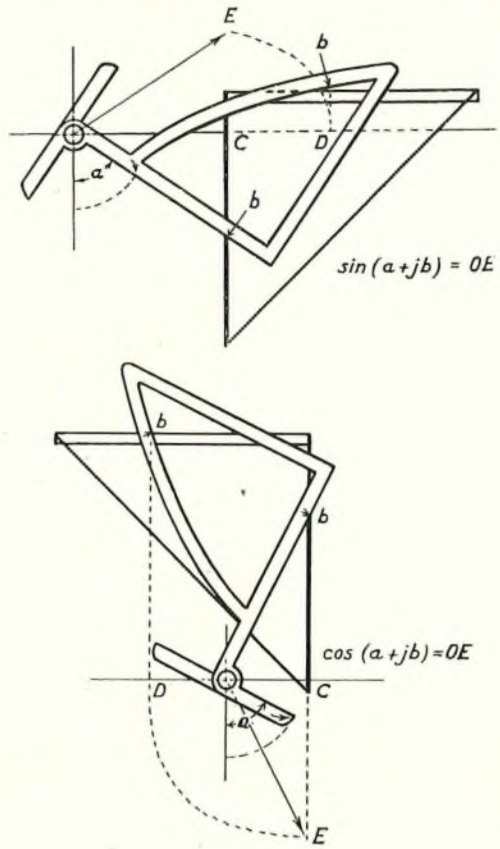


Fig. 8.

or α for hyperbolic functions) on the base line and on the hyperbola respectively the values OC and CD given by the projections on the horizontal axis are the numerical values of the real and imaginary components of the function. They can be read by inspection. To obtain the actual vector, CD is rotated round C through 90° anti-clockwise for circular functions and clockwise for hyperbolic to give a value such as OE $\underline{/\phi}$.

To assist in the process and to give the measurement CD an auxiliary may be used, in the form of a set square (Fig. 7) constructed from a sheet of the graph paper. This is set so that the vertical coincides with B and the horizontal with B_1. Then the value of the component CD is read on the horizontal scale of the set square, and arrows on the set square indicate the direction in which CD should be rotated. It must, however, be borne in mind that the points C and O are actually on the horizontal axis of the graph, not of the set square.

The particular arrow used initially to indicate the angle on the circular scale depends upon the function required.

Examples are given in sketches, Figs. 8 and 9. The rules are very simple, but in practice the operations are even simpler than they sound.

The points to remember are :—

(1) The proper arrow should be used.

(2) The real part (α) of the complex angle

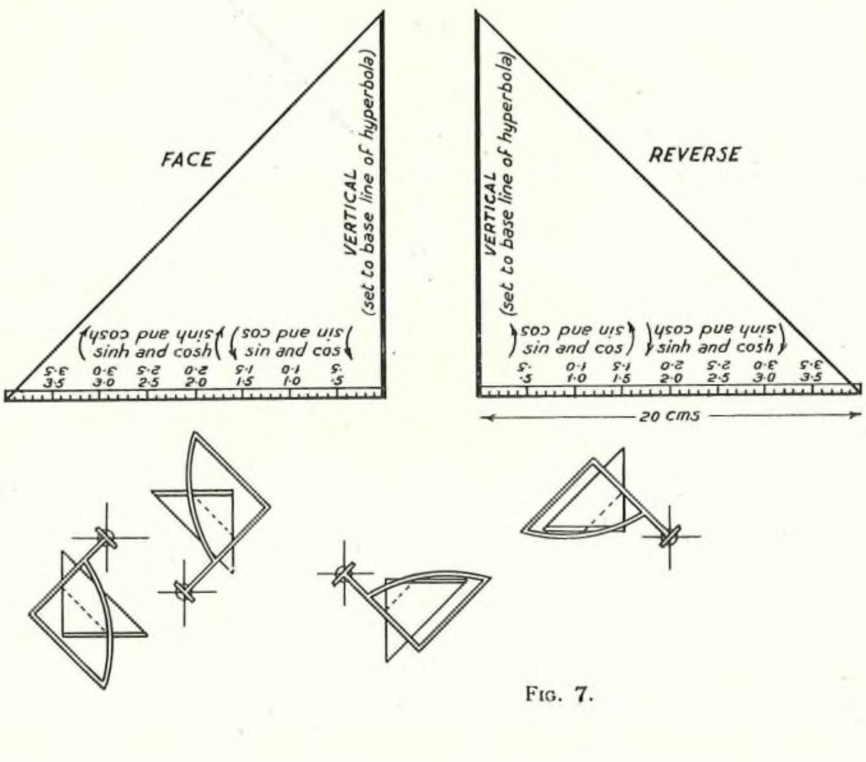
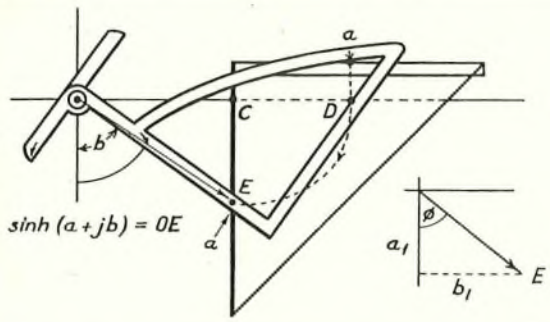


Fig. 7.



NOTE:—In this case (sinh values) the resulting vector OE is read as shown in the diagram referred to the negative vertical axis instead of to the positive horizontal axis.

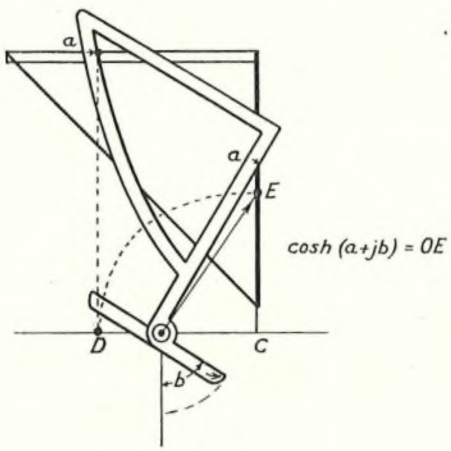


FIG. 9.

($\alpha + j\beta$) is read on the *circular* scale for *circular* functions and on the *hyperbolic* scales for *hyperbolic* functions.

(3) The base line reading of the hyperbolic scales is always the one which is used for the vertical edge of the set square and which gives the fixed point C.

(4) The reading on the hyperbola is the one to which the horizontal of the set square is set and which gives the rotated point D.

(5) Rotation is anti-clockwise for circular functions and clockwise for hyperbolic functions.

(6) For sinh values the resulting vector is referred to the negative vertical axis.

The notes on the diagram should prevent any confusion after a few examples have been tried.

As regards the actual construction very little need be said. The scale used was carefully chosen, but can be varied if required. The hyperbola should be made of a good quality of stiff white card. The scale distances for the hyperbola base line are the "X" values in the schedule. As regards the hyperbola scale, perhaps the best method is to draw the hyperbola first by working from the 45° lines, mark off a few important points like .5, 1.0, 1.5 and 2.0 radians by measurement from the horizontal and vertical axes, subdivide these into lengths of .05 radian using the values in the schedule and finally subdivide into hundredths of a radian by estimation.

It should, of course, be mentioned that both sides are graduated, the whole being simply turned over to give a negative hyperbola, *i.e.*, for cases where α (hyperbolic functions) or β (circular functions) is negative.

Finally it may be pointed out that with a little practice the ordinary process can be reversed, *i.e.*, if a vector function is given the complex angle can be found, thus saving an extremely tiresome calculation.

SCHEDULE OF VALUES FOR THE PLOTTING OF HYPERBOLAS.

Angle (μ)	x	y	Approximate length along hyperbola of .05 radian.
0	1.00	0	
			.05
.05	1.00	.05	
			.05
0.1	1.005	.10	
			.05
0.15	1.01	.15	
			.05
0.2	1.02	.20	
			.055
0.25	1.03	.255	
			.055
0.3	1.045	.305	
			.055
0.35	1.06	.355	
			.055
0.4	1.08	.41	
			.055
0.45	1.105	.465	
			.06
0.5	1.13	.52	
			.06
0.55	1.155	.575	
			.065
0.6	1.185	.635	
			.065
0.65	1.22	.695	
			.07
0.7	1.255	.76	
			.075
0.75	1.295	.82	
			.075
0.8	1.335	.89	
			.08
0.85	1.385	.955	
			.085
0.9	1.435	1.025	
			.09
0.95	1.485	1.10	
			.095
1.0	1.545	1.175	
			0.10
1.05	1.605	1.255	
			0.105
1.1	1.67	1.335	
			0.11
1.15	1.735	1.42	
			0.115
1.2	1.81	1.51	
			0.12
1.25	1.89	1.60	
			0.125
1.3	1.97	1.70	
			0.135
1.35	2.06	1.80	
			0.14

Angle (μ)	x	y	Approximate length along hyperbola of .05 radian.
1.4	2.15	1.905	
			0.145
1.45	2.25	2.015	
			0.15
1.5	2.35	2.13	
			0.16
1.55	2.46	2.25	
			0.17
1.6	2.575	2.375	
			0.18
1.65	2.70	2.505	
			0.19
1.7	2.83	2.645	
			0.20
1.75	2.965	2.79	
			0.21
1.8	3.105	2.94	
			0.22
1.85	3.26	3.10	
			0.23

Angle (μ)	x	y	Approximate length along hyperbola of .05 radian.
1.9	3.42	3.27	
			0.245
1.95	3.585	3.445	
			0.26
2.0	3.76	3.625	
			0.275
2.05	3.95	3.82	
2.1	4.145	4.02	
2.15	4.35	4.235	
2.20	5.57	4.455	
2.25	4.795	4.69	
2.3	5.035	4.935	
2.35	5.29	5.195	
2.4	5.555	5.465	
2.45	5.83	5.75	
2.5	6.13	6.05	
2.55	—	—	
2.60	6.77	6.695	

The above figures are approximate, but sufficiently accurate for the purpose.

Electrode Method of Locating an Earth Fault on Submarine Cables, and the Development of Apparatus for use on Cableships

S. Hanford, B.Sc., M.I.E.E., and L. Voss.

1. *Introduction.*

A MEANS of locating and buoying a fault when out of sight of land would be particularly valuable to the Submarine Cable Repair Department, and the work of Messrs. Palmer, Manning, and Tufnall, described in the April, 1933, issue of the *P.O.E.E. Journal,* has accordingly been followed up with the object of developing the electrode method of locating earth faults on sea cables until it is reliable at all distances and depths likely to be encountered on continental cables.

The investigations at Dover, described in that article, were undertaken in 1931 with the object of ascertaining the basic relationships between the indication received by electrode pick-up and such matters as frequency, strength of supply current, length of electrode span, distance from cable, and angle of electrode set to the direction of the cable. They are of fundamental importance.

The present article describes developments and trials since May, 1932, when the fault on the Granton—Aberdour cable was easily located by means of a rudimentary electrode set.

2. *Granton—Aberdour Tests.*

After the fault had been located with two electrodes on a 10-foot plank, and the position buoyed, an improved electrode set was constructed.

A 10-foot square skeleton raft with copper-plate electrodes fixed 2ft. 6ins. below each corner was made. To avoid variations due to contact resistance the backs of the electrodes were painted before they were fixed to the woodwork and the faces kept bright by a daily cleaning with emery cloth. The raft was quite stable in choppy water and kept the electrodes well away from surface disturbances. Having four electrodes, measurements in four directions could be taken, without turning the raft in the water, by choosing the pair which lay in the desired direction. This electrode raft was towed slowly by a motor launch.

As the fault was only ½ naut. from the Aberdour shore compass stations were set up there at each end of a triangulation base of 962 yards. By a system of signals, and by each observer having his watch synchronised, it was possible to record the position of the launch at any moment and to take a reading of the electrode pick-up as the raft was being towed along a definite course. The reliability of the zig-zag method of approach to the fault was tested on some half dozen runs, and it always resulted in quite definite indications being obtained, which permitted of the course of the cable being readily followed.

Twelve runs transverse to the cable were made and plotted, covering that part of the cable which lay from two to four and three-quarter nauts. from Granton, and in each case the position of the cable

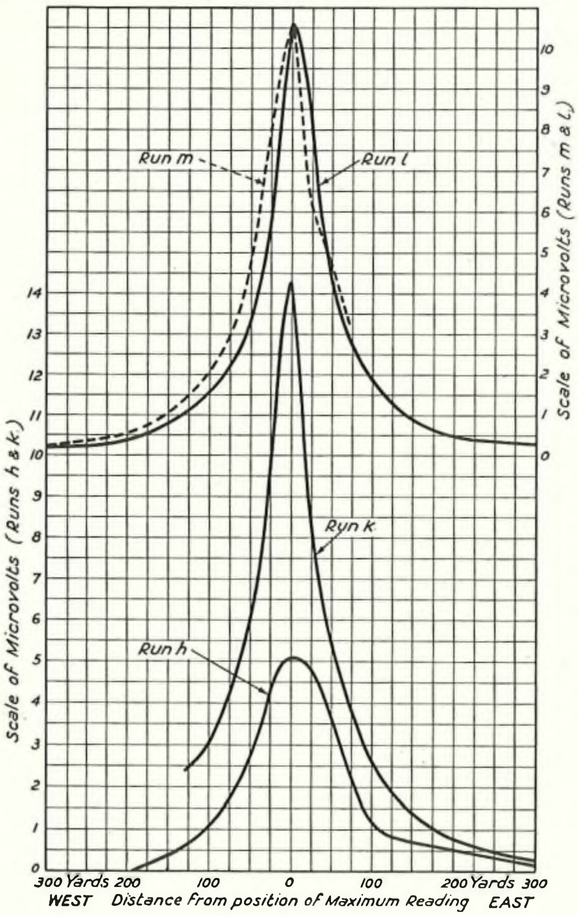


FIG. 1.—TYPICAL TRANSVERSE RUNS.

again as required. The raft used on the Granton trial was too clumsy and a simple set, consisting of two brass cylinders with conical ends, which could be towed in tandem, was made. The brass electrodes were joined by 18 yards of tow-line, a further 50 yards of tow-line was used to fasten the pair of electrodes to the launch. An insulated lead was run from each electrode along the tow-line to the apparatus on the launch, the leads being attached to the tow-line at intervals. With various minor modifications this electrode system has been employed on all subsequent work and the electrode set finally developed and shown in the photograph at the end of the article is constructed on these lines. The towing operation with these tandem electrodes is as simple as the towing of a ship's log.

Runs at an angle of about 40° to the cable line of the faulty La Panne II. cable were made and the deflection of the detector galvanometer noted at intervals. The position of the launch was charted periodically from sextant sights on prominent landmarks. In this way it was possible to determine within a little the location of the launch at the time of maximum deflection and these points were marked on the chart. This maximum occurs when over the cable and in nearly all cases the cable was found to be about $\frac{1}{4}$ naut. north of its charted position. The cable was found to be west of its charted position. Four typical transverse runs are shown in Fig. **1**, a longitudinal run along the line of the cable near the fault in Fig. **2**, and in Fig. **3** the maxima obtained when over the cable on the various runs are plotted against distance from the oscillator station at Granton. The pick-up between the 10-ft. electrodes is shown in each case in microvolts, the detecting amplifier rectifier having been calibrated accordingly. The tremendous rise at the fault is worthy of notice.

In these tests the 70-cycle oscillator and tuned detector described in Messrs. Palmer and Manning's article were used, the supply to line being about 120 mA. The results were considered sufficiently promising to justify developing the method and the gear until it became suitable for use under practical conditions on a faulty main submarine cable.

3. *Trial from launch off St. Margaret's Bay in July, 1932.*

For use in unsheltered water the electrode set must be as simple as possible and be capable of being drawn up on board and let back into the sea

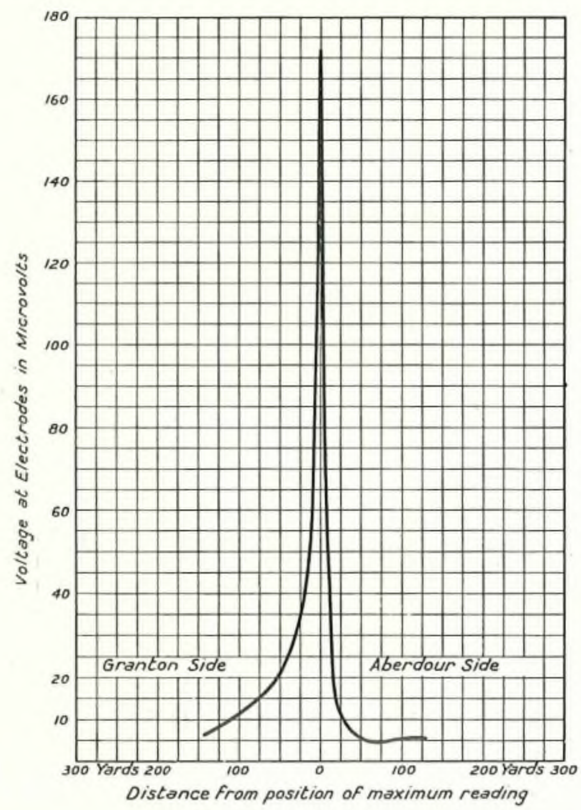


FIG. 2.—LONGITUDINAL RUN MADE ON A LINE ROUGHLY PARALLEL TO THE CABLE, BUT NOT NECESSARILY DIRECTLY OVER IT, AND AS NEARLY THROUGH THE FAULT AS POSSIBLE.

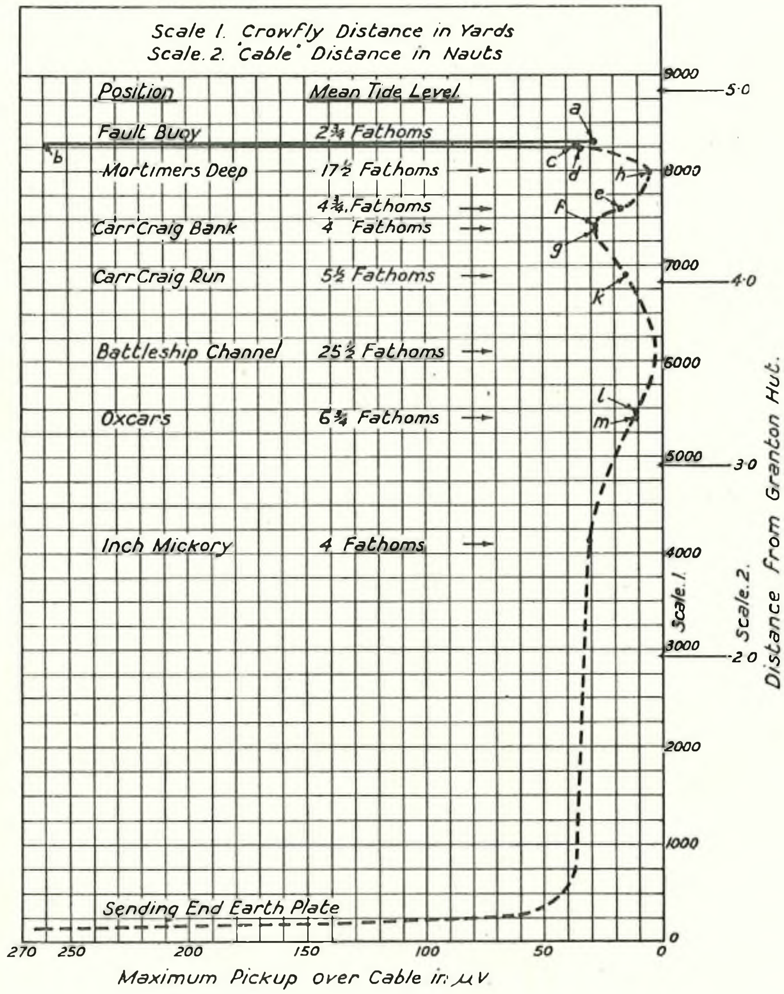


FIG. 3.—LONGITUDINAL DIAGRAM OF MAXIMUM VALUES OBTAINED DURING TRANSVERSE TESTS ; ELECTRODES PARALLEL TO CABLE.

appartus worked up to $7\frac{1}{2}$ nauts. from shore, the input to the cable being 160 mA of 70-cycle current.

A small battery-driven dynamotor running at Dover Exchange and feeding 17-cycle supply to the cable over land lines to St. Margaret's was next used, with a new amplifier-rectifier receiver tuned to accept frequencies below 30. The machine gave 75 volts when the output was 200 mA.

The indications obtained with this set with the same electrodes in similar locations near the cable were about three times as strong as with the 70-cycle apparatus due to (*a*) increased input, (*b*) increased percentage of return current flowing in the sea instead of the cable sheath and (*c*) increased amplification in the low pass amplifier-rectifier.

The cable was easily followed by a zigzag course for some 5 nauts. at a speed of about 6 knots, the turning points being governed solely by the galvanometer deflection having risen to a maximum and begun to fall again. The limit of distance was by no means reached, but approaching darkness necessitated ceasing operations.

4. *Test against an iron ship, and on a bend in a cable.*

Various suggestions had been made to attach the electrodes to the hull of cable repair ships, or to stages built out from the hull.

In August, 1932, therefore, tests were made with electrodes in the vicinity of the hull of an iron ship. It was found that at distances of as much as 20 yards from the hull the indications received were only one-fifth as strong as they were when the ship was not there. At smaller distances the sensitivity is so much reduced that the idea of attaching electrodes to the iron hull of a ship is ruled out as impracticable.

About the same time tests in miniature in a tank on a cable bent at right angles were made. The maximum deflections were always obtained over the cable and not along a line joining its ends, although at equal distances away from the cable the indications will be maintained at a higher level inside the bend than outside it.

5. *Trial on " Alert " on faulty La Panne II. g.p. cable in September,* 1932.

In view of the success obtained with the launch in July, a trial from cable-ship *Alert* was considered justified.

The derelict La Panne II. cable was traced out from a point 4 nauts. off St. Margaret's Bay by the electrode apparatus using 200 mA of 17-cycle and the low pass amplifier-detector. The electrode span was 18 yards, and the length of tow-line to the first electrode was 80 yards instead of 50 as previously. For towing speeds of over 4 knots, however, it will be necessary to increase this in order to clear the wash.

The zigzags continued for some 5 miles, crossing the cable thirty times in all. With the exception of two failures, due possibly to crossing the cable nearly at right angles, all crossings west of a point 8 nauts. from St. Margaret's gave good and reliable readings with definite maxima. To the east of this point no reliable readings resulted, but check runs made on the west side near the 8-naut. point gave good maxima. The point was marked by a buoy, and grappling commenced just beyond. The first dredge resulted in a cable being hooked which was seen to be slipping over the grapnel, due to its having broken on one side. Before the cable slipped right off, it parted on the other side and on being brought inboard one end was found to be a new break and the other an old one with the copper wires pointed as by the action of the 17-cycle current. It was not definitely proved that this was the fault, as due to the fact that the cable was derelict it was not considered worth while to regrapple for the broken shoreward end and test to shore. A location test from the hut the same night, however, indicated that La Panne II. had all cores full earth at 8 miles out. As this was the position where the electrode indications were lost, there is little doubt that the cable had been hooked within a short distance of the fault.

During this trial it was observed that flicking of the galvanometer needle took place, particularly when waves, some 6 feet trough to crest, were running, due to the electrodes trailing too near the disturbed surface of the sea. In future, when towing from cableships the tow-line should be weighted at about 20 yards on the shipside of the nearer electrode so as to increase trailing depth to well below the wave troughs.

The depth of water at the fault was 25 fathoms and a deflection just shoreward of the fault position indicated $7\frac{1}{2}$ microvolts. With unshunted galvanometer this gives an off-scale deflection, so that there is ample margin to get results from a more distant fault. It must be remembered also that near the fault, no matter how far away from the shore it may be, the indication will not be much reduced unless the depth is greater, provided there is not general low insulation along the cable, and provided there is enough 17-cycle voltage to get 200 mA out through the fault.

Capt. Firmin was in command of *Alert*, and the ship's officers plotted the zigzag course on the chart from rangefinder and compass observations. The fault was practically on the cable line as charted.

6. *Location of* (a) *earth fault and* (b) *a broken cable on Anglo-Belgian* 1932 *lead-sheathed cable before acceptance.*

(*a*) A crack in the alloy sheath occurred about $\frac{1}{2}$ naut. from St. Margaret's Bay during the laying of the shore section.

The electrode gear using 17 cycles and low-pass detector was employed, with a sea-going launch. Due to rough weather the first attempts were indefinite, the electrodes bumping bottom at slow speed in the choppy water and finally carrying away. On October 12th, however, after about two hours searching, the fault was found and buoyed. Accuracy of location was + or − 10 yards, depth being only $4\frac{1}{2}$ fathoms.

This piece of work expedited the repair operations considerably and reduced the length of cable cut out to 45 yards.

(*b*) An anchor break occurred about 4 nauts. offshore before acceptance.

The opportunity was seized of testing the electrode gear at this distance on a lead-sheathed cable which was rubber covered only for the first half naut.

The 17-cycle supply and detector apparatus and 50-yard electrode towing set were used with 18-yard electrode span. A small boat's compass was the only means at hand for determining our position.

On 27th October, 1932, after a few preliminary runs to find the cable on the shore side of the fault, *i.e.*, west of the South Goodwin lightship, and to prove that away to the eastward no indications were obtained, a series of parallel runs crossing the cable line at about 35° was started in the area north of the lightship. Each run was made a little more easterly than the previous one, compass bearings of the lightship at the moment of getting maximum indication being taken on each run to prove that we were gradually crossing more and more to the east. Fifteen crossings were made and there was a clear indication on all runs west of a certain point but nothing on runs to the eastward. A check test a little to the west again gave a full scale indication and turning eastwards a wooden flag buoy was dropped at the place where the fault was judged to be. The buoy was not found by the repair party so far as is known, but the test was quite a satisfactory one and proved that a break in a lead-sheathed cable could be located at 4 nauts. in about 12 fathoms.

7. *Construction of permanent supply and detector apparatus for use in future localizations.*

Since the last trial, two 17-cycle tuned amplifier-rectifiers have been made. The indication is read on a Paul unipivot galvanometer mounted on gimbals. The whole of the apparatus required on the ship, with the exception of the 4-volt accumulators, is contained in a strong teak case. These detectors have been calibrated and proved to be as powerful as the previous low-pass amplifier-detector.

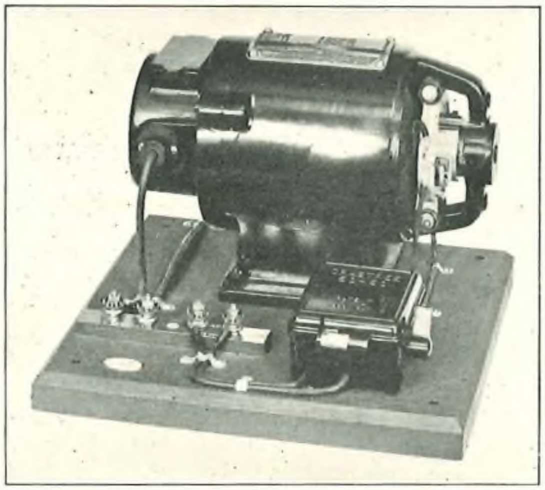
A dynamotor, designed to run off a 22- or 24-volt exchange battery, has been obtained. It will give 98 volts of 17-cycle supply at 400 mA output.

The electrode set consists of two torpedo-shaped brass bodies set at 20 yards distance at the end of 80 yards of tow-line. Insulated leads run up the tow-line connecting the electrodes to the detecting apparatus on board. Further work is necessary before this item of equipment is perfect—the best way in which the tow-line is to be allowed to shrink when wetted and subsequently stretch when in use without throwing strain on the insulated leads has yet to be finally decided in practice.

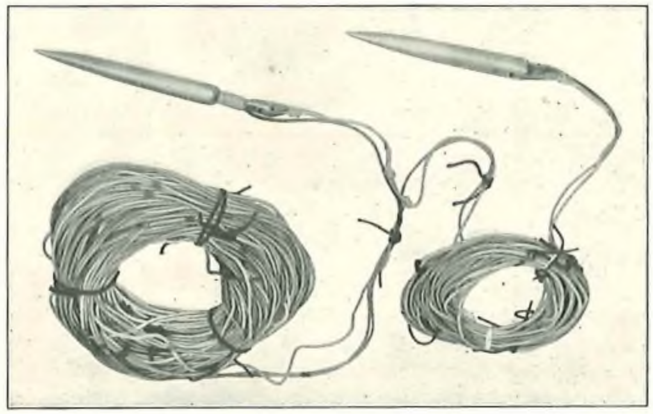
Photographs of the apparatus are shown in Fig. 4, which give an idea of its appearance.

8. *Fault localization on Bacton-Borkum No.* 1 *cable at* 70 *miles from Borkum.*

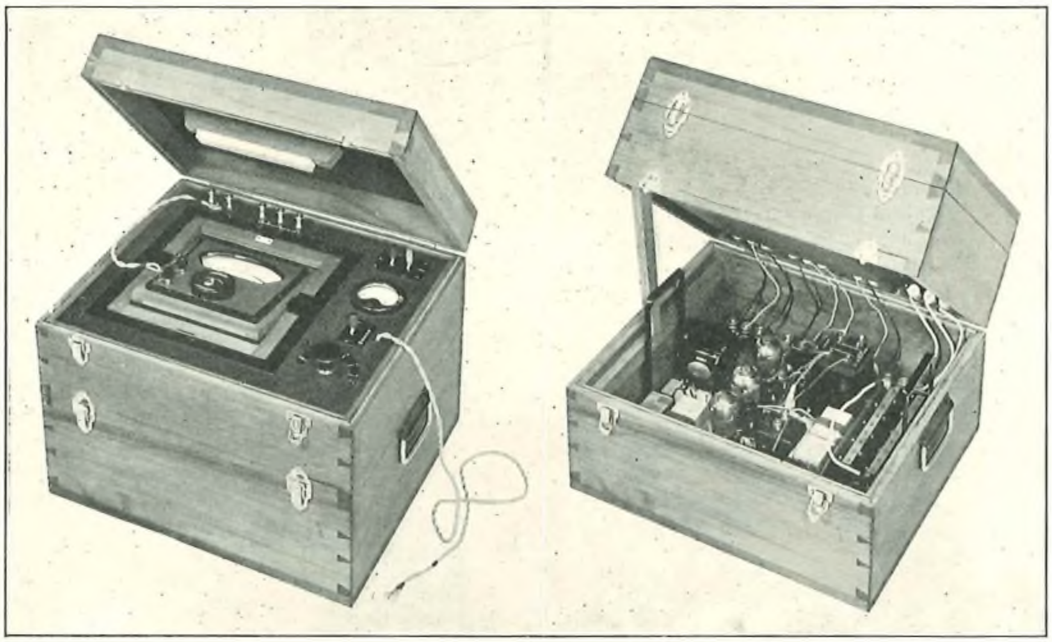
On May 11th, 1933, the electrode method was successfully employed to locate the position of the faulty cable and of the fault thereon. The apparatus



17-cycle Machine.



Electrodes, Towline, and Leads.



Amplifier—Rectifier—Detector.

Fig. 4.—Supply and Detector Apparatus.

described in the previous section was used. The 17-cycle machine was used at Borkum and supplied 180 mA into the faulty core—the resistance of which, including that of the fault, was about 800 ohms.

Electrodes at 20-yard span were towed in tandem from *Alert*, and excellent results were obtained. The maxima deflections were so strong that the third range of sensitivity had to be employed, *i.e.*, the deflection was equivalent to about 2½ times full scale with unshunted galvanometer.

The cable was located by a zigzag course being run and the positions of maximum being plotted on the chart. These all fell on a straight line and showed the cable to be one mile south of its charted position. The cable was crossed four times, the most westerly crossing giving only about one-sixth of the deflection obtained on the other three crossings. This was judged to be beyond the fault. The position of the fault was thus located to within a ¼ naut, the distance between the most westerly crossing and the previous one.

Length of dredges was reduced from 3½ miles to a few cables north and south of the known position of the cable. During grappling the electrodes were towed astern not in tandem but separately one from each side of the ship, the distance between them being 35 feet, and length of towlines each 40 yds. With this arrangement the electrodes were set parallel to the cable while the ship crossed at right angles to it. The strength of indications received was again great enough to need the third range of sensitivity of the detector and the moment of crossing the cable could be detected and reported to the Captain. The ship could then be turned without delay. In this way three crossings per hour were made good and as much work done in one day as would have occupied a further week had the electrode gear not been available.

The cable was hooked the subsequent day in a position on the new charted line.

A run on a zig-zag easterly course for a distance of some four miles crossing the cable eight times gave strong indications with a well defined maximum each time the cable was crossed, and there is no doubt that the ship could have traced the cable right in to Borkum had it been required, the indications being very much stronger than would have been essential for tracking the cable.

In conclusion, the authors thank all who have given such valuable assistance with the various sections of the work of developing the electrode method to its present very promising state, particularly mentioning Messrs. Tamplin and Sephton, of the Research Section, and Capt. Hutchons, Mr. Firmin, and all *Alert's* officers and crew without whose painstaking help the work would not yet have been accomplished.

Acceptance Testers used on Sleeve Control Equipment

E. J. Harrold and C. N. Smith.

Sleeve control equipment is now being installed in a large number of exchanges throughout the country. In this article it is proposed to give the reasons for the various tests and the method of applying testing conditions to ensure satisfactory operation when the circuits are brought into service.

The equipment to be tested falls into two main categories, namely: (*a*) Cord and Position circuits including Time Check Circuits, (*b*) Relay-sets and S.A.R. equipment.

Two testers have therefore been designed to apply functional tests to the apparatus and, in addition, to test the operating features (operate, non-operate, hold, etc.) of all the important relays together with the values of the resistance spools. The latter tests are additional to those made under the percentage adjustment and resistance check during acceptance testing.

The tests are applied with the exchange battery at its normal voltage, but the testers are designed to permit only the current which would be available at the minimum or maximum voltage to flow in the relays under test. The minimum current is applied on the " operate " tests and the maximum current for " hold," " non-operate," and " release " tests.

Tester No. 99 is used for applying tests to the Cord, Position and Time Check Circuits. The Relay-sets and S.A.R. equipment are tested by means of the Tester No. 105.

An earlier article dealt with the sleeve control equipment, but perhaps a recapitulation of the major features would be of interest.[1] Fig. 1 shows one cord circuit commoned to the operator's position equipment, the number of cord circuits per position varying according to the traffic requirements. The cord circuits are of the " empty " type and, with the keys normal, consist of a straight-through pair of wires from the answering to the calling plug.

The apparatus necessary for transmission and signalling purposes on the various types of circuits is associated with the particular circuit itself in the form of a relay-set. The sleeve conductors of the cord circuit carry the supervision of the lines to the operator. The tip and ring conductors merely extend the A and B wires between the relay-sets without any bridging apparatus. The cord circuit is therefore universal.

The apparatus required by the operator for setting up connexions is common to the position and can be associated with any cord circuit by operating a cord circuit speaking key.

The cord and position circuits have been provided with the following facilities:—

(1) A speaking key is associated with each cord circuit. With the speaking key operated the cord circuit is extended to the position equipment. The circuit of the speaking keys has been so designed to enable only one cord circuit to be connected at any one time to the operator.

(2) Ring answer and ring call keys are provided which connect negative battery to the tips of either plug. This battery operates a relay in the line relay-set which transmits ringing or battery recall signals to the distant end, depending upon whether the circuit is of the generator or C.B. signalling type. When the ringing key is operated on one cord, the key circuit has been arranged to connect a 600-ohm terminal impedance across the other cord of the pair, thus keeping this circuit closed to preserve stability on repeatered lines.

(3) Speak answer and speak call keys are arranged

[1] " Demand " Trunk Service. By J. H. Jenkins, M.I.E.E. P.O.E.E.J., Vol. 24, p. 193.

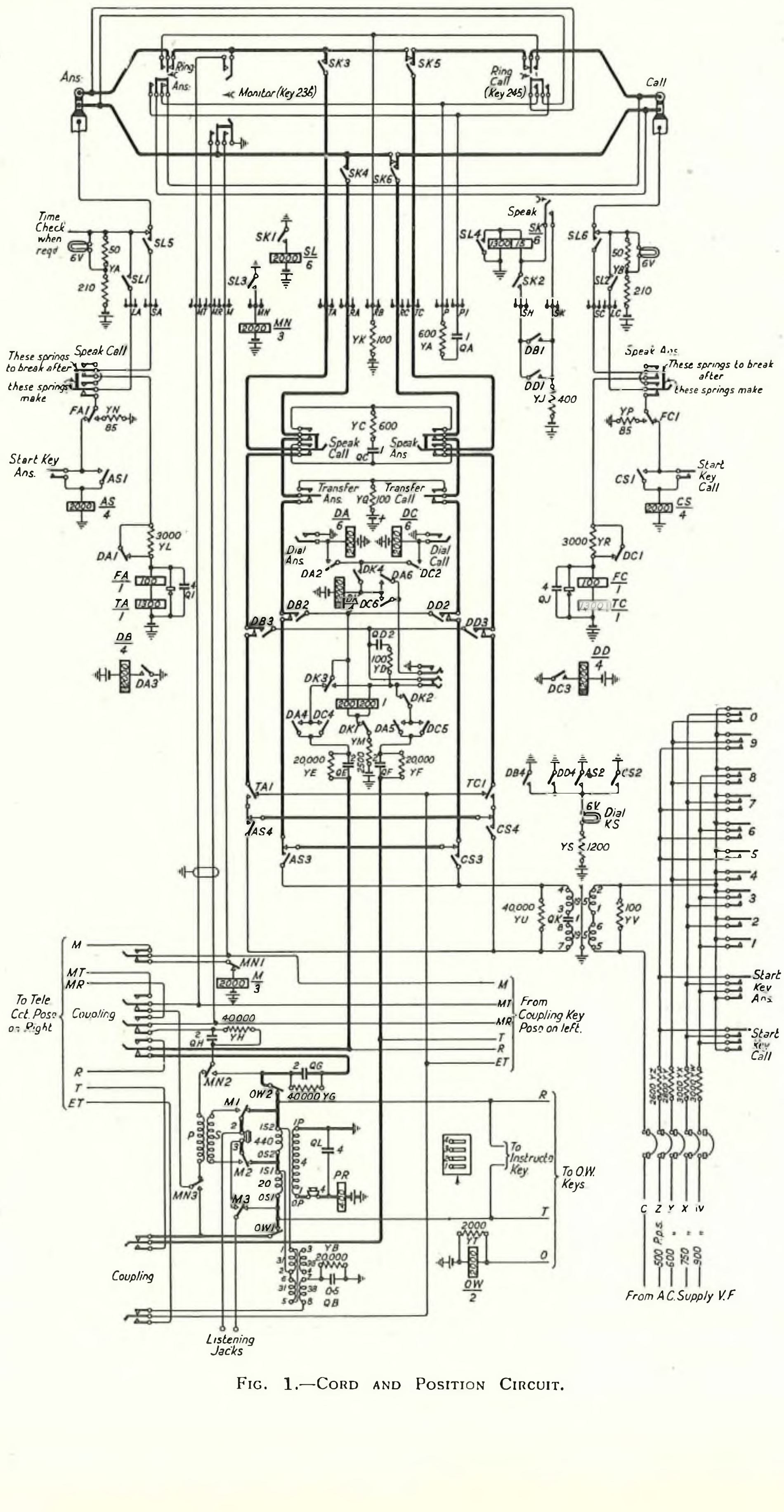


Fig. 1.—Cord and Position Circuit.

for speaking separately on either the answering or calling cord, a terminal impedance being connected across the cord which has been disconnected from the operator's telephone circuit.

(4) Dialling may be effected on either cord by the operation of the dial answer or dial call key.

(5) The transfer answer and call keys, when operated, connect a positive battery to the ring conductor of either cord. Automatic transfer of calls from one position to another, on lines requiring this facility, is accomplished by the operation of the transfer key which sets up the necessary transfer condition in the relay-set.

(6) A monitor key is provided on each cord circuit to enable the operator to listen on a circuit while conversation is in progress. When this key is operated, the operator's receiver is connected across the cord circuit *via* a high impedance transformer. This arrangement introduces a very low tapping loss.

(7) It will be observed that in Fig. 1 provision has been made for A.C. (Voice Frequency) keysending, but the equipments installed so far have only included the wiring for this facility. Testing arrangements have therefore not been included in the Tester No. 99.

The circuit shown in Fig. 2 is the portion of the Tester No. 99 which is used for applying tests to the cord and position circuits, the necessary conditions equivalent to the various types of relay-sets being set up by operating keys on the tester in conjunction with those on the position. In carrying out the tests, an operator's instrument is inserted into the position and use is made of the operator's receiver in conjunction with the tester.

Associated with the tip and ring of the answer jack are relays A and B, lamp D, and a buzzing relay which produces a tone used for proving the continuity of the speaking circuits in conjunction with the operator's receiver. The sleeve of the answer jack can be connected to relay C and various resistance spools for testing the sleeve relays in the position circuit.

Ringing and ringing return can be connected to the tip and ring of the calling jack. In circuit with the ringing supply are two relays E and EA which are used for proving the terminal impedance circuits of the speak answer, speak call, and ringing keys. The sleeve of the calling jack can be connected to relay F which is employed to prove the rectifier across the sleeve relays in the position circuit.

A change over key 6 is provided for interchanging the tip, ring and sleeve conductors of the answer and calling jacks. When a cord circuit is under test with its answering and calling plugs in the corresponding jacks of the tester, the operation of key 6

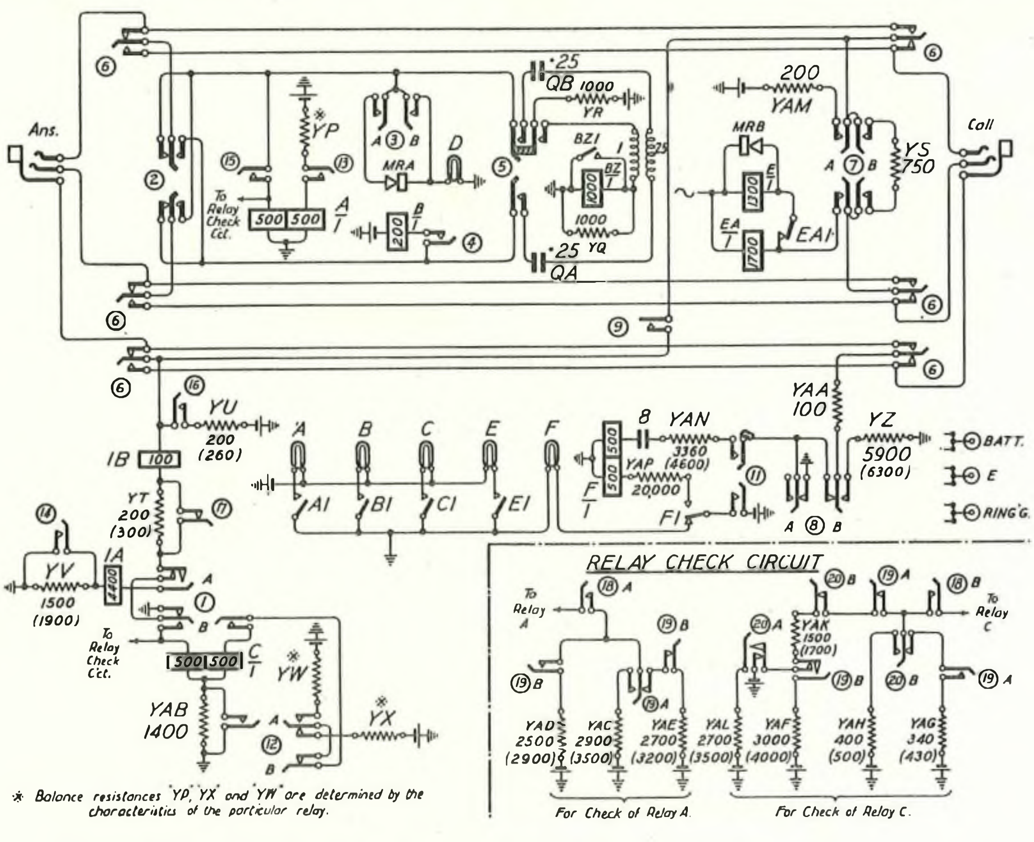


FIG. 2.—PORTION OF TESTER No. 99 USED FOR TESTING CORD AND POSITION CIRCUITS.

enables similar tests to be carried out on either cord without the necessity of interchanging the plugs.

The circuit employs a differential relay A for the purpose of checking the resistance values of the apparatus under test. The method employed is to energize the relay on one winding by means of a local circuit and when the other winding is applied to the circuit under test, the release or holding of the relay is determined by the current flowing in this winding.

The differential relay C operates in a similar manner.

In order to verify the adjustment of these relays, a relay check circuit is incorporated in the tester.

There are seventeen connexions made between the cord circuit and the common equipment when a speaking key is operated. In order to test the cord circuits fully, each one must therefore be tested in conjunction with the common equipment. Further tests are necessary to check local circuits in the position common equipment.

The following schedules show the various tests that are applied. Tests 1 to 32 are made on each cord circuit in conjunction with the position equipment. Tests 33 to 54 are made on the position common equipment only.

SCHEDULE OF TESTS APPLIED USING TESTER No. 99.

(1) Supervisory lamps.
(2) Continuity of sleeve circuits, *via* SL contacts and speak, answer and call keys.
(3) Resistance value of supervisory lamps and sleeve relays.
(4) Make-before-break of SL contacts in sleeve circuits.
(5) Ringing battery on answer cord.
(6) Ring answer key terminal impedance on calling cord.
(7) Break spring of ring answer key.
(8) Ringing battery on calling cord.
(9) Ring call key terminal impedance on answer cord.
(10) Break spring of ring call key.
(11) Continuity of speaking circuit on answer and calling cords.
(12) Terminal impedance on answer and calling cords *via* splitting keys.
(13) Positive battery on transfer answer and call keys.
(14) Break spring of transfer, answer and call keys.
(15) Dialling tone circuit, on calling cord.
(16) Check of pre-dialling 2,700-ohm battery, on tip and ring of calling cord.
(17) Operation of relay DK *via* DA6.
(18) Dial impulsing on calling cord.
(19) Lock-up of relays DC, DD, and SK.
(20) Release of relays DC, DD, and SK.
(21) Continuity of tip and ring of cord circuit.
(22) Dialling tone circuit on answer cord.
(23) Check of pre-dialling battery, on tip and ring of answer cord.
(24) Operation of relay DK *via* DC 6.
(25) Dial impulsing on answer cord.
(26) Lock up of relays DA, DB, and SK.
(27) Release of relays DA, DB, and SK.
(28) Lock-out of relay SK when two speaking keys are operated.
(29) Cut-in of relay SK when one speaking key is restored.
(30) Contacts between adjacent cord circuits.
(31) Operation of relay M and overhearing.
(32) Operation of relay MN and release of relay M.
(33) Operation and release of relay FA.
(34) Operation and release of relay FC.
(35) Check of 3,000-ohm resistances in answer and calling sleeve circuits.
(36) Make-before-break of speak call key.
(37) Make-before-break of speak answer key.
(38) Engaged test on answer cord with low and high resistance sleeve circuits.
(39) Engaged test on calling cord with low and high resistance sleeve circuits.
(40) Calling sleeve rectifier.
(41) Answer sleeve rectifier.
(42) Condenser in operator's circuit.
(43) Condenser in monitor circuit.
(44) Holding of relay TA.
(45) Holding of relay TC.
(46) Spark quench in dialling circuit.
(47) Coupling of speaking, monitor and engaged test circuits.
(48) Operation of relay OW.
(49) Continuity of order wire keys.
(50) Contacts between order wires.

SCHEDULE OF TESTS APPLIED WITHOUT USING TESTER No. 99.

(51) Overhearing from operator's transmitter circuit when monitoring.
(52) Transmission efficiency of operator's telephone circuits.
(53) Dial speed tests.
(54) Tapping loss of monitoring circuit.

The following explanation covers the more important features of the tests.

Tests 1 to 4, 36 and 37 determine the resistance values of the sleeve circuits, the tests being made by the manipulation of keys 1, 6 and 12 which bring into operation relay C. These resistance values are checked owing to the difference in resistance between the supervisory lamp in the cord circuit and the sleeve relays in the position circuit being used to control a differential relay DR in the relay-sets.

Tests 5 to 10 are made by means of keys 3, 6 and 7. The 100-ohm battery connected to the ringing key is received on lamp D when the ringing key is operated, whilst relays E and EA test the ringing key terminal impedance. If the latter circuit is in order, lamp E glows, but a short circuit on the 1 μF condenser causes the operation of relay EA which disconnects relay E and lamp E fails to glow.

Tests 13 and 14 are made by means of keys 3 and 6. The 100-ohm transfer key positive battery being received on lamp D *via* a rectifier.

Tests 15 to 27 are made by means of keys 2, 4, 5, 6, 13, and 15. It will be observed that the normal listening circuit with the speak and dial keys operated is disconnected at DB or DD contacts and the circuit for the receipt of dial tone is *via* condensers QE and QF. This circuit is proved by means of tone from the buzzing relay connected to the tip and ring being received in the operator's receiver.

Relay A checks the accuracy of the pre-dialling 2,700-ohm battery on the tip and ring conductors. (This battery is used to prepare the relay-set to enable the dial impulses to pass to line). Impulses from the dial are received on relays A and B of the tester.

As there is a possibility that the speak or dial key may be restored by the operator before the last train of impulses has been completely transmitted, the circuit has been arranged that, with the dial off normal, the cord circuit is locked to the position equipment, irrespective of the positions of the speak or dial keys. This ensures that the last train of impulses is not mutilated. The lock up is removed when the dial returns to normal.

This facility is tested by restoring the speaking and dialling keys with the dial off normal and receiving the impulses when the dial is released on relays A and B.

Tests 28 and 29 are made by using a busy tone and also the buzzing relay tone; they are applied to prove that when one SK relay is operated by the corresponding speak key the potential on the speaking key common is reduced to prevent the operation of a second SK relay. When the first SK relay is released the second SK relay should operate.

Tests 31 and 32 are made to check the operation of relays M and MN. When a monitor key is operated, relay M operates, changing over the operator's receiver to the high impedance transformer. Should a speaking key be operated on any other cord circuit while the monitor key is operated, relay MN operates breaking the circuit of relay M. The operator's receiver then reverts to the normal speaking condition and the monitor circuit conductors now function as a speaking pair. This enables the operator to speak on one cord circuit while dialling on another.

Tests of the foregoing are made by using the buzzing relay tone in conjunction with the operator's receiver, and operating the appropriate keys on the position to transfer the tone *via* the contacts of relays M and MN.

Tests 40 and 41 are made to prove the rectifiers across the sleeve relays. The object of these rectifiers is to prevent surges on the sleeve of the plugs. Tests are made with relay F associated with the calling sleeve of the tester. This relay will respond to surges and lock up when the sleeve is interrupted, should the rectifier be disconnected.

Tests 44 and 45 are made to prove the holding of the sleeve relays TA and TC. The contacts of these relays, when operated, are directly in the operator's speaking circuit and the relays are designed to hold should another operator overplug in error. Tests are therefore made to reduce the current flowing in these relays to 1 milliampere, this being the current which would flow in the overplug condition. The buzzing relay tone is employed in conjunction with the operator's receiver to prove the continuity of the operator's speaking circuit when the current flowing in the relays is so reduced.

Test 51 is made to prove that, when monitoring, no overhearing takes place in the wiring between the operator's transmitter circuit and the cord circuit. The monitor circuit is wired in screened cable to prevent such overhearing. The test is made by speaking into the operator's transmitter with the monitor key operated and listening on the cord circuit.

Test 54 is made to prove that the monitoring transformer is wired correctly. For the purpose of this test use is made of the valve oscillating operator's transmission testing set, fitted in large junction centres. These transformers have been designed to give not more than one decibel tapping loss when the operator is monitoring.

Fig. **3** shows the time check circuit associated with each cord circuit on sleeve control equipment.

The uniselector is driven by a 12-second pulse derived from the master clock. It is started on the operation of the time check key to the " start " position and is stopped when the calling subscriber

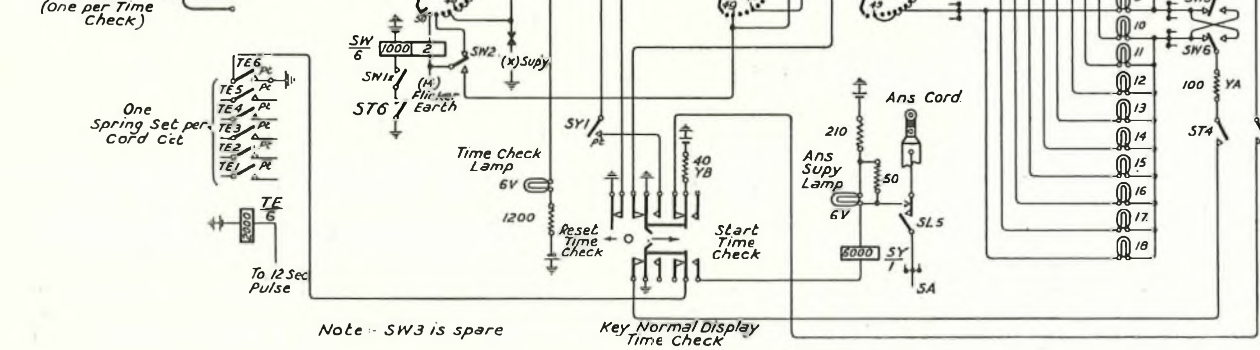


Fig. 3.—Time Check Circuit.

replaces his receiver, as relay SY is then shunted by an 85-ohm earth.

When the time check key is restored to the "display" position, the number of minutes elapsed on the call is shown on one of the eighteen display lamps which are common to the position.

The display is cleared and the uniselector homes on the operation of the time check key to the "reset" position.

To prove the above facilities, the following tests are applied by the portion of Tester No. 99 shown in Fig. **4**:

(1) Check of display lamp bank wiring.
(2) Check of time check lamp bank wiring.
(3) Timing of circuit for 3 minutes.
(4) Routine test of display.

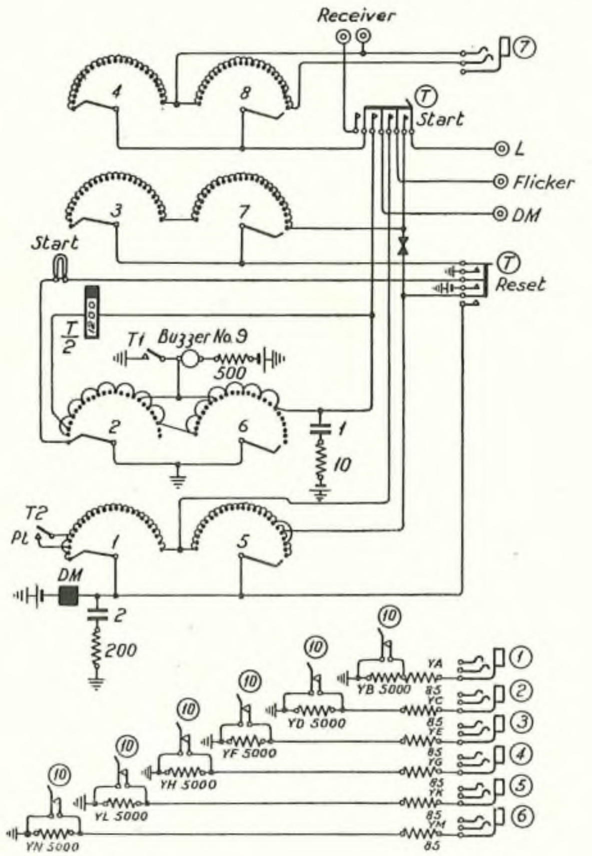


Fig. 4.—Portion of Tester No. 99 used for Testing Time Checks.

Connexions are made to tags at the rear of the position to connect the flicker earth supply, routine test jack, and the time check lamp of the cord circuit under test to the terminals FLICKER, DM, and L respectively of the tester.

When the start key on the tester is operated the tester switch steps, being driven by flicker earth, and transmits impulses over the routine test jack wire, causing the time check uniselector to step.

After five impulses have been transmitted, representing the elapse of 1 minute, the buzzer No. 9 operates, indicating to an observer that the display lamp No. 2 glows replacing the display lamp No. 1. The remaining display lamps glow in a similar manner after the transmission of each set of five impulses.

It will be observed from Fig. **3** that the time check lamp will glow for 12 seconds after each 3-minute period elapses and will flicker after the 9- and 18-minute periods due to an earth being returned *via* bank contacts 16, 31 and 46.

The first revolution of the uniselector in the tester transmits 15 impulses representing a period of 3 minutes. The wipers of the time check uniselector should then be resting on bank contact 16 when an earth is returned on the time check lamp wire, causing the tester uniselector to step on.

Further revolutions of the tester uniselector operate in a similar manner when the earth is returned on the lamp wire *via* bank contacts 31 and 46. Faults on the time check lamp will therefore be indicated by the premature stopping of the tester uniselector.

Relay T has been provided in the tester to delay the operation of the tester uniselector during the period of the change over from display lamp No. 9 to No. 10 to give the time check uniselector sufficient time to return to contact No. 2. When contact No. 2 is reached, the battery *via* the driving magnet of the time check uniselector is returned on the routine test jack wire, T relay operates, and the tester switch resumes stepping.

When the whole of the 18 display lamps have been tested, the tester uniselector stops and flicker earth causes the time check lamp to flicker continuously. The foregoing test is applied to each cord circuit in turn.

A separate test is made on six cord circuits simultaneously, the circuits being timed over a 3-minute period by means of a stop-watch. The six jacks shown in Fig. **4** are employed in conjunction with key 10 to give the sleeve conditions necessary for starting and stopping the time check circuits.

A large number of different types of relay-sets are used in the sleeve control system and Figs. **5** and **6** show typical circuits.

The circuit in Fig. **5** is of an incoming C.B. signalling junction and Fig. **6** represents a both-way generator signalling trunk. The facilities of the circuit shown in Fig. **5** are as follows:—

1. Calling signal.
2. Calling signal lock-out.
3. Through signalling.
4. Flashing.

The facilities of the circuit shown in Fig. **6** are as follows:—

1. Calling signal.
2. Engaged test applied to the outgoing multiple when the circuit is used incoming.

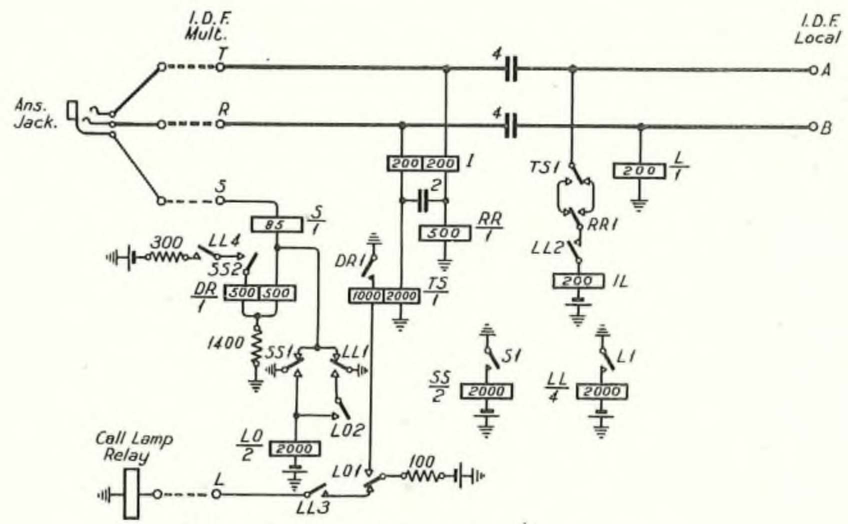


FIG. 5.—INCOMING C.B. SIGNALLING JUNCTION.

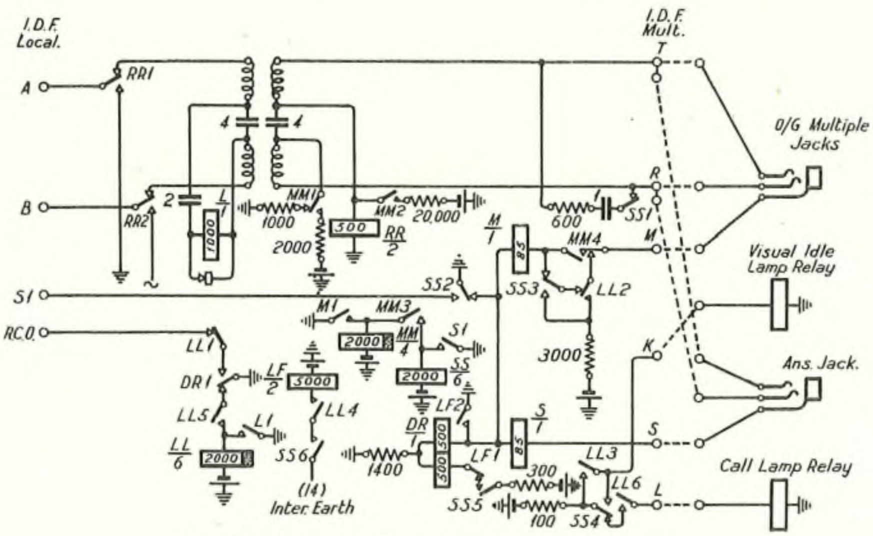


FIG. 6.—BOTHWAY GENERATOR SIGNALLING TRUNK.

3. Control of visual idle indicating signal when the circuit is used incoming.
4. Control of visual idle indicating signal when circuit is used outgoing.
5. Recall signals with flashing of cord circuit supervisory lamp.
6. Resetting of recall signal by operation of cord circuit speaking key.
7. Control of generator signalling from cord circuit ringing key.
8. Control of cord circuit repeater apparatus.

As already mentioned, Tester No. 105 (Fig. 7) is used for testing all types of relay-sets.

In order to facilitate the making of rapid connexions and consequent saving of time in testing, the connexions to the relay-set under test are made by the insertion of Clips No. 23 into the I.D.F. connexion strip, as shown in Fig. 8. The clips are connected to the tester by suitable wiring.

Relay R is a differential relay and, in conjunction with the resistances in the ring conductor, is used to prove the values of the resistances in the relay-set. Connected to the sleeve terminal is a supervisory lamp S and various resistances used to test the sleeve relays.

The A and B terminals are associated with various keys, relays, etc., to reproduce conditions from Trunk, C.B. and Auto exchanges.

Relays P and Q, which are connected to terminal P, are used when testing the P-wire of circuits connected to selector levels using booster battery.

Relay Q responds only when booster battery is applied and relay P operates on the normal P-wire busy condition.

Relay M is used to prove a 3,000-ohm resistance in the sleeve circuit.

The remaining terminals are connected to lamps to prove calling, visual idle indicating, and cord circuit repeater control conditions.

The receiver is normally through to the A and B terminals for proving the ringing tone circuits and, in conjunction with the buzzer, for proving continuity of the speaking circuit in the relay-sets.

When testing the circuit shown in Fig. 5, the A and B tags on the local side of the I.D.F. and the T.R.S. and L tags on the multiple side of the I.D.F. are " picked up " on Clips No. 23 and so extended to the corresponding terminals of the tester. Functional tests are then applied. C.B. calling conditions are set up in the tester on the A and B terminals with the appropriate test resistances inserted. Relay L will then operate and the call is received on lamp L of the tester.

Answering conditions are next applied by inserting by means of keys the appropriate resistances in the sleeve conductor. Relays S and SS operate, energizing relay LO and the calling signal darkens. The lock-out of the calling signal is tested by disconnecting the sleeve circuit.

The sleeve circuit is subjected to two testing conditions, one equivalent to the speaking key of the

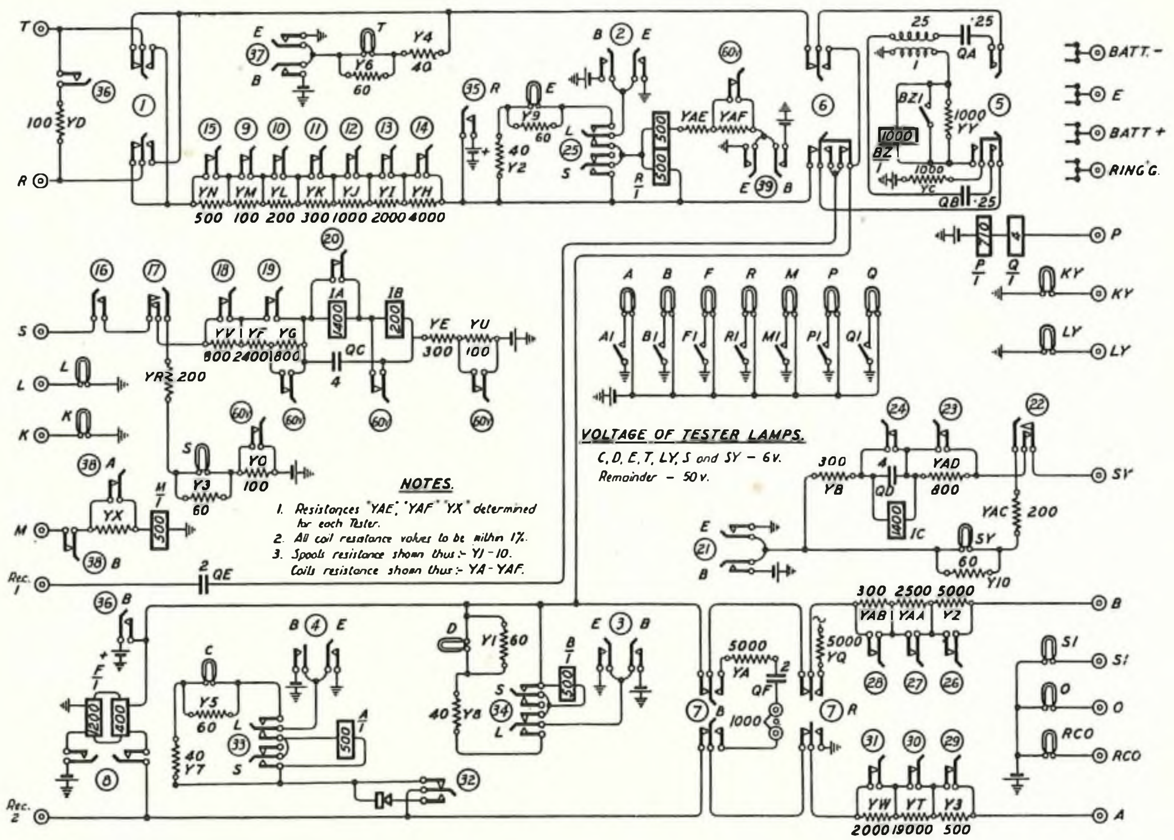


FIG. 7.—TESTER NO. 105.

cord circuit being normal, *i.e.*, supervisory lamp only connected to the sleeve, and the other equivalent to the speaking key being operated. The latter test condition is now applied to relay DR by varying the sleeve circuit resistance. Relay DR operates and, in turn, operates the through-signalling relay TS and the 200-ohm battery returned on the A-wire is received on lamp C in the tester.

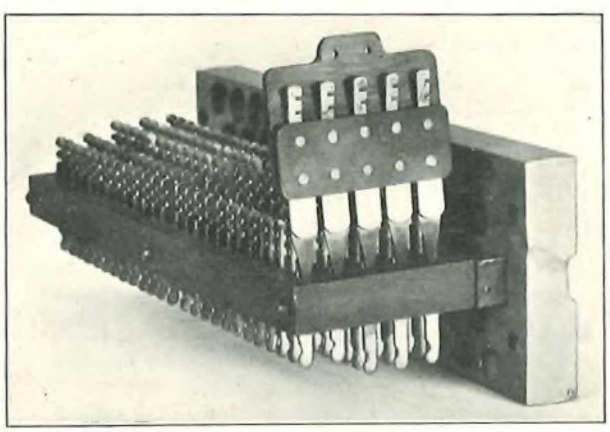


FIG. 8.—CLIP NO. 23 AND I.D.F. CONNEXION STRIP.

Continuity of the speaking circuit is proved by tone applied to the tip and ring conductors being received back in the test receiver across the A and B wires.

The earth *via* relay TS to the ring conductor is tested for resistance by means of the differential relay R, which is balanced by the current flowing in its local circuit and the circuit under test.

Relay RR, which controls flashing to the distant end when the ringing key in the cord circuit is operated, has been designed to prevent false operation due to the misoperation of the dial key, surges from condensers, etc.

This relay is therefore tested with a " non-operate " figure of 20 milliamperes applied by operating key 1 and utilizing the resistances in the ring conductor of the tester. The " operate " figure applied is 46 milliamperes. Line conditions are applied to relay TS by the insertion of resistances to prove that the relay will operate satisfactorily under through-signalling conditions.

On the release of relay L, an 85-ohm earth is returned on the sleeve conductor and lamp S in the tester glows.

The circuit shown in Fig. 6 is a both-way circuit and it is therefore tested for incoming and outgoing conditions; as similar tests are applied for both conditions, however, it is proposed only to describe one series of tests.

The A, B, S1 and RCO tags on the local side of the I.D.F. and the T, R, M, K, S, and L tags on the multiple side of I.D.F. are extended to the corresponding terminals of the tester by means of Clips No. 23.

Functional tests are then applied as follows :—

Ringing conditions are sent over the A and B wires by means of key 7 in the tester and relay L then operates. It will be observed that a rectifier is joined across this relay to enable it to retain during the application of ringing current. Relay LL operates and locks *via* its own contact.

Lamp L in the tester, corresponding to the calling lamp, glows; lamp K, corresponding to the visual idle indicating relay, glows; and relay M in the tester receives the 3,000-ohm engaged test battery from the multiple sleeve. The value of the 3,000-ohm resistance is checked by inserting additional resistance in series with relay M, as this relay has been designed to operate in series with 3,000 ohms and to release when additional resistance is inserted.

To prove the 600-ohm terminal impedance across the tip and ring conductors, tone is connected in series with the test receiver by means of key 6 and applied to the A and B wires. With the circuit closed full tone is heard in the receiver, but when the terminal impedance is disconnected by operating relay S and SS the tone becomes faint, due to the secondary winding of the repeating coil being on open circuit.

Answering conditions are next applied. Relays S, SS, and DR being operated by connecting the appropriate resistances in the sleeve circuit. Lamp L in the tester darkens, as the circuit of relay LL is broken by the operation of relay DR. Lamps M and K remain glowing over alternative circuits. Lamps S1 and R.C.O. in the tester glow due to earth being returned on the cord circuit repeater control wires. Relay DR, when operated, completes an earth circuit to the repeater cut-off terminal (R.C.O.) to disconnect the cord circuit repeater when the operator operates a speaking key.

Tests are applied by varying the value of the sleeve resistance to check the release of relay DR.

Continuity of the speaking circuit is proved by tone applied to the tip and ring conductors being received in the test receiver across the A and B wires.

The 1,000-ohm earth connected to the ring conductor is checked for resistance by means of the differential relay R in the tester.

Ringing is applied to the A and B wires to reproduce recall conditions from the distant end. Relays L and LL again operate and, in addition, relay LF responds to interrupted earth, causing an 85-ohm earth to be connected to the answering sleeve. Relay LL is a slow-to-release relay to prevent its release should relay DR flick due to the LF contacts not making and breaking simultaneously. The correct operation of these relays is tested by the flashing of lamp S in the tester.

To break the flashing circuit set up by the recall condition, relay DR is again operated.

The function of relay RR is to transmit ringing current to the distant end and is of similar design to relay RR described for Fig. 5. It is therefore subject to the same testing conditions, the ringing being tested on a bell in the tester.

Similar tests to those described are applied to all other types of relay-sets used on sleeve control equipments.

Electrical Tests on the Anglo-Belgian (1932) Submarine Telephone Cable

E. M. Richards, A.C.G.I., B.Sc. (Lon.), M.I.E.E.

THE steady increase in Anglo-Continental telephone traffic, due in no small measure to the continued growth in importance of London as an international switching centre, rendered necessary yet another submarine link between England and the mainland in 1932.

The considerations which led to the adoption of the particular design of the Anglo-Belgian (1932) semi-continuously-loaded submarine telephone cable have already been published.[1] The same article also gives a description of the construction of the cable and the principal physical dimensions.

The total length of cable laid between the existing repeater station at La Panne, Belgium, and the new repeater station at St. Margaret's Bay, Kent, is 49.12 nautical miles. The cable terminates at La Panne with a half-length (0.0625 naut.) manufacturing section, and at St. Margaret's Bay the end length (0.123 naut.) is practically a full section.

Tests in Works.

Tests in works on a 5.0 nauts. armoured length over the frequency range 300 to 4,000 p.p.s.

(*a*) with a full loaded section ($\frac{1}{8}$ naut.) at the testing end

and (*b*) with a half loaded section (1/16 naut.) at the testing end

gave a maximum difference in the modulus of the

[1] *P.O.E.E.J.*, Vol. 25, Page 283.

impedance of 15.5 ohms (3.1%) at 4,000 p.p.s. The average difference was less than 5 ohms.

Measurements up to 6,000 p.p.s. were taken to determine the difference in impedance due to the insertion (at 5.0 nauts. from the testing end) of two consecutive unloaded sections followed immediately by two consecutive loaded sections (although the presence of the paper marked with the distance in centimetres to the nearest joint[2] should reduce the possibility of such an occurrence during repairs). The maximum difference of impedance due to this cause was 5.2% (at 3,500 p.p.s.), and in the particular case tested the maximum deviation from a smooth mean curve was increased from 7% to 8.8% (at 3,800 p.p.s.) Fig. 1 shows the effect on

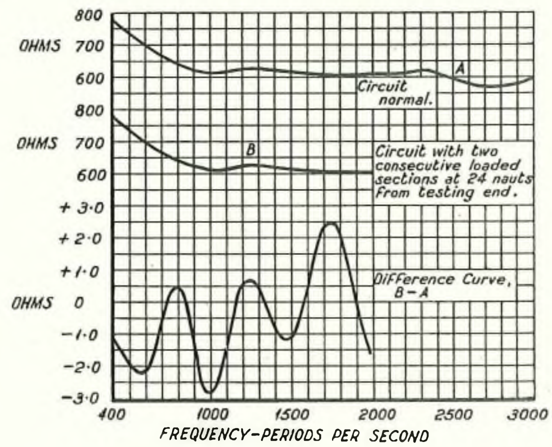


Fig. 1.—Effect on Impedance of Two Consecutive Loaded Sections at 24 Nauts. from the Testing End.

impedance (up to 2,000 p.p.s.) of jointing together two loaded sections at a distance of 24 nauts. from the testing end, the rest of the circuit being normal. The " difference-curve " is given and it will be seen that the values are negligibly small.

These considerations show that the sections are sufficiently short to prevent serious differences of impedance arising from an interruption of the sequence of loaded and non-loaded portions, even though comparatively near to one end of the cable.

Fig. 2 shows values of $\frac{G}{C}$ up to a frequency of 10,000 p.p.s. The value at 800 p.p.s. is 16.

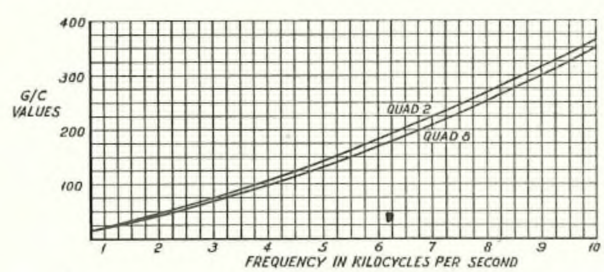


Fig. 2.—Variation of G/C with Frequency.

Fig. 3 gives the attenuation and phase constants of an armoured section of the cable up to 18,000 p.p.s. It will be seen that the latter is proportional to frequency up to about 14,000 p.p.s.

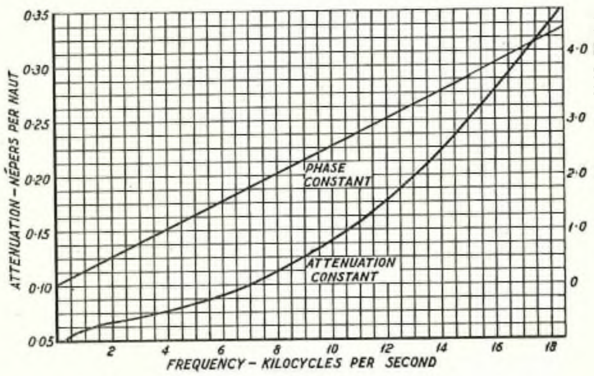


Fig. 3.—Variation of Attenuation and Phase Constants

The increase of attenuation at 800 p.p.s. on a 30 nauts. length with increase of line input current from 0.1 to 10.0 mA was very small, being less than 0.2%.

Figs. 4 and 5 show the effective resistance and reactance up to 40,000 p.p.s. testing on to a loaded

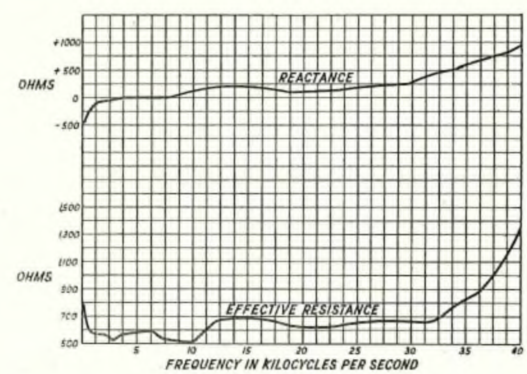


Fig. 4.—Impedance up to 40,000 p.p.s. Measured from a Loaded Section.

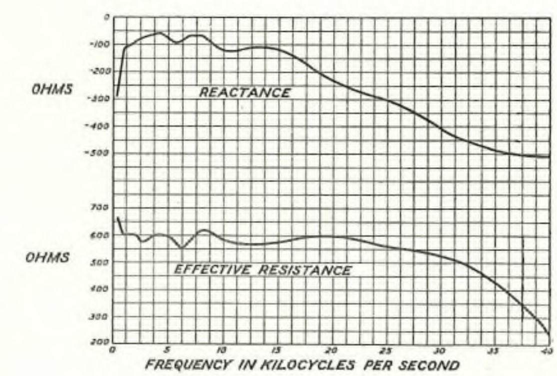


Fig. 5.—Impedance up to 40,000 p.p.s. Measured from a Non-loaded Section.

[2] Ibid., Page 286.

and a non-loaded section respectively. It is evident that there is a cut-off in the vicinity of 40,000 p.p.s.

Table I gives a summary of the principal electrical constants calculated from open and closed impedance measurements on an un-armoured section. The specified attenuation values for the completed cable are also added.

approximation) is equal to the cross-talk in millionths. A four-valve amplifier is used to increase sensitivity, and aural or visual detection may be employed. In this case, owing to the very large number of readings to be taken, the more rapid aural method was used. Readings were recorded to the nearest 0.1 millionth.

TABLE I.

Frequency p.p.s.	$Z_0 \backslash \phi_0$ Vector Ohms.	β Népers per naut. Measured.	Specified.	α Radians per naut.	R Ohms per naut.	L mH. per naut.	C μF. per naut.
300	781.8 \28° 42′	0.0507	—	0.0926	69.6	23.6	0.0716
500	678.8 \22° 1′	0.0560	—	0.1398	70.9	23.3	—
800	610.4 \17° 15′	0.0588	0.074	0.2120	—	—	0.0717
1,600	—	—	0.079	—	—	—	—
2,000	581.5 \6° 43′	0.0640	—	0.5098	71.7	23.1	0.0703
2,400	—	—	0.084	—	—	—	—
3,000	—	—	0.087	—	—	—	—
6,000	597.6 |3° 2′	0.0882	0.118	1.519	—	—	—

TESTS AFTER LAYING.

The electrical measurements made from November 7th onwards after laying included the following :—

(1) *Conductor Resistance.*

The mean and maximum single wire D.C. resistance per naut. were 34.20 and 34.36 ohms respectively, the specified value being 36.125 ohms. (The mean loop resistance was 3,360 ohms).

(2) *Insulation Resistance,* measured after one minute's electrification with 100 volts, was 45,000 megohms per wire per naut.

(3) *D.C. Capacity* values obtained by a ballistic method are given in Table II.

TABLE II.

	Micro-farads per naut. Min.	Mean.	Max.
Side Circuits	0.0727	0.0734	0.0740
Phantom Circuits	0.1856	0.1862	0.1875
Ratio $\frac{\text{Phantom Capacity}}{\text{Side Capacity}}$	2.55	2.54	2.53

(4) *Near End Cross-talk Between Groups.*

The large values of cross-talk attenuation to be measured necessitated the use of a sensitive method. That adopted at La Panne is shown in Fig. 6, the received voltage being compared with a known fraction of the sent voltage. At balance, the reading in ohms of the slide wire (to a very close approximation) is equal to the cross-talk in millionths.

Measurements were taken at the specified frequencies, 640, 800, 1,100 and 1,900 p.p.s., say b_1, b_2, b_3 and b_4 millionths. Then the mean cross-talk attenuation in népers is

$$B = -\log_e \tfrac{1}{4}\left(e^{-b_1} + e^{-b_2} + e^{-b_3} + e^{-b_4}\right)$$

The value of B was specified to be greater than 10.5 népers for near-end cross-talk between "Goes" and "Returns," and for distant-end between any two "Goes" or any two "Returns."

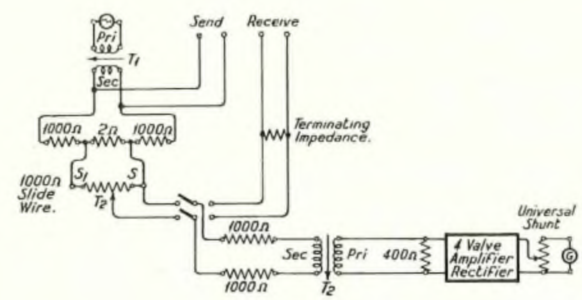


FIG. 6.—A SENSITIVE METHOD OF CROSS-TALK MEASUREMENT.

As the logarithmic mean of the values at the four specified frequencies was found to agree closely with the value at 1,100 p.p.s., all 900 cases were measured at the latter frequency and only the worst cases at all four frequencies. A number of tests were also made at 5,000 p.p.s.

At St. Margaret's Bay, a Siemens and Halske cross-talk set (calibrated to read values from 8 to 18 népers in steps of 0.1 néper) was available, and this was used for the tests.

Since most of the values were of the order of 0.4 millionths (14.7 népers) elaborate precautions were necessary to avoid errors due to stray fields, all apparatus and connexions having to be shielded by earthed screens.

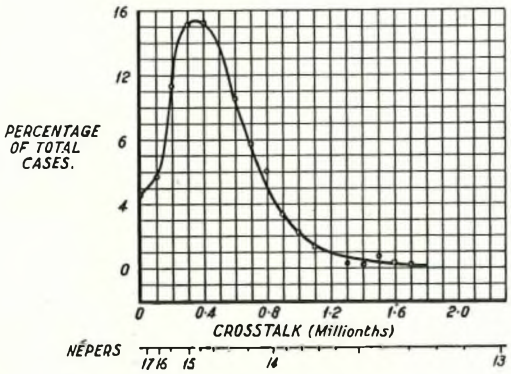


FIG. 7.—NEAR-END CROSS-TALK MEASURED FROM LA PANNE; DISTRIBUTION OF VALUES.

Fig. 7 shows the distribution of the near-end cross-talk values at La Panne. Ordinates are the percentages of the total cases having values equal to the corresponding abscissæ, which are given in millionths and népers.

The results are summarized in Table III. which gives—

(*a*) Average and worst values for all pair-to-pair cases at 1,100 p.p.s.

(*b*) Average and worst values at the four specified frequencies and at 5,000 p.p.s., for a number of cases having bad values at 1,100 p.p.s.

(*c*) Average and worst of the logarithmic means of the values at four frequencies.

It will be seen that the specification has been easily met, the worst value being about 2.1 népers better than the specified value.

Near-end cross-talk between groups at 5,000 p.p.s. for the cases measured is good, the worst value, 11.6 népers, corresponding to a signal-to-noise ratio of 7.6 népers.

TABLE III.

NEAR-END CROSS-TALK BETWEEN GROUPS.

			At La Panne.		At St. Margaret's Bay.	
		Frequency p.p.s.	No. of Pr./Pr. cases tested.	Népers.	No. of Pr./Pr. cases tested.	Népers.
(*a*)	Average ...	1100	304	14.6	900	14.4
	Worst ...	,,	,,	13.2	,,	12.6
(*b*)	Average ...	640	72	14.8	160	14.4
	,, ...	800	,,	14.4	,,	14.1
	,, ...	1100	,,	14.0	,,	13.7
	,, ...	1900	,,	13.5	,,	13.2
	,, ...	5000	,,	12.8	,,	13.5
	Worst ...	640	,,	13.8	,,	13.1
	,, ...	800	,,	13.5	,,	12.9
	,, ...	1100	,,	13.2	,,	12.6
	,, ...	1900	,,	12.7	,,	12.0
	,, ...	5000	,,	11.6	,,	11.9

(*c*) *Logarithmic Mean of the values at the four Specified Frequencies on the worst quads.*

	At La Panne.		At St. Margaret's Bay.	
	No. of Pr./Pr. cases tested.	Népers.	No. of Pr./Pr. cases tested.	Népers.
Average Mean	72	14.0	80	13.7
Worst Mean	72	13.4	80	12.6

Note:—The total number of pair-to-pair cases between groups is 900.

(5) *Distant End Cross-talk, Within Groups.*

The Siemens and Halske cross-talk set was used, the telephone terminals being joined to a two-valve amplifier, followed by a copper-oxide rectifier, continuously variable shunt, and a Tinsley reflecting galvanometer. The scale of the latter was calibrated to read directly in népers.

The results, summarized as described above for near-end values, are given in Table IV.

The worst value is about 0.8 néper better than the specified value.

TABLE IV.

DISTANT-END CROSS-TALK, WITHIN GROUPS.

		Frequency p.p.s.	Népers.	No. of cases tested.
(*a*)	Average ...	1100	13.4	870
	Worst ...	,,	11.4	,,
(*b*)	Average ...	640	13.0	72
	,, ...	800	12.7	76
	,, ...	1100	13.0	116
	,, ...	1900	12.4	98
	Worst ...	640	11.8	116
	,, ...	800	11.5	,,
	,, ...	1100	11.4	,,
	,, ...	1900	10.9	,,

(*c*) *Logarithmic Mean of the values at the four Specified Frequencies on the worst quads.*

	Népers.	No. of cases tested.
Average Mean	12.4	60
Worst Mean	11.3	60

Note :—The total number of pair-to-pair cases (including side-to-side) within the two groups is 870.

(6) *Cross-talk-Frequency.*

Figs. **8** and **9** each show two cases of near-end between-groups cross-talk-frequency characteristics at La Panne and St. Margaret's Bay respectively. The curve in Fig. **8** which descends to 11.1 népers at 6,000 p.p.s. is for the pairs which gave the worst logarithmic mean of the values at the four specified frequencies. The other three curves are for pairs of average cross-talk.

Fig. **10** shows two distant-end within-group cross-talk-frequency characteristics, measured on pairs of average value.

(7) *Attenuation.*

The values of attenuation length at 800 and at 6,000 p.p.s. (the lowermost and uppermost of the five specified frequencies) are 2.9 and 4.5 népers respectively. These values are too large to be measured rapidly by the open and closed impedance method. The Mayer method would involve measuring values from 5.8 to 9.0 népers, which is also too high to give satisfactory results. In addition, the Mayer method has the disadvantage that measurements cannot normally be made at any pre-

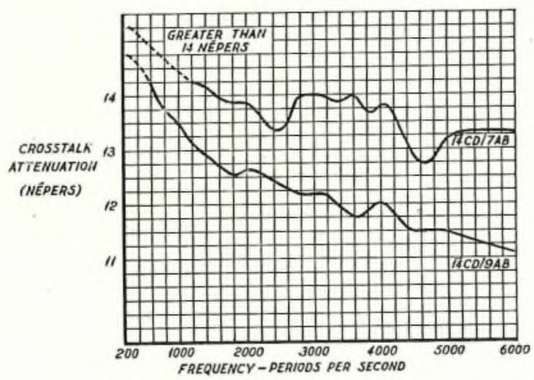


FIG. **8**.—NEAR-END BETWEEN-GROUP CROSS-TALK/FREQUENCY CHARACTERISTICS. MEASURED AT LA PANNE.

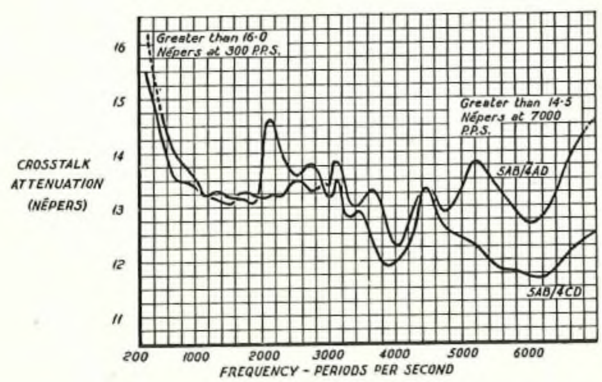


FIG. **9**.—NEAR-END BETWEEN-GROUP CROSS-TALK/FREQUENCY CHARACTERISTICS. MEASURED AT ST. MARGARET'S BAY.

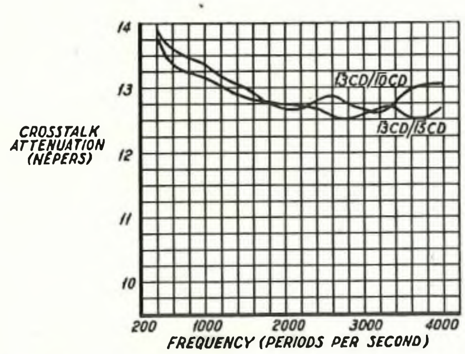


FIG. **10**.—DISTANT-END WITHIN-GROUP CROSS-TALK/FREQUENCY CHARACTERISTICS.

determined frequency, but only at frequencies at which the received voltage is in phase with the sent voltage. In this case the interval between frequencies would be about 120 p.p.s. In view of these facts, a potentiometer method, shown in Fig. **11**, was adopted.

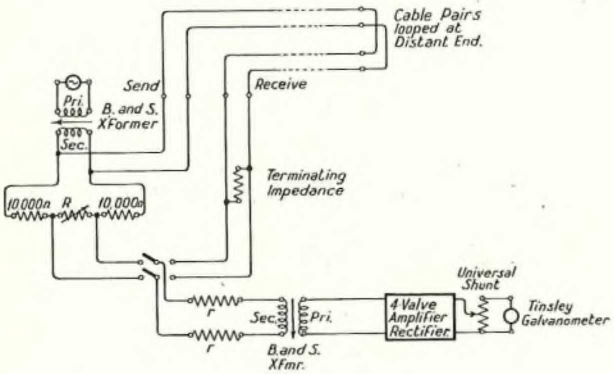


FIG. **11**.—A POTENTIOMETER METHOD OF ATTENUATION MEASUREMENT.

Each cable pair was looped to the corresponding pair on the opposite side of the diametric screen (to avoid errors due to within-group cross-talk) and the fraction of the sent voltage tapped off by the non-reactive resistance " R " was made equal to the voltage received on the return pair. The two resistances " r " were each about 6,000 ohms. A four-valve amplifier, rectifier and Tinsley reflecting galvonometer were employed to give visual indication.

The attenuation in népers is given by the expression

$$e^{2\beta l} = \frac{20{,}000 + R}{R}$$

$$\text{or} \quad \beta = \frac{2.3026}{2l} \log_{10} \frac{20{,}000 + R}{R}$$

where " l " is the length of the cable.

Values of $2.3026 \log_{10} \dfrac{20{,}000 + R}{R}$ are plotted against R, and the curve used to give $2\beta l$ directly from the balancing resistance R.

The maximum values are approximately 20% below the values specified for 60°F, at each of the five frequencies. This is largely due to the specified values assuming a mutual capacity value of 0.09 microfarad per naut., whereas the actual maximum value is 0.074.

At higher frequencies especially, the method requires careful screening of all apparatus and connexions. Efficient electromagnetic screens on the transformers, and orientation of the various components are also necessary to reduce to a negligible amount any interference from stray fields. A Wagner earth device on the potentiometer components to ensure that the centre-point is at earth potential is also beneficial.

(8) *Attenuation-Frequency.*

Measurements were made on average loops from 200 to 8,000 p.p.s., the visual method described above being used. Fig. **12** gives the values per naut. for one of the loops. The specified values are shown by the broken line.

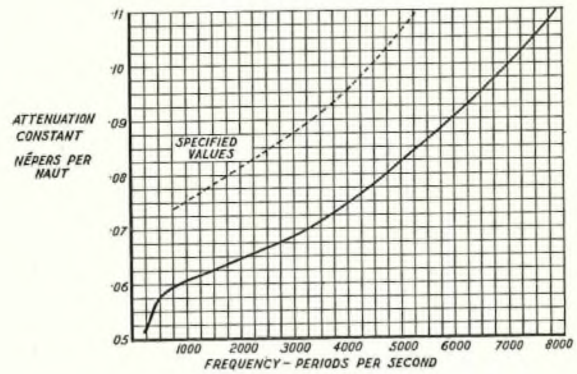


FIG. **12**.—VARIATION OF ATTENUATION CONSTANT WITH FREQUENCY (AFTER LAYING).

The attenuation length at the frequency of the first carrier, 5,800 p.p.s., is 4.35 népers. Overall attenuation-frequency distortion from 300 to 3,000 p.p.s. is 0.78 néper as compared with 0.86 néper for the side circuits of the Anglo-Belgian (1930) Cable and 0.9 néper for the Anglo-Belgian (1926) Cable. It will be observed[3] that at about 6,000 p.p.s. the 1926 and 1932 Anglo-Belgian cables have the same value of attenuation.

The maximum value of attenuation which was measured was 10.9 népers at 8,000 p.p.s.

(9) *Impedance-Frequency.*

Measurements were made on 40 pairs at La Panne and on 45 pairs at St. Margaret's Bay over the frequency range 300 to 3,000 p.p.s. At least one pair from each quad was tested. Where both the pairs of a quad were tested they were found in all cases to have impedance-frequency characteristics closely resembling one another. This fact rendered tests on both pairs unnecessary except where the specified limits[4] were approached.

In a number of cases the deviations from a smooth mean curve were about 1% or 2% at St. Margaret's Bay and a little higher at La Panne. The condition that all pairs should have mean curves within $\pm 7\frac{1}{2}$% of an average mean curve has been satisfied. Two pairs at each end of the cable had deviations from their own smooth means just outside the 10% limit at one or two frequencies; but the usual difficulty of

[3] *P.O.E.E.J.*, Vol. 25, Page 288, Fig. 10.

[4] Ibid., Page 286.

deciding on the precise mean curve of a pair having large deviations rendered it difficult to insist that these pairs did not comply with the specification. The majority of the curves are smooth and as the cable is designed for 4-wire working, it is considered satisfactory in respect of impedance-frequency deviations.

Figs. **13** and **14** give effective resistance and

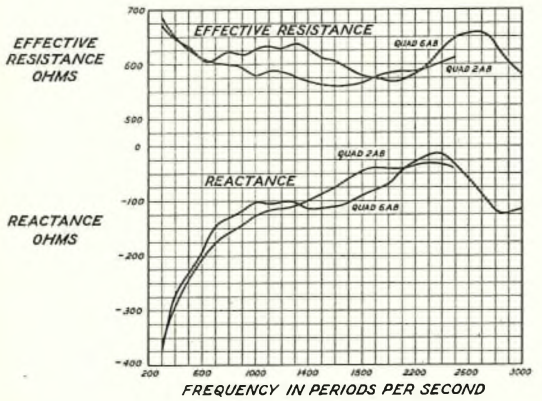


FIG. 13.—IMPEDANCE AT AUDIO FREQUENCIES. MEASURED AT LA PANNE.

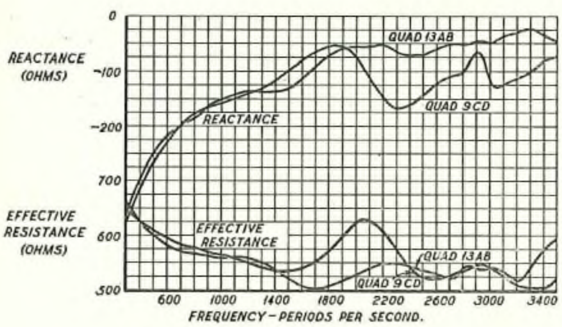


FIG. 14.—IMPEDANCE AT AUDIO FREQUENCIES. MEASURED AT ST. MARGARET'S BAY.

reactance curves of two pairs measured at La Panne and two at St. Margaret's Bay, respectively.

A number of pairs were also measured up to higher frequencies, visual detection being employed. Fig. **15** shows the effective resistance and reactance components of a pair up to 9,000 p.p.s.

(10) *A.C. Fault Localization Constant.*

The formula for locating by alternating current measurements[5] the distance to a cable fault is

$$d = \frac{K}{(f_2 - f_1)}$$

where d is the distance required, $K \doteqdot \frac{1}{2\sqrt{CL}}$ (L being the inductance and C the capacity per unit distance) and $(f_2 - f_1)$ a mean value of the difference in frequency between consecutive maximum or minimum values on the impendance-frequency curve of a faulty circuit.

The value of K is found by introducing an artificial fault at a known distance (conveniently, at the far end). If the value of $(f_2 - f_1)$ is found from a difference curve (obtained by subtracting a normal curve from the curve for a faulty circuit), the frequency interval between the points of maximum, minimum or zero difference may be used. The most accurate value of the three is that obtained by using the frequencies of zero difference, since, by taking points at sufficiently close intervals and plotting to an enlarged scale a small portion of the difference curve, the frequency of zero difference may be obtained with great accuracy. In the case of a maximum or minimum value on the curve, it is not easy to see accurately which is the correct frequency to take.

The value of K was measured by obtaining the points of zero difference between the impedances of a pair looped back and the same pair insulated at the far end. Visual detection was used as maximum sensitivity was required, the attenuation length being 2.9 népers at 800 p.p.s. and 3.4 népers at 3000 p.p.s., and hence the " difference " values very small. (The maximum value on the difference curve was 2.9 ohms). Points of zero difference were found at 2,795 and 789 p.p.s., with eight complete waves between. This gives the value of K, for the type of fault considered, equal to

$$\frac{2,006}{8} \times 49.12 = 12,320.$$

The process of dividing by the complete number of waves from zero frequency is not adopted since it gives rise to appreciable errors. Recent research work has shown that the assumption that, in the case of a contact fault the first maximum (and in the case of an open circuit or high resistance fault the first minimum) occurs at a frequency $= \frac{1}{2}(f_2 - f_1)$ is inaccurate. The actual value differs appreciably

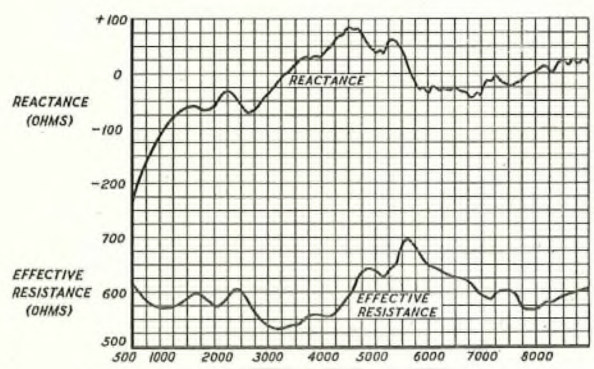


FIG. 15.—IMPEDANCE UP TO 9,000 P.P.S. MEASURED AT LA PANNE.

[5] *P.O.E.E.J.*, Vol. 23, Page 42 et seq.

from half the mean frequency interval, generally being less. Hence a more accurate value for K is obtained by the method used here.

Tests after 30 days.

A number of the tests enumerated above were repeated on the expiration of the Contractor's maintenance period of 30 days.

Attenuation and D.C. conductor resistance were each 1% less, corresponding to a mean reduction in temperature of 2.5°C. (from 9th November to 6th December). All cross-talk values were essentially the same. In addition, about 70 pair-to-pair cases of distant-end within-group cross-talk were measured at 5,000 p.p.s. The mean and worst values were 12.6 and 11.0 népers respectively.

Except for the development of a high-resistance conductor fault on one wire at a distance of about 4.3 nautical miles from St. Margaret's Bay, the electrical constants of the cable have remained satisfactory.

Telegraph Line Construction in India

N. F. Frome, D.F.C., M.Sc., A.M.I.E.E.

Part I.—Historical.

"..... *In concluding this perhaps too long Report, I claim the indulgence of Government while I touch briefly on a matter of merely personal interest to myself. It is now just twenty years since I erected the first long line of telegraph ever constructed in the world. The subject has been my occupation or pastime ever since and circumstances have enabled me to extend that line from 20 to over 10,000 miles.* ....

I have the honour to be, Sir,
Your most obedient Servant,
W. B. O'Shaughnessy,
Superintendent Elec.
Tels. in India."

Bangalore,
31st Oct., 1858.

This extract from the "General Report of the Electric Telegraph in India, 1857-58" written by Sir William O'Shaughnessy, F.R.S., the founder of the Telegraph Department, refers to the first long telegraph line ever constructed in India. The line, 21 miles long (including a river crossing of 7,000 feet), was erected by Dr. O'Shaughnessy, as he was then, in 1839. It was not until 1849, by which time telegraphy was a proved success in Europe, that any further development took place in India. Finally in 1850 sanction was given to the erection of a line between Calcutta and Diamond Harbour and this circuit commenced working on October 4th, 1851. By the 29th of March, 1852, some 82 miles of line were in use, and on that date the Calcutta-Kedgeree line was opened for traffic.

The first lines constructed were of an experimental nature to gain experience of the requirements in India with a view to the extension of the telegraph over the country. The Calcutta to Diamond Harbour lines were underground in Calcutta itself—one conductor of $\frac{3}{8}''$ iron rod, taped and tarred, being laid in a cement of melted resin and sand in earthenware troughing (Fig. 1), from Chandpal Ghaut (in Calcutta) to Rajmoola Chucka village where the overground system commenced.

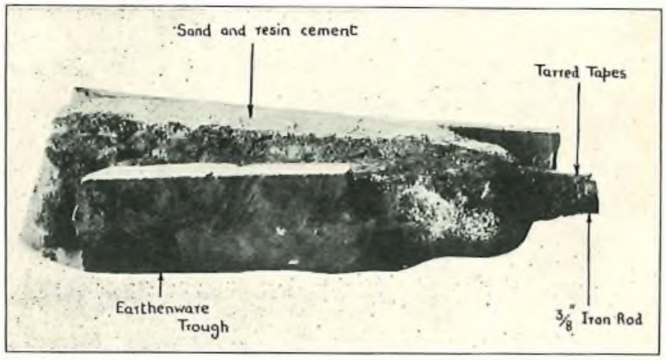


Fig. 1.—Piece of Original Iron Rod Cable Laid in Calcutta in 1851.

There were peculiar difficulties to be overcome on these routes in the Ganges delta—the lines were exposed to violent storms and much electrical disturbance. Having little to guide him in accepted practice elsewhere, Dr. O'Shaughnessy considered the use of heavy iron rod for his conductor instead of wire to be essential.

The rods used, obtained from England in short lengths, were welded into 200-foot lengths at a central depot and on the line, with one village forge carried by two coolies, a mile of rods was welded in a working day.

The proposal to extend the telegraph throughout India involved solving the problem of crossing rivers. Various schemes were tried (on the Huldee river) and eventually a gutta-percha covered wire secured in the angles of a chain cable proved to be the only means which was successful in avoiding damage from ship's anchors.

The success of these small telegraph systems was so great that Lord Dalhousie persuaded the Court of Directors to sanction the immediate construction of some 4,000 miles of line between the important towns of India. (1853).

Based on the experience gained on the lines in the Calcutta area, the telegraph was extended over the length and breadth of the country with promptitude, and by 1856 lines had been constructed from Calcutta to Peshawar (1,615 miles), with numerous branches; Calcutta to Berhampore on the east coast (116 miles); from Agra to Bombay (800 miles); and Bombay to Madras, Mysore, and Ootacamund (1,130 miles) (Fig. 2). On these lines various types of posts were used, bamboo in the first place in some instances, but these were replaced by iron-wood posts (16 to the mile); toddy-palm trees with metallic caps and insulators (10-12 to the mile); sal spars inserted in iron screw piles and fitted with caps and insulating brackets; stone and masonry pillars and obelisks; hill fir spars, etc., depending upon local supplies and the type of country over which the line was being erected.

The conductor used was galvanized iron rod weighing 1,120 pounds per mile. Spans were of various lengths, from 250 to 1,000 feet. There were some 21 river crossings between Calcutta and Peshawar, mostly cabled, others crossed by means of masts or masonry piers.

On the Agra-Bombay section of the line red sandstone pedestals supporting sal spars 5 ft. long and 1 ft. square, 16 to the mile were used; blackwood posts 20 to 24 feet high, 16 to the mile, with spans varying from 330 to 1,100 feet; teak masts for river crossings carrying single spans of No. 8 charcoal iron wire; teak spars in screw piles fitted with metal caps, oak brackets, and earthenware insulators, 16 to 20 to the mile.

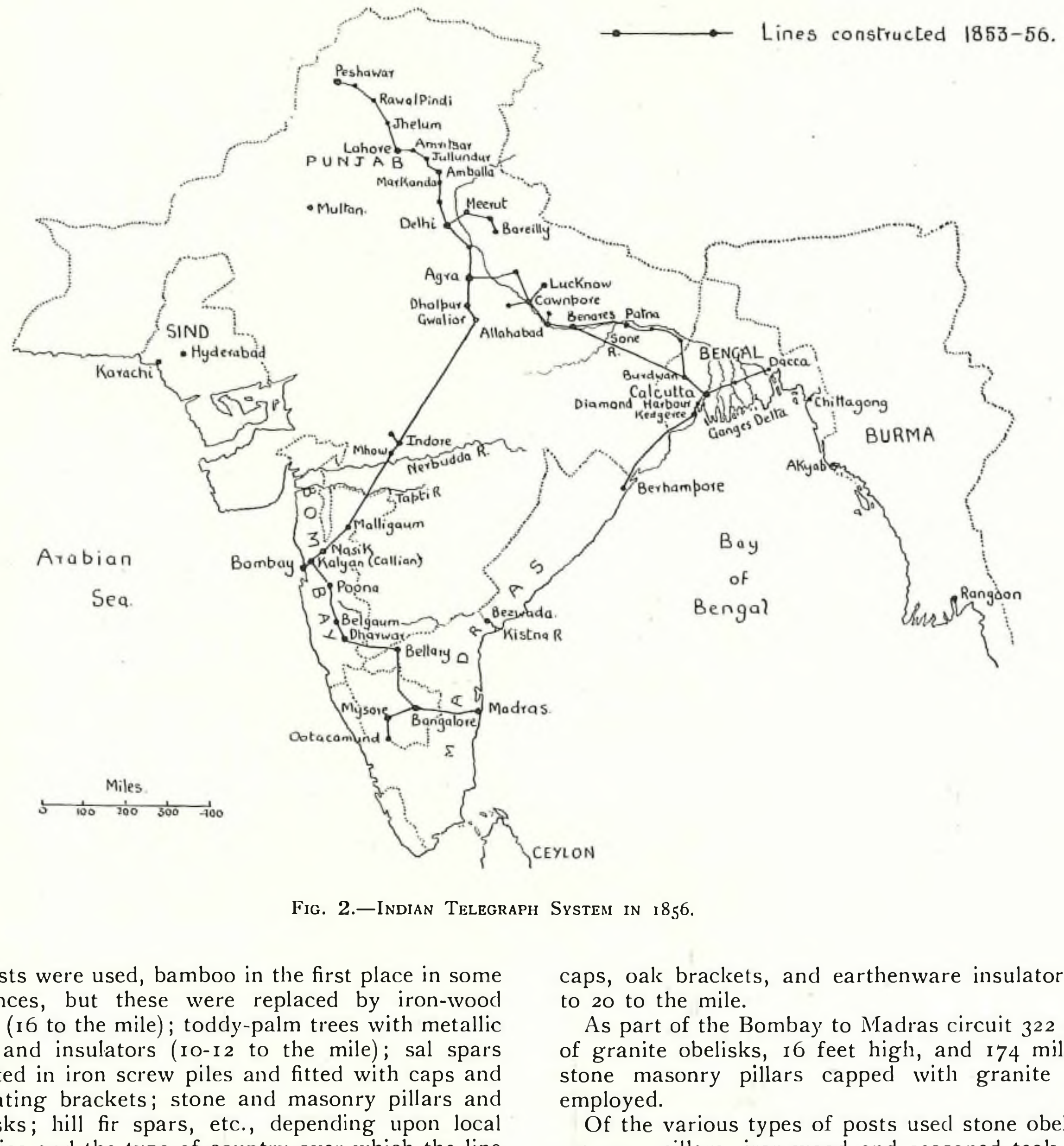


FIG. 2.—INDIAN TELEGRAPH SYSTEM IN 1856.

As part of the Bombay to Madras circuit 322 miles of granite obelisks, 16 feet high, and 174 miles of stone masonry pillars capped with granite were employed.

Of the various types of posts used stone obelisks, masonry pillars, iron-wood and seasoned teak were considered to be the permanent fixtures. Sal posts were destroyed by white ants and palms, owing to their spongy texture, rendered them literally so many pillars of water during the rainy season, making it difficult to work through long lines.

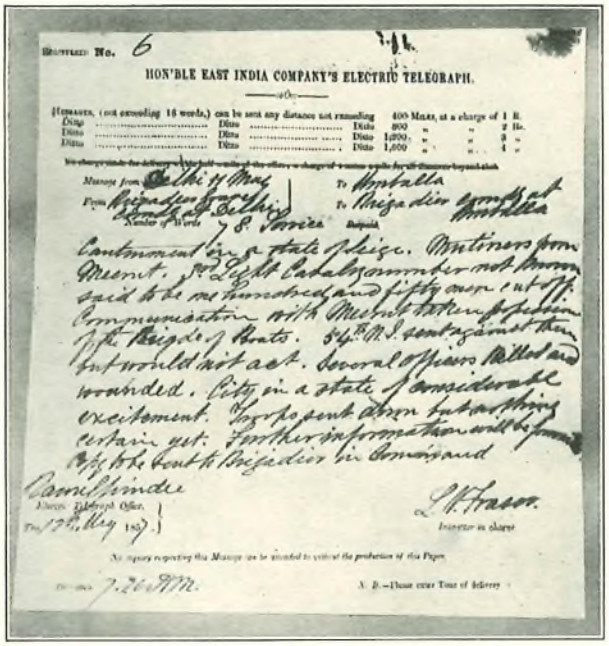
The effects on the lines of the heavy lightning which occurs in India caused considerable difficulties until lightning conductors were fitted to each post. The maintenance of adequate insulation over the long circuits was also a matter in which trouble was experienced, particularly when toddy palm posts were used.

By 1857 there were 7,000 miles of line in service, and during that year the Delhi office in a last effort signalled to the Punjab news of the march of the mutineers on Delhi. Facsimiles of the last messages sent from Delhi office are shown in Fig. **3** (i) and (ii).

iron socket, and surmounted by a wooden pole nine feet six inches long, the tube also being filled with sand and resin cement. Both types were fitted with earthenware insulators fixed on a galvanized collar.

In 1859 the iron posts were reported as being thoroughly successful in every point of view, granite posts only being their equal. Masonry posts were by then condemned because the incessant vibration of the wire disintegrated the cement, and rain and wind completed the ruin. Of wooden posts, all types except iron-wood were condemned as a result of further experience. Some 10,000 miles of line were in use at this date.

By 1861, 40,000 Hamilton's standards had been erected and were reported as giving the utmost satisfaction.


No. 6

HON'BLE EAST INDIA COMPANY'S ELECTRIC TELEGRAPH.

Messages, (not exceeding 16 words,) can be sent any distance not exceeding 400 Miles, at a charge of 1 R.

Message from Delhi 11 May To Umballa

From Brigadier Graves Comdt. at Delhi To Brigadier Comdt. at Umballa

Number of Words 78 Service

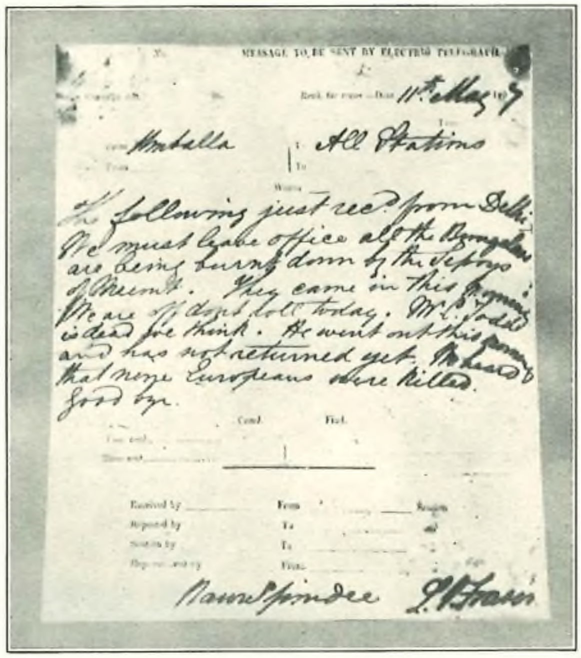
Cantonment in a state of siege. Mutineers from Meerut. 3rd Light Cavalry number not known said to be one hundred and fifty men cut off. Communication with Meerut taken possession of the Bridge of Boats. 54th N.I. sent against them but would not act. Several officers killed and wounded. City in a state of considerable excitement. Troops sent down but nothing certain yet. Further information will be forwarded. Copy to be sent to Brigadier in Command

Barnell Pindee

Inspector in charge

No inquiry respecting this Message can be attended to without the production of this Paper.

7.20 P.M.


MESSAGE TO BE SENT BY ELECTRIC TELEGRAPH.

11th May 1857

Umballa To All Stations

The following just recd. from Delhi. We must leave office all the Bungalows are being burnt down by the Sepoys of Meerut. They came in this morning. We are off dont call today. Mr. C. Todd is dead we think. He went out this morning and has not returned yet. We heard that nine Europeans were killed. Good bye.

Barnell Pindee

Fig. **3**.—Messages Sent from Delhi to Umballa, 11th May, 1857.

It was now evident that the many advantages of the use of iron posts in India in their immunity from damage, permanence and strength more than outweighed considerations of local supplies. We find it recorded in 1858, therefore, that iron posts, 20,000 whole and 20,000 half standards (Hamilton's patent) were being distributed along the new Sind-Bombay, and Sind-Punjab lines, and in the Bengal and Madras Presidencies. These Hamilton's "whole standards" consisted of three parts—a cast iron socket 3′ 8″ by $6\frac{1}{2}$″ diameter in the ground, a wrought iron tube 13 to 15 feet long, and a terminal spar of timber 2′ 6″ to 3′ 6″ long. To prevent the tube being bent or indented, it was filled with a melted mixture of sand and resin. The "half standard" consisted of a hollow iron cylinder six feet long fitted in a screw pile by means of a cast-

In 1885 some wooden post lines were still in use, but mainly confined to those of iron-wood posts in Burma, and oak and chestnut in the Himalayas, the wood being coated with a tar and oil preservative mixture. Temporary lines were occasionally erected on bamboo "A" posts. The use of Hamilton's graded series of tubular posts, Siemen's tubular posts, and old railway rail posts had generally extended throughout the country. Rail posts were extensively used and lines carried on these supports along railway routes are still much in evidence in all parts of India.

From those days onwards (except in the highest ranges of the Himalayas), the post material used in India has been confined to iron, and to the present time practically all overhead line construction developments have been in the design, improvement and adaption of steel and iron components. The expansion of the overhead line telegraph and telephone system which has taken place in India since the early days of the Department is indicated by the figures published in the Annual Report for 1930-31 :

Miles of line in use	...	105,386.
Miles of wire in use	...	490,952.

PART II.—PRESENT DAY PRACTICE.

(1) *Tubular Posts.*

The standard overhead line post in general use in the Department in India to-day is the tubular post of the Hamilton's series pattern. A series of heavily galvanized sheet steel tapered tubes, to make up the size and strength of post required, are fitted together and mounted on a ground fitting consisting of a cast iron socket and soleplate. The series of tubes, lettered A to F, are 8 feet long, whilst in the smaller sizes they are also made in 4-foot lengths. The dimensions of the tubes are such that each one of the series can be joined with a driving fit into the next size. Types of posts are designated by the letters of the tube combination used to form the support—thus a BCD post (23 ft. 8 ins. high) consists of a B, C and D 8 ft. tube fitted together and mounted on a D socket. Such a post is illustrated in Fig. 4. Similarly an A 4′ BC post (20 feet high)

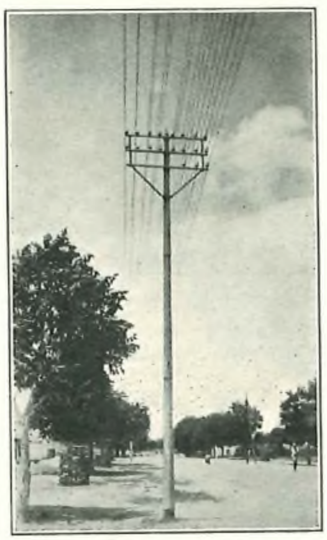


FIG. 4.—TELEGRAPH LINE BCD POST.

consists of an A tube 4 ft. long, and 8 ft. B and C tubes mounted on a C socket. Coupled posts are built with the standard post units and coupling braces, a type of coupled post being shown in Fig. 5. The thickness of metal of the tubes is varied throughout the series, increasing with size, the relative strengths of the tubes being such that in a line composed of one size of post, the next larger side would form terminal posts for it and posts are of one regular strength throughout the series. Thus a BC post forms a terminal for an AB line, and the load supported by an AB post can be carried by an ABC or ABCDEF support. In addition to the A to F series, a number of special tubes are made, for example, a T tube, a size smaller than the A, which is used in conjunction with an A tube to form a TA post for light line loops into village offices where such posts are never likely to have to carry more than two light wires, and also for the Canal telegraph lines required for the regulation of the huge irrigation canals on which so much of the well-being of the country depends.

The normal span used between posts is 220 ft., but in the case of light lines this is increased up to 310 ft.

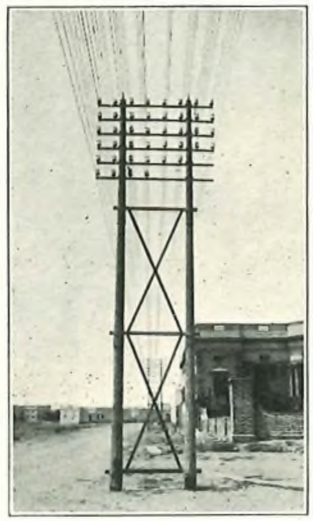
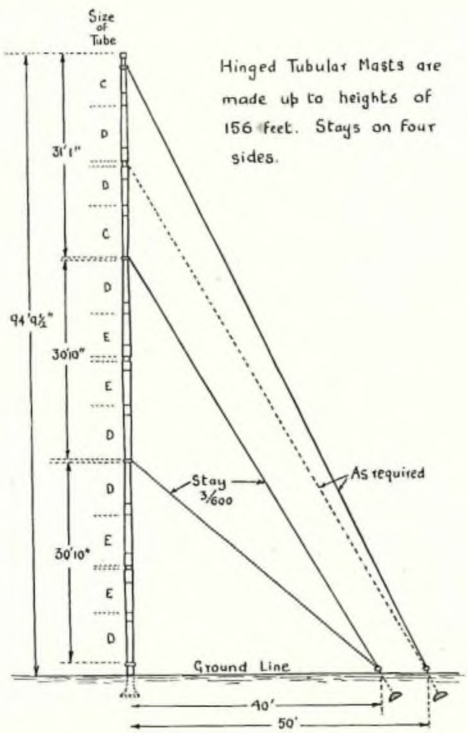


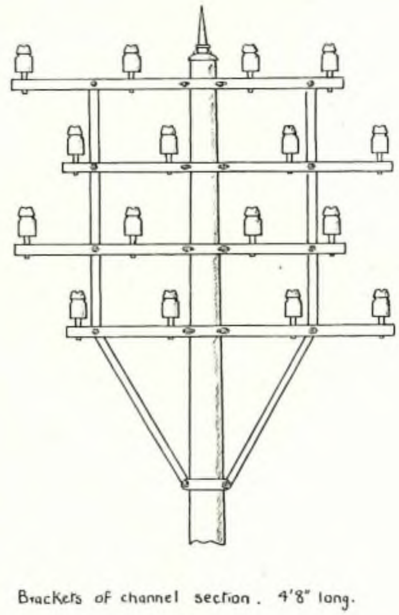
FIG. 5.—COUPLED BCD POST.

The standard tubes are also used in the construction of masts for river crossings. The " hinged tubular " type mast is built up of sections each composed of three or four Hamilton tubes. Two tubes of the same size are fitted together, base to base, upon a double-ended socket and a tube of the next smaller size is added to one or both of them. This produces a section larger in the centre, representing a shape best suited to withstand the compressive and bending stresses to which a mast is subjected. These sections are erected one above the other—a ball and socket joint connects the sections, with stays attached at the point of junction (Fig. 6). This form of construction gives an extremely light, portable, cheap and easily erected mast. Hinged tubular masts are made in two grades of strength—the light pattern up to 100 feet in height with a B tube top, and the heavy pattern, up to 156 feet, with a C tube top.

For heights greater than 156 feet, the " tubular " type mast is used. This consists of a CDE unit extended with a 17 ft. tapered F unit and thereafter



Method of Building Hinged Tubular Masts.



Flying Fox Brackets.

FIG. 6.—TUBULAR MAST AND FLYING FOX BRACKETS.

with 12 ft. and 10 ft. cylindrical tubes, the latter being bolted together, and is used for masts to a height of 264 feet.

The application of tube posts to form heavy line terminals is illustrated in Fig. 7, a tripod post of CDE components.

The Hamilton tube series provides a very flexible system of building durable standards as the foregoing examples show. The units are easily fitted together and easily dismantled when required. Post components can be handled without difficulty—an A tube weighs 32 lb.; a C tube 68 lb.; an A socket 50 lb.; a C socket 94 lb.; and the transport of line components over difficult country is rendered possible, an important feature where there are no good roads along which they can be transported, *e.g.*, along new railway lines and in the hills, where heavy, full length posts could not be dealt with.

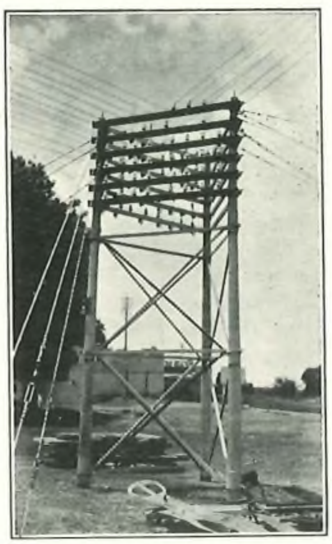


FIG. 7.—TRIPOD TERMINAL CDE POSTS.

(2) *Rail Posts.*

The only other type of post in general use, although not now usually erected, is the rail post—old railway rails of various weights and cross sections varying from 18 to 25 feet in length and weighing from 49 to 85 lb. per yard. Rails are heavy to handle and transport, are rather top heavy and have a small bearing surface when erected, and involve considerable labour in drilling and jointing to form posts of greater height than that provided by a single length, but can often be obtained more cheaply than tubular standards and are almost everlasting apart from the increase of carrying capacity required due to the growth of the system. When coupled they make strong and durable supports. Examples of single and coupled rail post lines are given in Figs. 8 and 9. Brackets and post fittings

FIG. 8.—RAIL POST LINE.

are made to fit all the various patterns of single and double headed rails.

(3) *Post Fittings.*

Brackets. The standard brackets are made of galvanized channel iron to carry 4 or 8 wires at 12-inch spacing and are fitted to the post by means of U-bolts with a cast-iron packing piece between the bracket and the post (Fig. **10**). Where spans are greater than usual, longer brackets are used, the spacing between wire positions being increased to 15 inches. In addition to the regular patterns a special staggered type of bracket, shown in Fig. **6**—the " flying fox " pattern—is used in some parts of the country. This fitting is designed to give a large vertical clearance between the wires of adjacent levels to avoid contact faults due to flying foxes, which have struck the wires and been killed, bridging the wires on one level to the next.

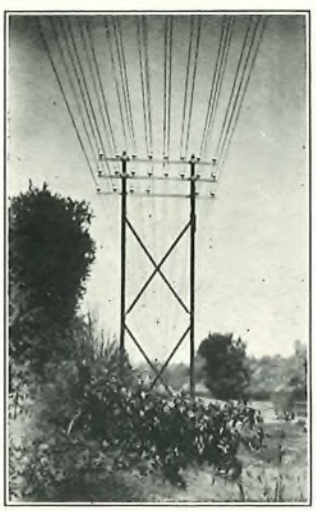


FIG. 9.—COUPLED RAIL POST.

Insulators. In addition to the ordinary varieties of double shed, pothead, and shackle porcelain insulators used, the oil insulator may be mentioned. This type is used on lines in the neighbourhood of the sea coast, and in places of high humidity where the line insulators are subject to salt and sand encrustation and where adequate insulation cannot be maintained with the ordinary pattern insulator.

Spindles. Insulator spindles are made of galvanized iron threaded at one end for the insulator and tapered at the other to give a tight fit in the spindle holes of the bracket. Ordinarily spindles are not bolted to the brackets, the tapered fit being all that is necessary.

Caps carrying lightning spikes are made to fit the various tubes of the Hamilton series and for the different types of rail.

(4) *Wire.*

The chief types of wire in use are galvanized iron, 150, 300 and 600 lb., per mile, for general telegraph circuits and for subscribers' overhead loops in local telephone systems; 40 and 70 lb. bronze wire for the latter also; 200 and 300 lb., copper for main telegraph lines and telephone trunk circuits; and 376 lb. copper weld wire, The latter type is especially used near large towns where ordinary copper wire is frequently stolen. Iron wire joints are made in the ordinary twist and Britannia patterns, MacIntyre sleeves being generally used for jointing copper wire.

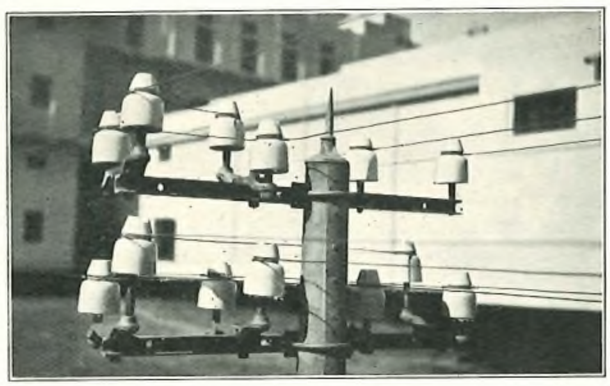


FIG. 10.—PHYSICAL AND PHANTOM TRANSPOSITIONS, SHOWING BRACKET ATTACHMENTS.

(5) *Transpositions.*

All line transposition work is now a-days done on the cross system, and some years ago the Department adopted a method of making these transpositions for both physical and phantom types in which the wires, instead of being terminated and cross-jumpered at each transposition point, are taken straight through under strain, using bracket attachments as shown in Fig. **10**. This form of construction has been found to reduce considerably the number of faults which occur at transposition points as well as being quicker and easier to erect than the older method. Examples of phantom transpositions employing this method are shown in Fig. 11.

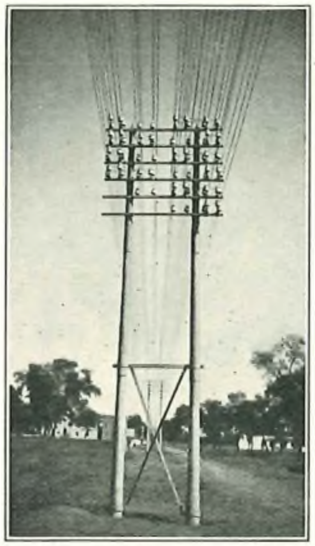


FIG. 11.—MAIN TRUNK LINE: BCD COUPLED WITH PHYSICAL AND PHANTOM TRANSPOSITIONS.

(6) *Line Faults.*

As would be expected in a tropical country of large area and varying climatic conditions, the overhead lines in India are subject to a variety of causes of interruption and much of the organization and activities of the Departmental line staff is concerned with overcoming these difficulties. Mention has been made of the special measures taken to avoid flying fox contacts. Lines are subject, almost yearly in some part of the country or other, to damage from extensive floods, cyclones, and heavy thunderstorms in the plains, and snow storms and landslides in the hills—damage by such causes is illustrated in Fig. **12**. Amongst some of the causes of faults which are peculiar to such countries as India may be mentioned :—Contacts due to snakes and entrails (usually left on the wires by hawks and vultures); contacts due to the nesting efforts of the Indian house crow which endeavours to build a nest at transposition points or on the brackets of terminal posts with a foundation of pieces of wire; weaver birds' nests (Fig. **13**); lines damaged by elephants; and thick spiders' webs which bridge the line wires and cause low cross insulation in wet weather. The popularity of kite-flying in India in which the flyers aim at severing their rivals' lines is also a frequent cause of low cross insulation. In addition throughout most of the country the cutting of quick-growing jungle (of which sirkanda grass, prickly pear, and aloes in particular may be mentioned) is always a source of heavy expenditure.

(7) *Long Spans.*

River crossings and lines constructed in the hills have necessitated the use of long spans in India since the early days of the Department. In 1855 a span 1,600 feet long of one conductor (No. 8 iron wire) crossed the Tapti river on 40 ft. masts, another across the Warna river erected in the same year measured 1,230 feet. Amongst many long spans in use at the present time one of seven wires of 3,060 feet crosses the Karnafuli River near Chittagong on 150 feet tripod masts. Fig. **14** shows the south terminal of the Pandu-Amingaon span across

FIG. 12.—LINES DAMAGED BY FLOODS.

FIG. 13.—WEAVER BIRDS' NESTS ON TELEGRAPH LINE IN ASSAM.

FIG. 14.—TERMINAL OF SPAN CROSSING BRAHMAPUTRA RIVER.

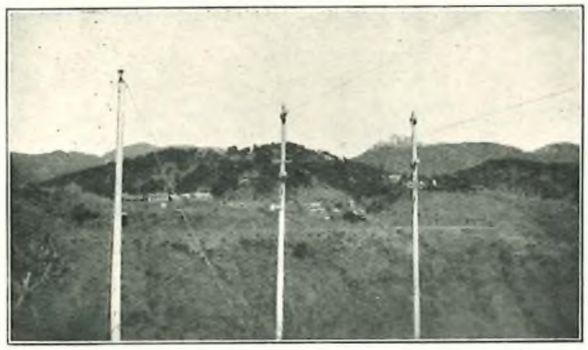


FIG. 15.—LONG SPAN IN SIMLA HILLS. The Group of Terminal Posts on the Distant Hillside are discernible to the left of the Centre Post and to the right of the Buildings.

the river Brahmaputra carrying fifteen 450 lb. stranded steel wires each just under a mile long. These two spans are on the main routes carrying the circuits required for the important traffic between India and Burma.

In the Simla hills a telegraph line carrying 11 wires crosses many valleys in long spans, the longest being 2,960 feet, one of 2,320 feet being shown in Fig. 15. The effect of accumulation of snow on the wires of these long spans in the hills both from the weight of snow which clings to the conductors and the results of the whipping of the wires when the snow is released can well be imagined.

(8) *Conclusion.*

In the foregoing notes only such items as are somewhat unusual compared with overhead construction in other countries have been touched upon. In conclusion, it may be mentioned that at present the long distance trunk lines in India connecting Calcutta to Bombay, to Delhi, and Peshawar, and numerous shorter distance trunk lines elsewhere are all aerial circuits, whilst some 4,500 telegraph offices and much of the local distribution of the Departmental telephone systems throughout India are served by the same type of construction.

Telegraph and Telephone Plant in the United Kingdom.

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH JUNE, 1933.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange†	Spare.		Telegraph.	Trunk.	Exchange†	Spare.
792,187	609	8,802	42,722	3,055	London	41,250	191,217	3,552,932	153,634
95,702	1,946	19,330	44,304	5,133	S. Eastern	4,234	50,585	348,422	44,888
110,210	3,888	36,415	68,939	5,259	S. Western	24,916	36,979	280,023	63,896
76,038	4,715	40,566	65,917	8,638	Eastern	18,762	56,197	159,559	56,554
121,714	7,686	49,847	53,586	7,846	N. Midland	30,452	150,782	328,547	122,401
97,185	3,979	31,472	62,511	3,938	S. Midland	17,667	57,313	301,193	71,391
67,139	3,275	30,773	53,539	5,890	S. Wales	7,278	47,176	164,972	45,406
132,762	6,237	30,171	56,264	5,805	N. Wales	15,087	72,805	435,459	114,558
180,179	852	11,700	25,333	6,190	S. Lancs.	12,618	119,090	630,062	79,934
112,363	5,002	29,584	37,563	7,497	N. Eastern	14,822	80,028	333,313	65,640
74,842	3,914	22,433	26,364	5,514	N. Western	5,622	47,192	240,001	54,118
57,108	1,890	16,459	21,544	5,036	Northern	8,856	40,012	187,564	36,600
28,148	3,372	11,286	11,741	808	Ireland N.	527	4,281	65,871	6,304
81,580	4,711	32,295	39,601	2,854	Scotland E.	8,858	43,570	177,963	32,416
102,683	5,590	23,889	31,168	2,135	Scotland W	10,198	43,983	261,994	39,000
2,129,840*	57,666	395,022	641,096	75,598	Totals.	221,147	1,041,210	7,467,875	986,740
2,130,420	58,690	399,374	631,774	69,962	Figures as at 31/3/33.	231,119	1,009,879	7,383,618	903,899

† Includes low gauge spares (*i.e.*, wires of 20 lb. or less in cables and 40 lb. bronze on overhead routes).
* Reduction due to recount in connexion with revised Unit Maintenance Cost procedure.

Telegram Conveyors

D. P. Gilbert, A.M.I.E.E.

In the re-organization of the Telegraph Service at present proceeding, the extended use of conveyors is becoming an important factor, and the general interest which is being exhibited in this development has prompted these notes.

The introduction of mechanical aids has the two-fold object of speeding-up the service and, by the displacement of manual labour, reducing the working cost of the service.

The instrument room at Leeds was the first to be equipped with conveyors for the purpose of collecting and distributing unfolded telegram forms. The installation is experimental and is designed mainly for the collection of telegram forms from the instrument tables, and in order not to encroach upon existing gangways an overhead system was adopted. This was made possible by the Riser Band Conveyor (Fig. 1) specially designed for the purpose.

For the Central Telegraph Office and the larger Provincial Offices, a rapid and continuous system of distribution and collection was a matter of great importance. Single-band selective systems were first considered, but such systems depend upon the automatic clearance of boxes at fixed intervals of time and are, therefore, fundamentally discontinuous and failed at once to secure the outstanding advantage of a continuous flow of traffic without intermittent handling which was the first and main object of the British Post Office in installing conveyors. In 1930, the multiple band conveyor made its appearance and the results obtained from a small 3-band Model constructed with Meccano parts (Fig. 2) were so satisfactory that authority

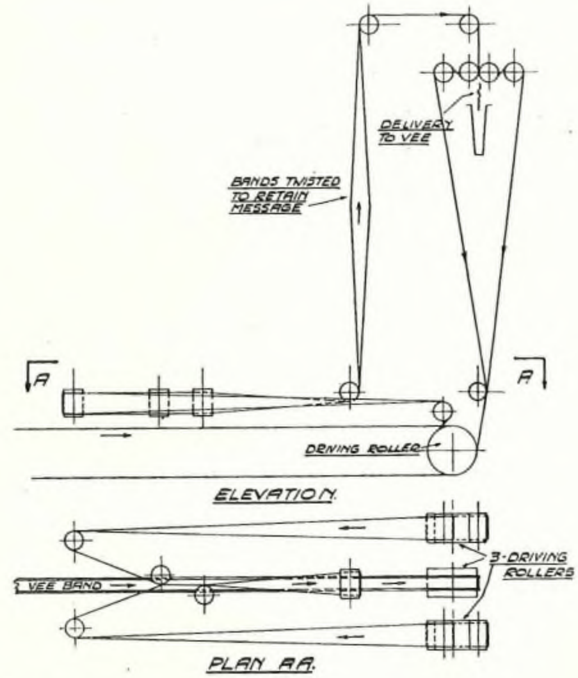


Fig. 1.—Transfer from Table Vee to High Level Vee.

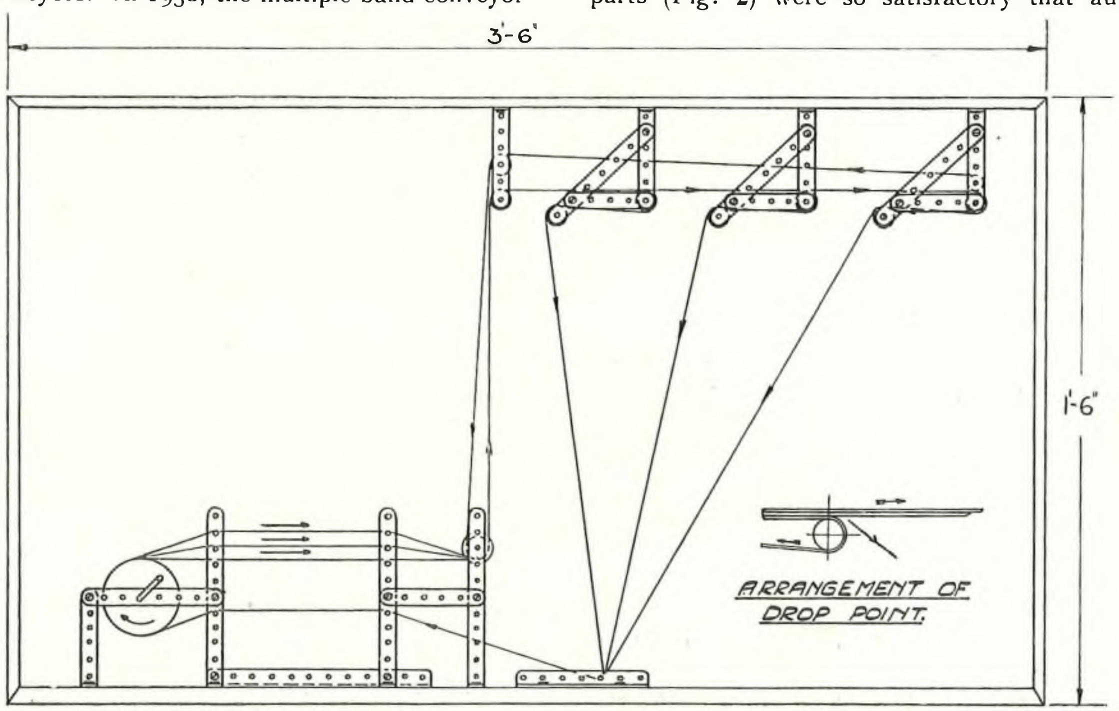


Fig. 2.—Original Model of the Multiple Band Conveyor.

was given for an experimental conveyor of five selections to be constructed. The East Gallery on the Fourth Floor of the Central Telegraph Office was selected as the most suitable available site for the Conveyor which is shown diagramatically in Figs. 3 and 4.

through automatic tensions, travel through the Sorting Fitting. At the point where the bands leave the fitting, an auxiliary band is added and is placed over and in contact with the uppermost band of the Multiple. The six bands are then brought together by passing them under a roller and in this

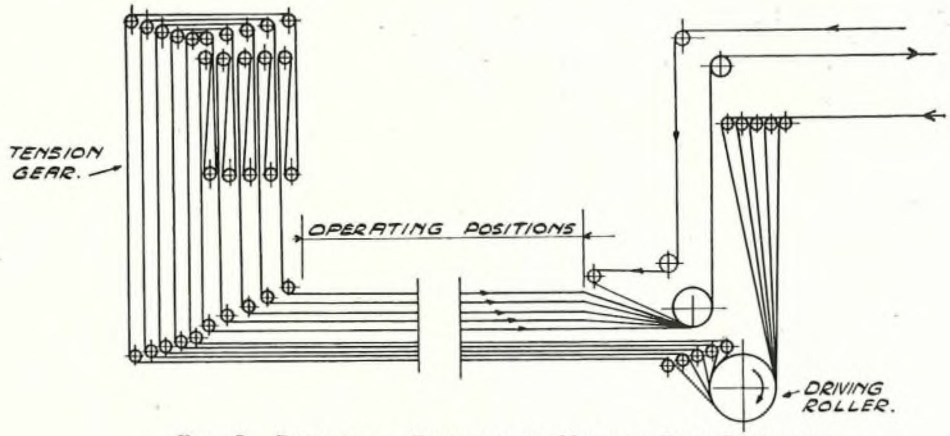


FIG. 3.—DIAGRAM OF EXPERIMENTAL MULTIPLE BAND CONVEYOR.

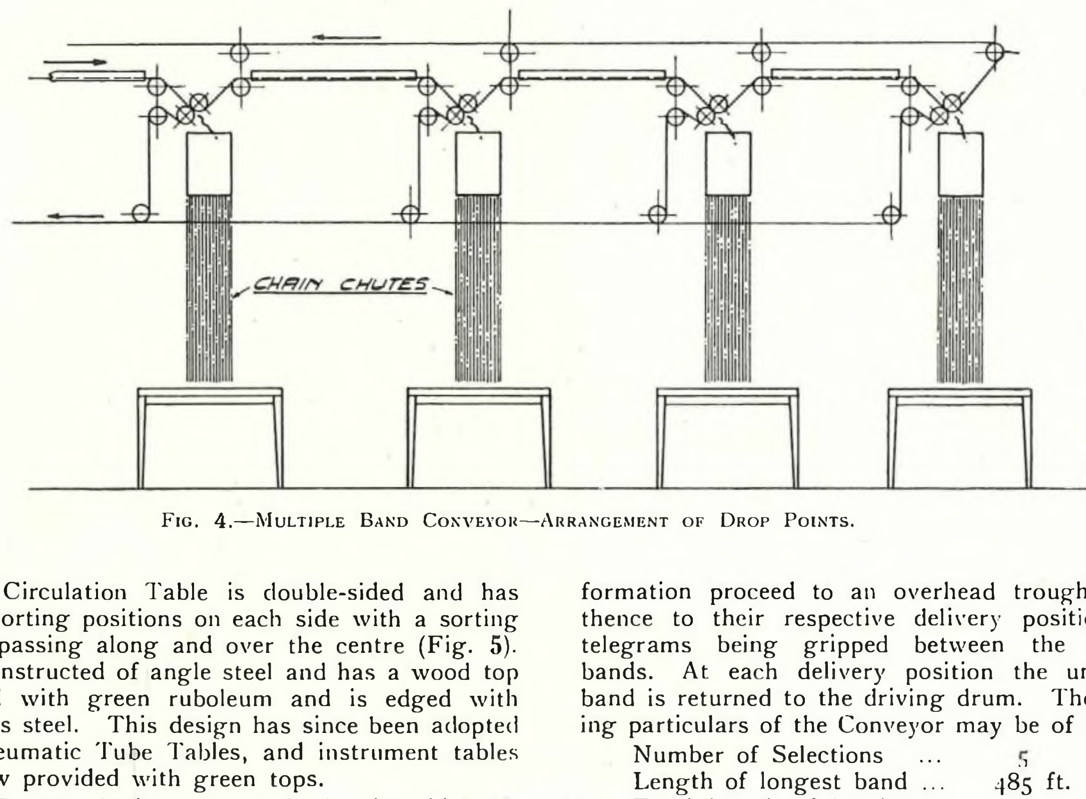


FIG. 4.—MULTIPLE BAND CONVEYOR—ARRANGEMENT OF DROP POINTS.

The Circulation Table is double-sided and has three Sorting positions on each side with a sorting fitting passing along and over the centre (Fig. 5). It is constructed of angle steel and has a wood top covered with green ruboleum and is edged with stainless steel. This design has since been adopted for Pneumatic Tube Tables, and instrument tables are now provided with green tops.

The Sorters obtain access to the bands, which are six inches in width, *via* apertures 12 by $1\frac{1}{2}$ inches and the space between the positions is filled in with panels of plate glass.

The five bands are driven from a common driving drum 18 inches in diameter; on leaving the driving drum the bands are separated and after passing formation proceed to an overhead troughing and thence to their respective delivery positions, the telegrams being gripped between the separate bands. At each delivery position the undermost band is returned to the driving drum. The following particulars of the Conveyor may be of interest :

Number of Selections ...	5
Length of longest band ...	485 ft.
Total length of band on Conveyor	1,763 ft.
Total weight of band ...	275 lb.
Speed of bands	200 ft. per min.
H.P. required	1.5 H.P.

The Conveyor is dealing satisfactorily with from 10,000 to 12,000 telegrams per day.

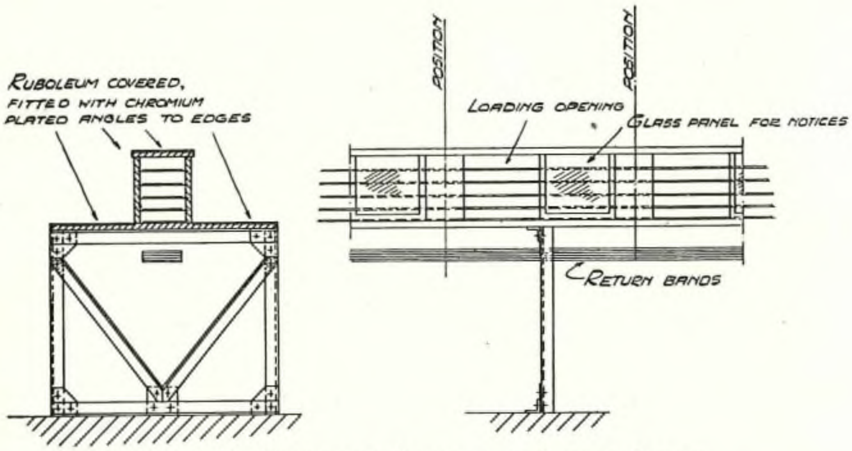


FIG. 5.—SECTION AND ELEVATION OF SORTING FITTING.

Many difficulties were encountered during the experimental stages, one of which—the electrostatic charge created on the face of the bands—may be of more than ordinary interest.

An electrostatic charge is present on the face of all Riser Band Conveyors and is produced by the friction caused by the bands passing over rollers and that between band and band caused by their relative difference in speed and, possibly, also due to the friction between the bands and the air. The charge covers the entire face of the bands and at a given temperature the quantity of electricity varies inversely with the hygrometric condition of the air. The telegram forms become very highly charged and adhere to the bands and even when persuaded to leave the bands they are at once attracted to the sides of the chute and will remain suspended for several minutes. Certain flimsy forms are capable of most wonderful performance when so charged. Telegrams are liable to fall from between the bands of some conveyors at sudden changes in the climatic conditions, and as the electrostatic charge tends to keep them in position, it is desirable to retain the charge on the bands and in fact to encourage it and make provision at the delivery positions for actually breaking the telegram away from the bands. This practice has been followed in all conveyors of this type and is effected by a sudden sharp bend in the band. The accomplishment is made certain under the worst conditions for ordinary telegram forms—by the introduction at the delivery points of special rollers which have an additional advantage in that they have the effect of stiffening up the telegram form at the moment of delivery. These rollers were designed and developed by Messrs. Sovex, Ltd., Union Works, Southwark, S.E., who manufactured the conveyors.

Although the bands are always more or less under the influence of the charge it is only troublesome in this country when the bands are new and during extremely cold, dry, periods and then only in connexion with some of the forms in use, *e.g.*, phonogram form. This country does not experience such conditions so frequently as others and the periods are of shorter duration, but when they do prevail, some provision, in addition to the special rollers referred to above, may be necessary to reduce or counteract the phenomenon if phonogram forms are to be carried. The charge resides on the surface of the bands and does not flow through them. As the bands are not good conductors it cannot readily be got rid of, but its effect may be reduced by treating the bands with a mixture of Glycerine and Water in the proportions of 5 to 1.

In printing works electrical neutralizers have been used—an inductive bar subjected to a high tension alternating current—but the telegram form is neutralized only at the moment it passes under the bar and the method is not applicable in this case—nor is earthing, as the bands are in contact from the point where the telegram form is inserted to the point where it is released. Also they are running at different speeds ow.ng to the increasing radii. The telegram forms between the bands are therefore being rubbed by the bands throughout their journey and as a result are charged to a lesser or greater degree depending upon the climatic conditions and the type of paper of which the telegram form is constituted. With a view to overcoming the trouble experiments are being made to maintain the bands in a slightly damp condition by means of humidifiers or alternatively atomizers, automatically operated by the conveyor tension weights, which

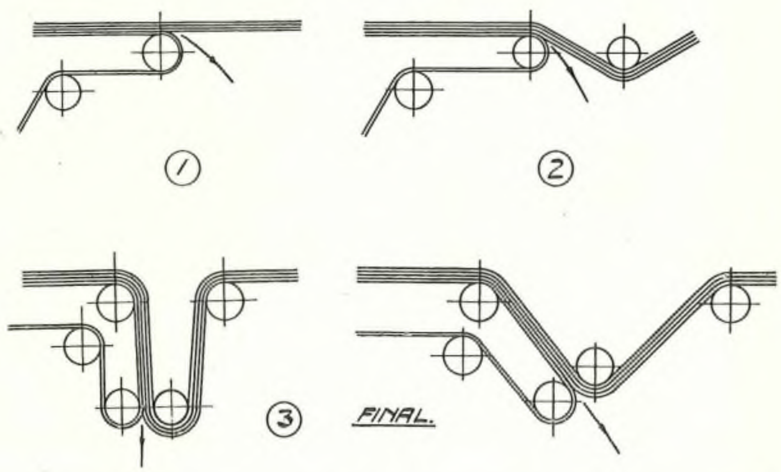


FIG. 6.—THE EVOLUTION OF THE DELIVERY FROM THE MULTIPLE BAND CONVEYOR.

would be used at times when electrification is troublesome.

Experience with the many and varied telegram forms which have to be dealt with has proved that forms having a matt surface are far less difficult to handle mechanically than forms having a glossy surface; the latter are not only more highly charged but hold the charge for a longer period.

It is desired to avoid folding and also to be able to carry every type of telegram form without risk of loss, and in this connexion steps are being taken to improve the actual forms.

Fig. **6** shows the evolution of the delivery point; This type of conveyor has been installed in large provincial offices. The bands run past the ends of and about 2 feet 6 inches above the level of the table tops. Seven bands are used giving six selections and the last band of the multiple is returned some 18 inches below the level of the table tops (Fig. **7**).

All the incoming traffic to the circulation Table from the Instrument Tables is automatically discharged from the "Vee" conveyors on to this return band which conveys it to and delivers it on to a slow moving band passing in front of the sorters at the circulation table. The telegrams are

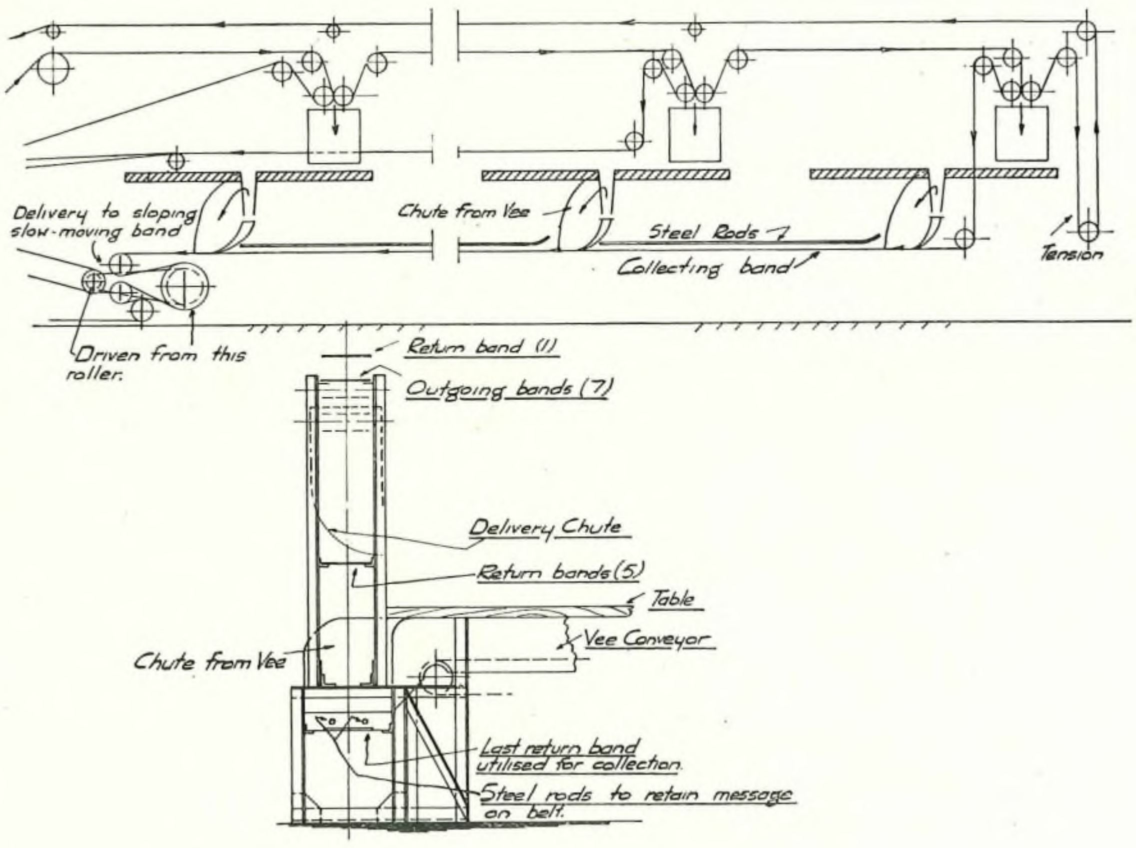


FIG. **7**.—MULTIPLE BAND CONVEYOR FOR COLLECTION AND DELIVERY.

the two final rollers must be as close together as possible for correct delivery.

In some cases it is advantageous to run the bands of the multiple at a low level (Fig. **7**). Day to day maintenance is thereby facilitated and carried out without interfering with the work of the operators. In addition telegrams can more easily be removed if the conveyor should stop from any cause and telegrams are less likely to come into contact with draughts from open windows. Faults caused by draughts are often wrongly attributed to the conveyor. A method of overcoming this difficulty is shown in Fig. **8**.

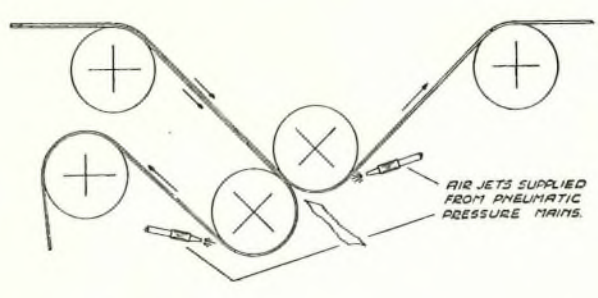


FIG. **8**.—MULTIPLE BAND DROP POINT, SHOWING AIR JETS ARRANGED TO PREVENT PAPERS ADHERING TO BELTS.

therefore distributed and collected by the same conveyor.

The discharge chutes from the " Vee " conveyors to the multiple band are so arranged that if telegrams are placed into the " Vee " conveyors correctly they will arrive at the circulation table faced ready for the Sorters. The return band travels to the circulation table in an open shallow trough 10 inches in width at a speed of 200 feet per minute. In order to prevent any telegrams being removed by sudden draughts of air a light steel rod has been fixed ½ inch above and parallel with the band. It may perhaps be mentioned that at a band speed of about 220 feet per minute telegrams begin to rise from an ordinary open band.

Seventeen multiple band conveyors are to be installed. Eleven have already been brought into use and the remainder are in various stages of manufacture or erection. These conveyors will save their capital cost in a few years.

In provincial offices the main multiple band conveyor deals with up to 20,000 telegrams a day :—

Five conveyors have six selections.
Three conveyors have five selections.
One conveyor has four selections.
One conveyor has three selections.
Seven conveyors have two selections.

In cases in which a multiple band cannot be justified or in which the return band of a multiple cannot be conveniently used for the purpose of collecting telegrams, the " Vee " conveyor, so called on account of its shape, has been employed. Some types of this conveyor are shown in Fig. **9**. That used in this country is a modification of the American design.

The telegrams travel on edge and in that position may be carried at high speed. The conveyor may be loaded by hand or automatically at a number of positions without fear of the telegrams colliding as immediately one is placed into the conveyor it falls to one of the sloping sides.

The following conveyors are used for point to point work :—

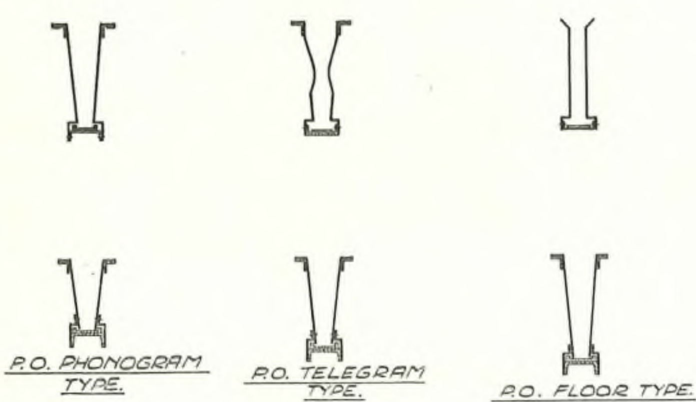


FIG. **9**.—SOME TYPES OF " VEE " CONVEYORS.

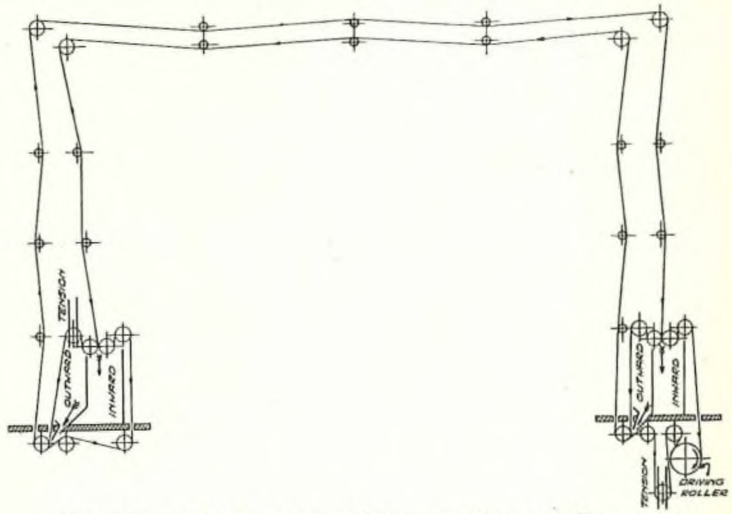


FIG. **10**.—DIAGRAM SHOWING BANDS ARRANGED FOR TWO-WAY WORKING.

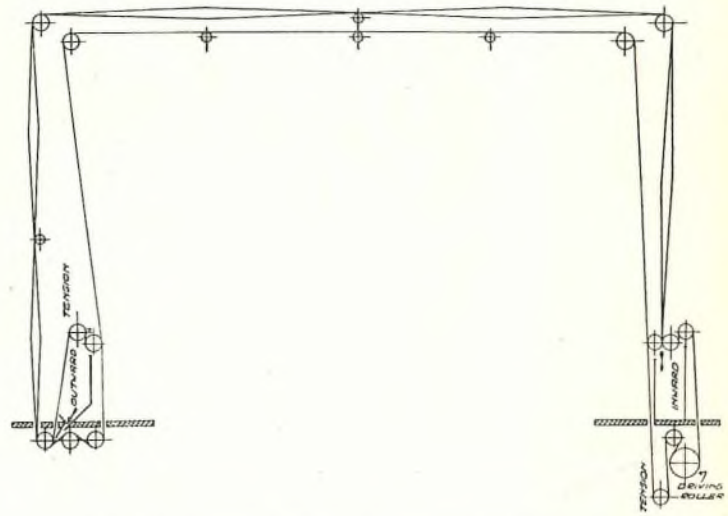


FIG. **11**.—DIAGRAM SHOWING BANDS ARRANGED FOR SINGLE-WAY WORKING WITH TWISTED BANDS.

The Riser Band Conveyor (Fig. **10**) in which the bands are kept in contact with each other by passing them under and over rollers. Telegrams are liable to fall from between the bands of this conveyor on sudden climatic changes as, owing to the fact that the two bands are in contact with each other and also with the rollers, the automatic tensions are prevented from acting quickly and effectively throughout the length of the bands and they are apt to separate. At high speeds the trouble is accentuated by the consequent rush of air helping to dislodge the telegram.

The Twisted Riser Band (Fig. **11**) developed by Messrs. Sovex, Ltd., is a great improvement. The bands remain in better contact, fewer rollers are re-

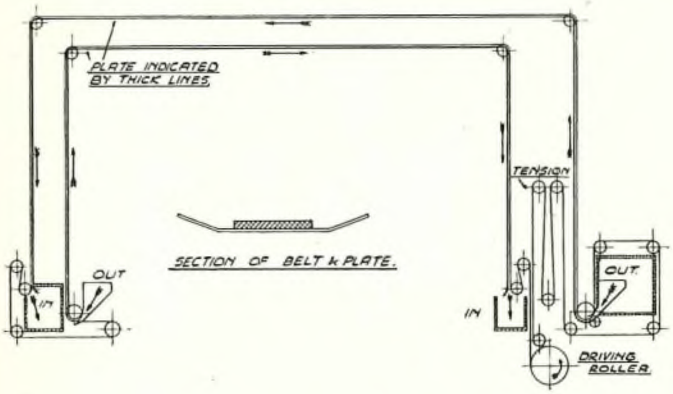


FIG. 12.—DIAGRAM SHOWING DRAG BAND ARRANGED FOR TWO-WAY WORKING.

quired, and the speed may be higher. A test at 1,000 feet per minute proved quite satisfactory, but at such a speed, noise and wear and tear are at a maximum.

The Drag Band Conveyor (Fig. **12**)—so called because the telegram is dragged along a troughing—seems to have been first used in France for telephone tickets and was developed later in America for telegrams. This conveyor has been designed and developed on lines to suit the traffic requirements in this country. It provides a satisfactory link between conveyor and conveyor when automatic transfers are required and is less costly to maintain than the Riser Band Conveyor. It can be constructed with one or more pick-up or loading stations. The correct alignment of the troughing is a matter of great importance, as, if a telegram is delayed in its passage through the conveyor and is overtaken by one travelling behind, it is certain to be crumpled.

Fig. **13** shows some loading and delivery stations which have been specially designed for use in the British Post Office systems.

Figs. **14** and **15** show designs of single and two-way elevators.

Once a telegram has been placed into a conveyor it should not be released until it has reached the end of its journey. Unfortunately this is not always possible and in most installations it is necessary to arrange automatic transfers from conveyor to conveyor. As many as five transfers in a single journey are necessary in the Central Telegraph Office scheme (Fig. **16**). The transfer from a table "Vee" Conveyor to a floor "Vee" Conveyor is carried out by means of a simple chute (Fig. **17**). The same figure shows also how a right-angle bend in a "Vee" Conveyor is negotiated.

Transfers from a "Vee" Conveyor to a drag band conveyor are shown in Figs. **18** and **19**. The design shown in Fig. **18** is also used for transfers to riser band conveyors. In the case of a multiple band conveyor, if more than one right angle-bend is to be negotiated a transfer to another conveyor is advisable. Such transfers are very difficult to arrange, as, owing to the highly electrified state of the telegram form on leaving the multiple band conveyor it must not be allowed to come into contact with any stationary wood or metal chute before entering

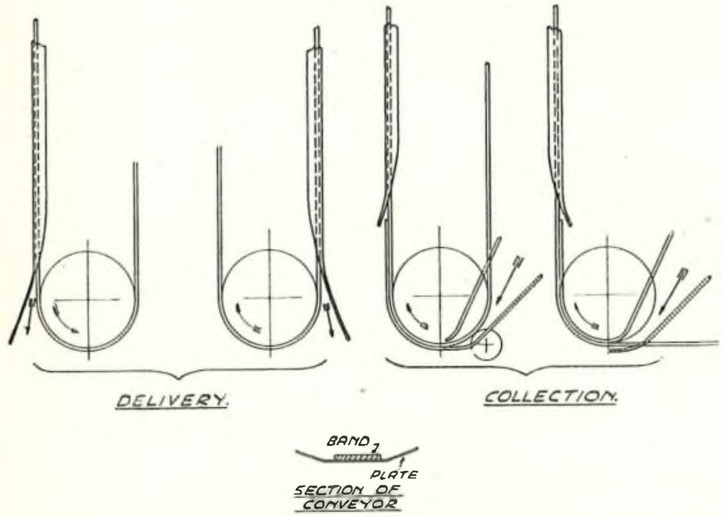


FIG. 13.—DETAILS SHOWING COLLECTION TO AND DELIVERY FROM DRAG BAND CONVEYOR.

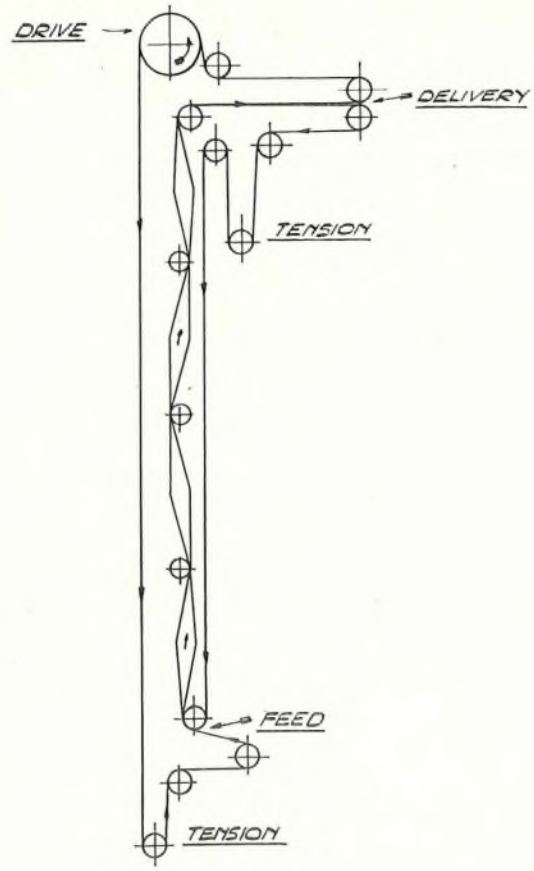


FIG. 14.—TWISTED BAND ELEVATOR.

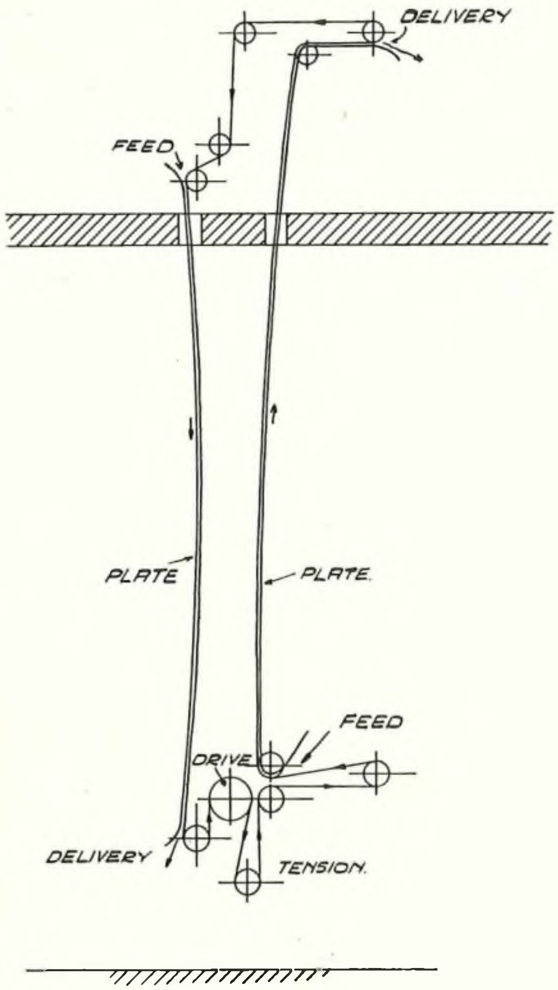


FIG. **15**.—DRAG BAND ARRANGED AS ELEVATOR.

the second conveyor. Methods of transfer to a riser band conveyor and a drag band conveyor, designed by Mr. J. P. Treen, are shown in Fig. **20**. The transfers depend for their success upon the special rollers referred to earlier.

During the past 18 months conveyors have been installed at Glasgow, Edinburgh, Liverpool, Manchester, Birmingham, Bristol, Cardiff, Swansea, Exeter, Plymouth, Sheffield, Nottingham and Belfast and an installation at Newcastle is proceeding. A large part of the Central Telegraph Office has also been equipped. This rapid progress has placed the British Post Office ahead of other administrations and it can now claim to have the finest and most complete systems and in the Central Telegraph Office (Fig. **16**), will have the largest system in the world.

The original intention was to describe some of the types of conveyor which have been developed, but a short description of the Central Telegraph Office scheme which is at present under construction, may not be considered out of place.

The Primary Circulation Table has 16 working positions on each side, and is equipped with two Multiple Band Conveyors, one 2-way, and one 3-way; one serving the South West Circulation Table and the T.T.T. section which is on the floor above; and the other, the North West Circulation Table and the Addressing Table, one way being left spare for future development.

Two slow moving bands 7in. in width are on one side of the table, travelling towards a dump in the centre. On the other side is a " Vee " conveyor which feeds automatically into a Drag Band Conveyor. These two conveyors are for L.P.S. traffic which is carried direct from the Primary Circulation Table to Table No. 38.

All incoming traffic from any position in the room, from the pneumatic tubes or from phonogram or telephone-telegram circuits on the floor above, is automatically conveyed to the Primary Circulation Table by means of conveyors.

For the purpose of collection the room is divided into two halves, South West and North West, the dividing line being down the centre gangway, and each half of the room is sub-divided into three sections. Each Instrument Table is equipped with a " Vee " Conveyor, and each section with a Floor " Vee " Conveyor into which the Table " Vee " Conveyors discharge. The Floor " Vee " Conveyors are linked up with the Primary Circulation Table by means of Drag Band Conveyors.

Reference to Fig. **16** will show that a telegram arriving at any position on Table No. 41 and placed into the Table " Vee " Conveyor is transferred at T1 to a Foor " Vee " Conveyor, transferred again at T2 into a Drag Band Conveyor, again at T3 to a Floor " Vee " Conveyor (South West centre), again at T4 to a Drag Band Conveyor which, in turn, transfers it on to the slow moving band on the Primary Circulation Table.

The time for this journey of upwards of 275 feet will be approximately 90 secs., and it will have been accomplished without handling.

Similar arrangements are made for the other sections.

Phonogram traffic is conveyed from the Primary Circulation Table to the Addressing Table by the Multiple Band Conveyor, and after being marked there it is placed into a " Vee " Conveyor, from which it is automatically discharged into a Drag Band Conveyor and elevated to the floor above. This latter conveyor is 2-way, and the return half conveys the incoming phonogram traffic direct to the Primary Circulation Table.

The outgoing T.T.T. traffic is conveyed direct to the floor above by the Multiple Band Conveyor, and delivered on to the slow moving band on the Circulation Table. The incoming traffic will be conveyed to the Primary Circulation Table by similar means to that provided for the phonogram traffic.

If the phonogram circuits should be out of commission at any time, all traffic to the 4th Floor will travel by the T.T.T. band, and vice versa.

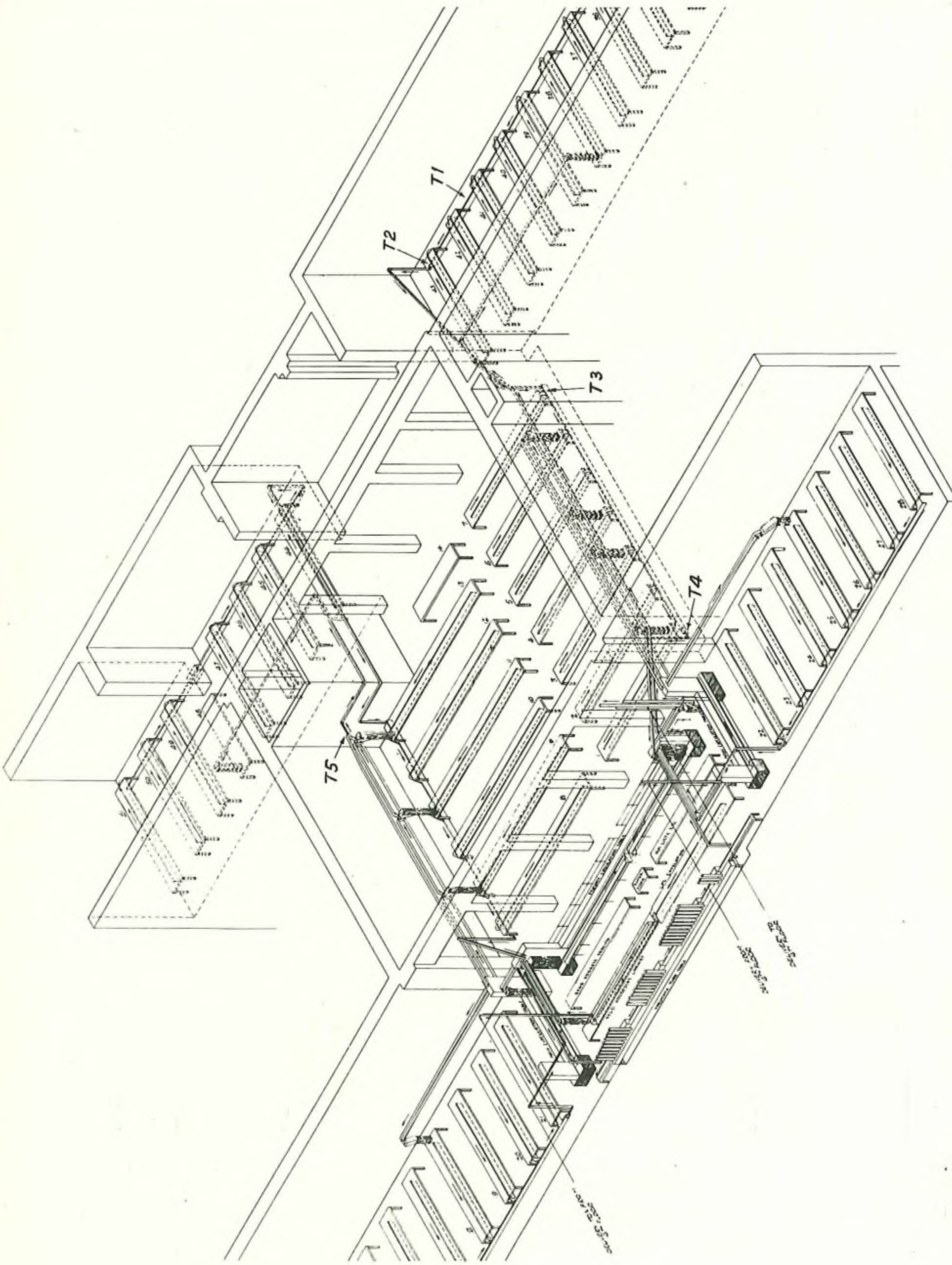


Fig. 16.—Central Telegraph Office Installation.

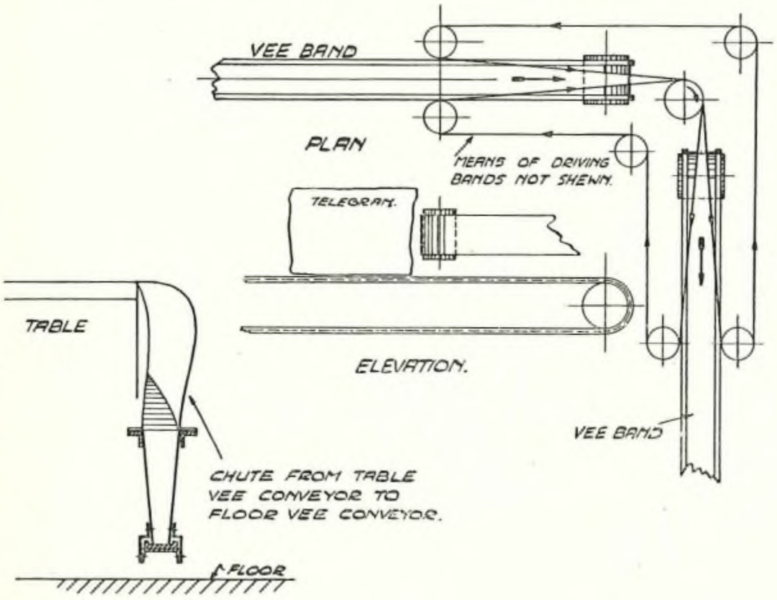


Fig. 17.—Transfer from Table Vee to Floor Vee and Right Angle Bend in Vee Conveyor.

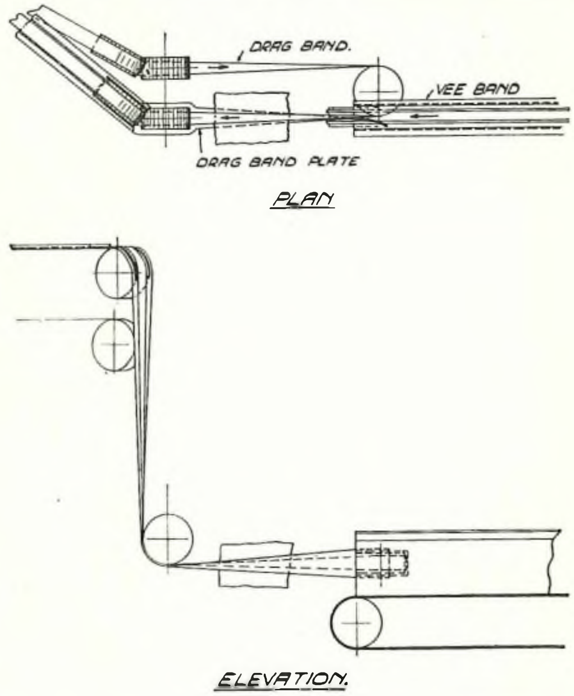


Fig. 19.—Transfer—Vee to Drag. Straight Through or at Right Angles.

The outgoing traffic for the pneumatic tubes is conveyed to the Addressing Table on the same band as the phonogram traffic, and, after being addressed and enveloped, is conveyed to the Tube Attendant. The Pneumatic Tube table is equipped with two 9in. bands, running at 100 ft. per minute. One conveyor is reversible. The carriers from the tubes are automatically delivered on to these bands, and may be carried to one end or half to each end as desired, for unloading. At each end of the table a Drag Band Conveyor is provided to convey the traffic to the Primary Circulation Table.

For distribution two Circulation Tables are provided, one for the South West half, and one for the North West half of the room. Each table has 12 positions, and is equipped with a 5-way Multiple

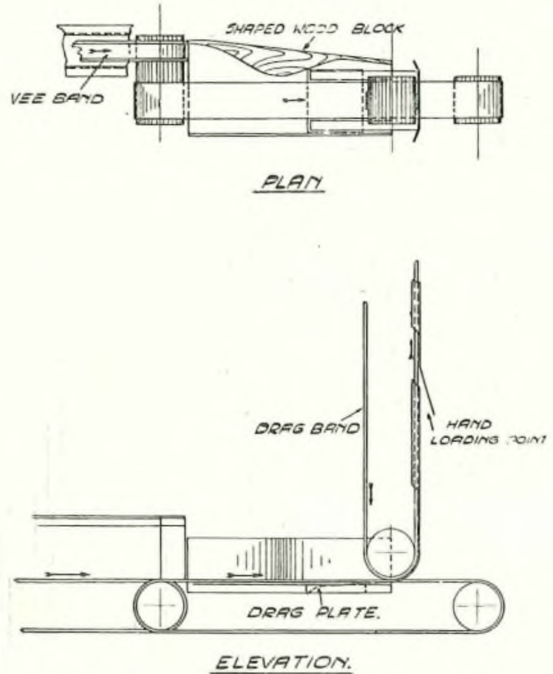


Fig. 18.—Transfer—Vee to Drag. Straight Through.

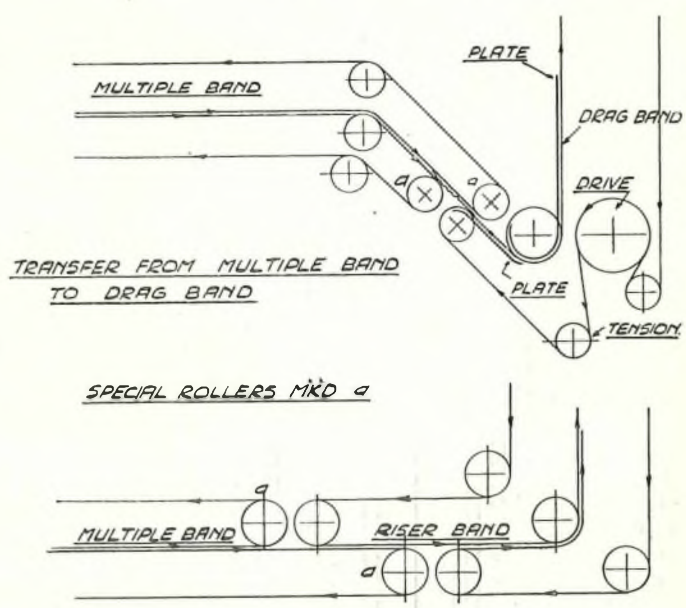


Fig. 20.—Transfer from Multiple Band to Drag and Riser Bands.

'Band Conveyor and two slow moving bands, one on each side. The traffic from the Primary Circulation Table is carried on the slow moving bands to the sorters, and is placed on to the bands of the multiple, and distributed from the South West Table Nos. 1, 3, 4, 6 and 25, and from the North West Table to Tables Nos. 9, 11, 13, 18 and 45.

The circuit to Table No. 45 is too long and winding to be dealt with by a single conveyor band, and an automatic transfer to a Drag Band Conveyor is arranged at T5.

All slow moving bands which pass in front of sorters are dyed green in colour, and travel at a speed of 30 ft. per minute. Tests, experience and observation prove this to be the best and most economical speed for a band from which telegrams can be taken by hand for any length of time without fatigue, and the green bands are of assistance in this respect.

The whole of the steel-work and supporting structure has been designed as light as possible, having due regard to strength.

Fig. **21** shows the layout of the Liverpool Instrument Room which is typical of the larger offices. The Multiple Band Conveyor deals with 35,000 to 40,000 telegram journeys per day.

Fig. **22** shows a simple but useful type of cord conveyor which has been in use in a Post Office abroad for many years. The telegrams are folded and placed on the cord. The speed is about 50 feet per minute.

The bands used on the multiple band conveyor are 0.055 inch in thickness. Thin bands together with a large diameter driv'ng drum reduce the relative difference in speed between band and band to a minimum. They have been specially treated to reduce friction and to restrict the variation in length which is caused by changes in the climatic conditions.

The continual variation in length of conveyor bands necessitates the introduction of an automatic tension device into each band to take up the stretch and maintain an even tension on the bands under all conditions. The tension also performs the further function of providing adequate driving effect and the amount of tension applied has an important bearing upon the life of the band. Tension should not be unduly increased to prevent slip. Slip may

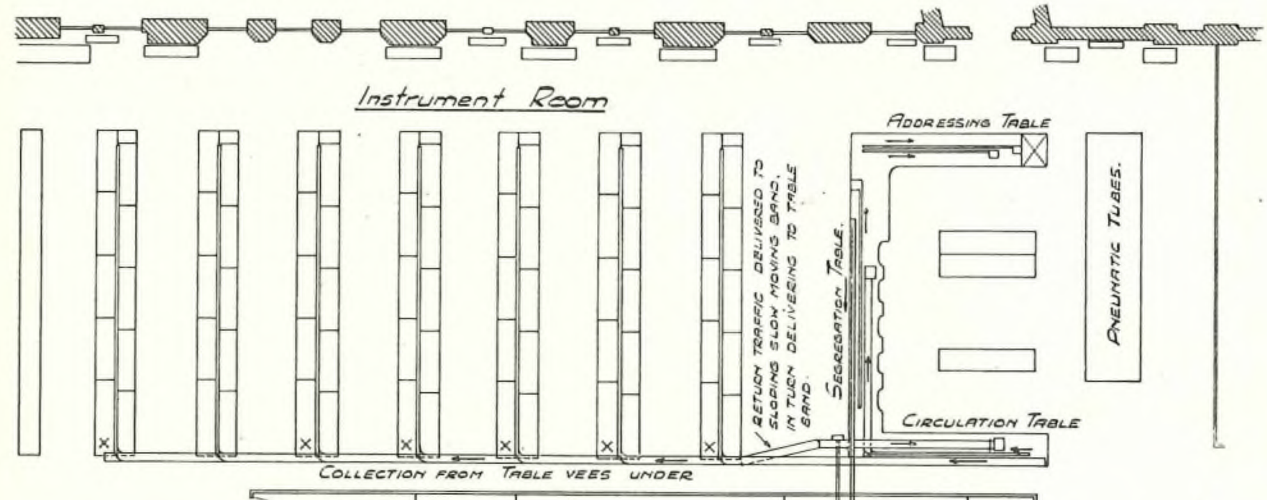


Fig. 21.—Lay-out of Liverpool Instrument and Phonogram Rooms.

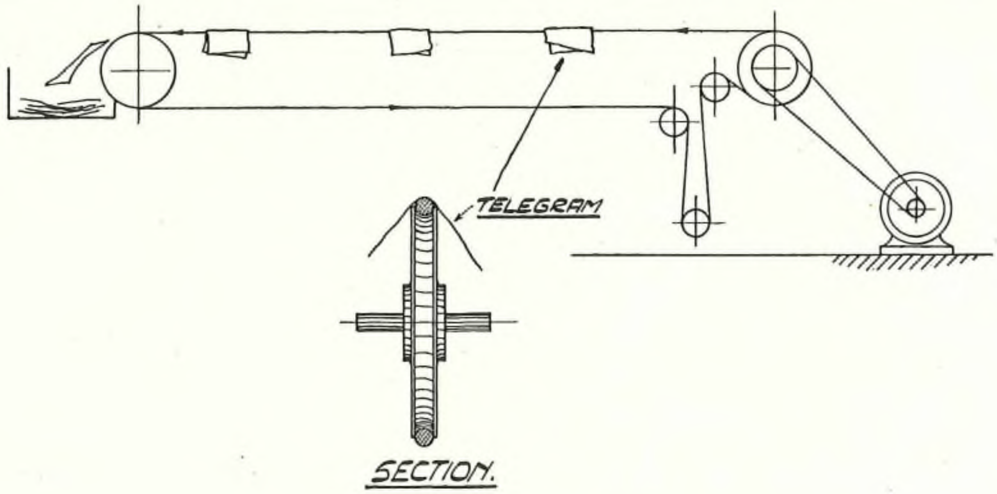


FIG. 22.—SIMPLE CORD CONVEYOR.

be due to insufficient lap on the driving pulley and may be corrected by the introduction of a snubbing roller or a " Hugger " belt (Fig. 23).

The joints in the bands must be made without appreciably increasing the thickness of the band at the joint, and are made by overlapping 1in. fringes, which are then machine-stitched and vulcanised. The total length of the joint is then 2in.

The average strength of this type of joint in new

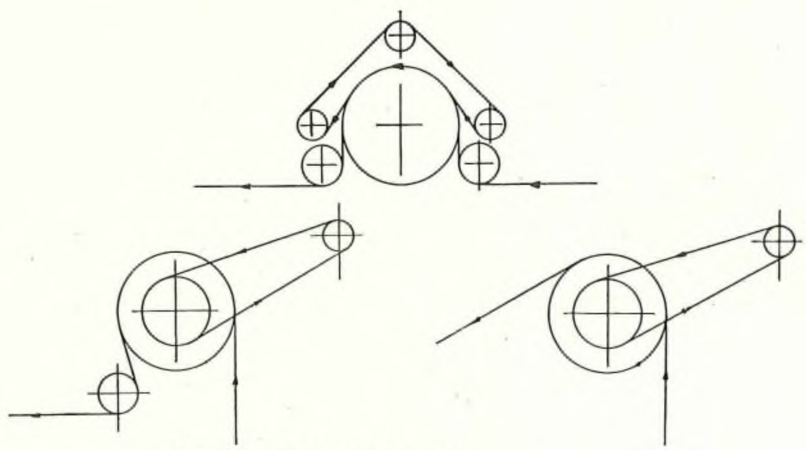


FIG. 23.—CORRECTION OF SLIP.

material is more than 500 lb. per inch of width, and of a similar joint made in material used for 12 months, more than 376 lb. per inch of width. These figures give some idea of the strength of the material finally selected for the bands, and also the gradual reduction in strength due to warp abrasion, by constant wear. The sample of used band tested had been working for 12 hours per day for 12 months, under most exacting conditions.

Ball bearings of ample size have been used throughout and grease gun lubrication provided. Once the bearings have been filled with grease, they will require no further attention for two to three months. An all-round speed of 200 feet per minute has been adopted as the most economical having regard to wear and tear, noise and vibration.

The idler rollers on the phonogram room conveyors have been insulated from the conveyors, an idea suggested by Mr. H. A. Hill of the Power Section, Scotland West District. The insulation of these rollers prevents any noise being conveyed to the telephone apparatus.

With a few exceptions the conveyors and transfer devices referred to are believed to be original and have been designed to meet the special requirements demanded for the mechanical handling of unfolded telegram forms at comparatively high speed. The design and manufacture of conveyors of this type and for this purpose may be said to be a new industry and other and better conveyors will no doubt be developed in the future. Every new idea must contend with severe criticism. These conveyors have proved no exception and in some quarters bid fair to gain a place in the famous Engineer's Toast " Dam your rivers " " Blast your furnaces, etc.," and " Transport your conveyors."

Continuous Suspension of Aerial Cables

W. H. Brent, B.Sc. (Hons.).

THE use of a continuous binding for the suspension of the cable from its catenary wire is by no means of recent introduction. The practice was a recognized one in America at the end of the last century and the method by which a wrapping of marline was applied with a cable spinning jenny is of interest. Fig. 1 illustrates

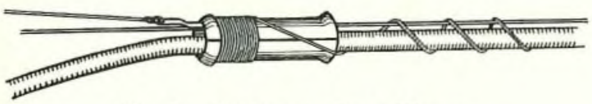


Fig. 1.—Chinnock's Cable Winder.

" Chinnock's Cable Winder " and it will be seen that the marline unwinds from a hollow revolving cylinder about both the cable and its suspending wire—as the cable spinning jenny is drawn from one end of the span to the other. The comparatively short life of the marline, the limitation of the method to cables of very small size, and the fact that a whole span of cable could become unsupported if the marline parted, are, however, definite objections to the arrangement. More recently these objections have been overcome by a British firm of cable manufacturers, Messrs. Pirelli-General Cable Works, Ltd., and the use of " Combined Catenary " aerial cable has been investigated by the British Post Office by the erection of a number of cable lengths for field tests at Caxton, near Cambridge.

For this work the cables, which are manufactured in the factory complete, were designed as follows: The lengths and sizes of cable required were 2,450 yards of 25 pair/20-lb. (diameter, 0.84 in.) and 522 yards of 15 pair/20-lb. (diameter, 0.67 in.) and each was laid up side by side with a 7/14 galvanized steel strand suspension wire (breaking weight, 5,700 lb.). The cable and wire as they passed through the machine were then bound together with two tapes, $\frac{1}{4}$ inch wide and 30 mils in thickness, put on close together in an open spiral of 10-inch lay. The tapes are of high purity iron and are wiped-galvanized and compound treated to prevent corrosion. Fig. 2 is a photograph of one of these cables.

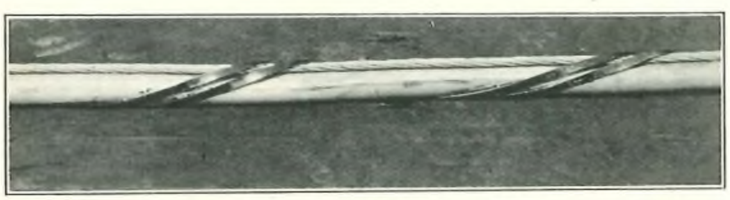


Fig. 2.—Combined Catenary Cable.

The complete cable is wound on the drum without twist, to facilitate erection, and with hessian wrappings between the turns to prevent damage to the tapes or cable.

Thus, in the same way that the use of steel cable rings in place of marline suspenders gives a much longer life and lower maintenance costs to the aerial cable system, so the " all-metal " construction in this case provides the reliability required for the continuous binding of the cable. In addition, although the stiffness of the tape should prevent it unravelling far on breakage, this objection has been countered by the use of two separate bindings.

An advantage, which is claimed by the manufacturers and which is of importance to designers of power transmission lines, is that the load due to the surface exposed to wind, when there is an ice coating over cable and strand in close formation is less than when each has to be considered separately, so that there can be a saving in the cost of towers. This does not necessarily hold in the case of telephone practice, but there is certainly an increase in the factor of safety of the suspension strand under ice and wind loading.

The manufacture and supply of a cable already bound to its suspension wire provides special

Fig. 3.—Cable Sheaves secured to Pole.

problems in regard to its erection into position on the poles, and a number of different ways were considered before deciding upon the methods to be described. The first method, adopted for the 25-pair/20-lb. cable, consisted of drawing the cable out over sheaves fixed to each pole from a stationary drum and so bringing it into position for clamping in the brackets. In the second method, the cable, 15-pair/20-lb. in this case, was run out at the foot of the poles from a drum mounted in a travelling lorry and then lifted into position.

The cable sheaves used in the first method consisted of two single blocks bolted to the ends of a short length of channel iron, which was secured to the pole by wood chocks and bolts. The arrangement is shown in Fig. 3 and in this way a free portion of cable in the correct position for fixing was given for the attachment of the brackets later. A $\frac{1}{4}$ inch diameter wire rope was placed in the sheaves and the end taken back to the cable drum. Here it was connected to the leading end of the cable for pulling, which was done by means of a lorry, to the chassis of which the other end of the rope was fixed *via* a safety link consisting of 2—150-lb. copper line wires with an auxiliary loop of wire rope to hold the tension should the link break.

In this method a brake must be provided on the cable drum to resist the pull. By this means, a tension of 200-300 lb. can be maintained throughout the length, so that the cable is kept clear of the hedges and with ample clearance over roads for normal traffic to pass. The first length to be erected was 880 yds. and included two road crossings as well as high hedge banks and bends and dips in the road, thus giving experience of all the difficulties likely to be encountered. An idea of the tension in the cable during running is given by Fig. **3** and also by Fig. **4**—although the latter photograph was taken during a halt for the lorry to be fleeted. The cable drum jacks were mounted on timber baulks and the braking action obtained on flanged wheels, keyed to the ends of the spindle. Over each wheel was passed a steel band which could be tightened by a lever at one point of attachment to the base.

Fig. **4**.—Cable Drum and Brake.

Actually, the length of 880 yds. was found to be too long in the circumstances for effective communication and somewhat shorter lengths are advisable. Signalling was carried out using portable telephone sets.

The inner end of the cable having been released from the drum and the strand terminated on the first pole of the section, the tension was applied using blocks and tackle. A distinction from normal methods of aerial cable erection, in which the suspending wire is erected before the cable, arises as the final tension must be applied and not a tension calculated from the loaded and unloaded conditions. Further, as the strand is securely bound to the cable the method of checking the tension by oscillating the wire cannot be used and for this reason a dynamometer of the type shown in Fig. **5** was inserted in the pulling tail adjacent to the tackle. The tensions and sags (40-yd. spans) adopted for both cables are given in Table I.

Table I.

Temperature.	25-pair/20-lb. cable.		15-pair/20-lb. cable.	
	Tension.	Sag.	Tension.	Sag.
°F.	lb.	ins.	lb.	ins.
20	1990	15	1850	11½
40	1880	16	1740	12½
60	1770	17	1630	13½
80	1670	18	1520	14
100	1580	19	1420	15

The next step was to clamp the cable in position. To do this it was found necessary to cut away the binding tapes for about 18 inches at each pole as there was not enough space between the cable and suspending wire to insert the lip of a 3-bolt bracket (Bracket No. 13) without rubbing contact on the sheath taking place. Before cutting the tapes, however, a secure binding of 60-lb. G.I. binding wire was made round the whole on each side of the pole to prevent unravelling. Having done this, the bracket was attached to the strand in a reverse manner, *i.e.*, with the lip undermost, and secured to the pole by means of an arm bolt with a suitable tubular washer inserted to provide clearance between the pole and the cable. The cable sheaves were finally removed and transported to the next section.

For the erection of the 15-pair/20-lb. cable the cable drum was mounted on jacks in a 3-ton lorry and the cable carefully paid out over the back end onto the side of the road at the foot of the poles. Fig. **6** shows the progress of the lorry during this operation. While this part of the work proceeded, the free end of the cable was being terminated by means of the strand wire at the first pole of the section (the junction pole for the 25-pair/20-lb. cable) and the raising of the cable at each pole commenced. For this purpose, a single block was

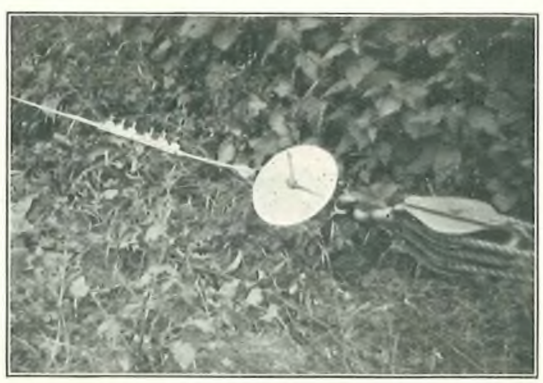


Fig. **5**.—Dynamometer.

Fig. 6.—Paying Out Cable from Lorry.

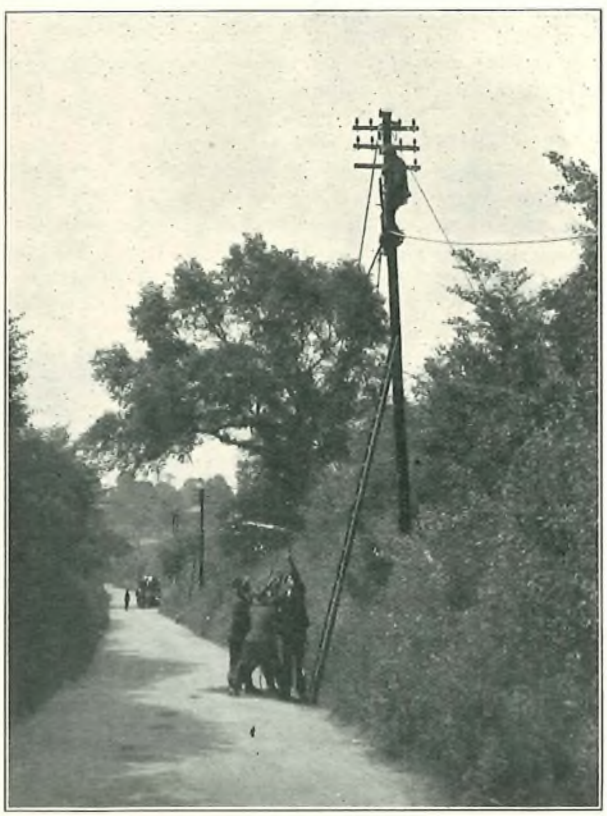


Fig. 7.—Lifting Cable into Position.

fastened to the top of the pole and the weight of the cable taken by a rope passing over it. Three or four men hauling on the rope raised the cable, whilst one man was ready to assist it over the third arm; Fig. 7 illustrates this stage of the proceedings, the lorry also being visible. The cable was then allowed to rest on the arm with sacking protection until the correct tension had been applied, this being carried out as before using the dynamometer. The cable was finally fixed in the brackets, but in the absence of the sheaves holding the cable in the correct position, some little difficulty was encountered at angle poles where the cable was under a tension of 1500/1600 lb. and either hard against the pole or against a temporary spindle. In the latter case, the best method of drawing in the cable was found to be the use of a long bolt with which the bracket could be screwed into position.

The "lifting-up" method might be considered to be at a disadvantage where road crossings are frequently met with, but if at such points the cable

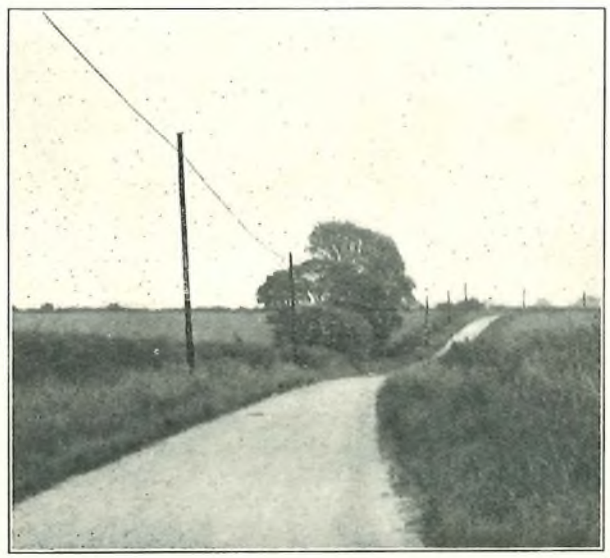


Fig. 8.—A Section of Continuously Suspended Aerial Cable.

drum is kept close to the party raising the cable, little obstruction of traffic need occur. It is useful to have a tail of strand wire with a clamp ready fixed at the back of the lorry so that on any such occasion it can be clamped to the suspension strand on the cable and tension applied to take out the sag. The cable can then be held up by bolting a stay clamp to the strand wire on one side of the bracket on the pole. In this section of cable there were two road crossings and at no time were cars—not very frequent it is true—delayed.

In comparing the costs of the two methods, the "lifting-up" method proved to be more economical than the "cable-sheave" method, the recorded labour costs, exclusive of ineffective time, being 330 manhours per mile as against 406 manhours per mile. A considerable proportion (25%) of the latter figure was due to time spent on erecting and recovering the sheaves and by attention to this item it should be possible to improve the performance. Some allowance must, however, be made for the heavier cable involved in the "cable-sheave" method, although this would not account for the difference shown. An estimated figure for cable ring methods based on the London-Brighton Aerial Cable work, in which the cable was approximately the same weight as the larger of these cables, is 383 manhours per mile.

An important feature of this type of cable, not so far mentioned, is its favourable appearance. When erected the impression given is in effect little more than that of a single self-supported cable—as can be judged from Fig. 8. The absence of the separate suspension wire and the numerous suspenders makes a marked difference from standard types of aerial cable.

Trailer Handcarts and Pumps.

J. J. Edwards, B.Sc. (Eng.), A.C.G.I., D.I.C., A.M.I.E.E.

The realization of the benefits to be obtained from the scientific utilization of motor transport has led in recent years to the adoption of trailers for economic haulage Not only can the motive power vehicle often be released for other work after towing the trailer to the scene of operations, but also the load which can be hauled is considerably greater than the rated carrying capacity of the lorry. For example, the haulage of a trailer of 10 cwt. gross weight is equivalent to carrying only about 2 cwt. load on the van body. A 20 cwt. Morris vehicle (other than Utility type) can therefore carry a load of 18 cwt. (men and stores) besides trailing a load of 10 cwt. and the effective load transported is 28 cwt., an increase of 40 per cent.

Also the reduced overall dimensions of the trailer due to the absence of the engine unit, with consequent greater ease of manœuvring, are extremely valuable in the case of the cable drum bogey or trailer. Conversely, the additional length obtainable with a telescopic chassis pole trailer permits longer poles to be carried than is possible on a standard lorry. Trailers of these types have been in use for some time and have already been described in detail in this Journal, but a few notes on a type of trailer which has recently been introduced may be of interest.

The "Gibson" trailer, Fig. 1, is an extremely light two-wheeled chassis built by Messrs. J. Brockhouse & Co., Ltd., of West Bromwich. It weighs only 2¾ cwt. complete with tyres and has a carrying capacity of 12 cwt. The drawbar is built integral with the main frame of angle irons and is fitted with a self-locking ball hitch. The latter is spring-loaded and not only absorbs all starting shocks, but automatically operates internal expanding brakes on the trailer when the brakes are applied on the towing vehicle. The axle is of nickel steel and is fitted with tapered roller bearings for the wheels which carry 27 in. × 4.40 in. low pressure tyres. An independent hand brake operated from the trailer is also fitted.

This type of trailer has so far been introduced to carry handcarts and pumps.

Trailer Handcart (Fig. 2).

The standard chassis dimensions are 5′ 6″ × 3′ 6″, but these were reduced somewhat to accommodate a wooden body identical with that of the standard jointer's handcart, which is 4′ 9″ × 3′ 0″. Wood was chosen for the material of the body in preference to steel after consideration of the reports obtained

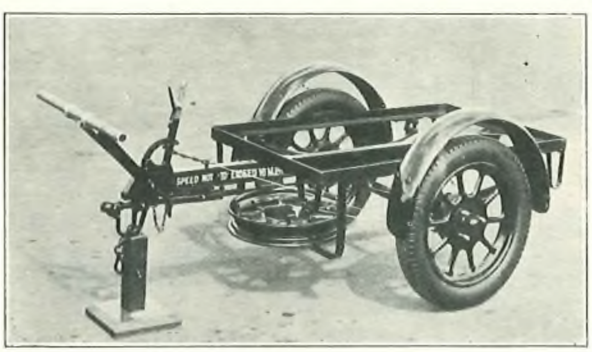


Fig. 1.—The "Gibson" Trailer.

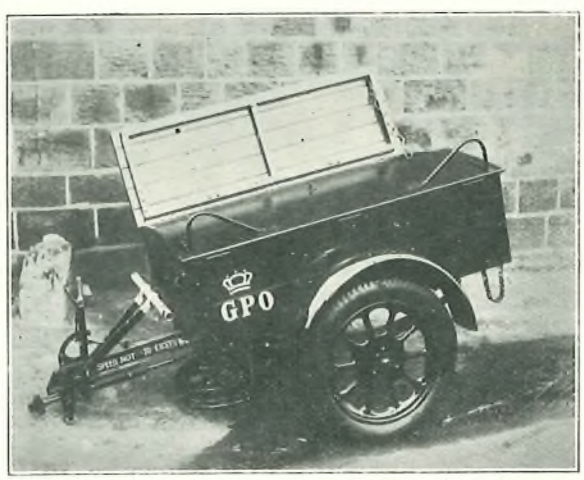


Fig. 2.—Trailer Handcart.

from users of experimental all-steel handcarts which had been on trial for some time.

Twenty of these trailers carrying handcart bodies have been built and are in use in various parts of the country. They are towed by vehicles of 20 cwt. capacity and upwards, including both ordinary and Utility types except the 30 cwt. Utility vehicle. The attachment of the towing hitch on the rear of the latter vehicle is somewhat difficult owing to the presence of other fixings, but special arrangements are being made so that this type of vehicle is not excluded from use with the trailer.

An additional number plate is provided for every vehicle used to tow a trailer and the latter is provided with the necessary rear lamp and flexible extension and plug to connect it to the lighting system of the vehicle. They are a first attempt to provide for the gang working with ordinary handcart and motor transport facilities some of the advantages enjoyed by a gang using a Utility vehicle. Where previously it was necessary to haul the handcart up into a lorry for transport from job to job as required, with the trailer handcart it is the work of a moment to couple up the towing hitch to the rear of the lorry and the gang then has the advantage of the space previously occupied by the handcart.

The facility for moving the trailer short distances is provided for by means of a folding handle which can be raised and locked out of the way when the trailer is on tow, and lowered into position for pushing when it is only a question of moving from one joint box to the next or some similar distance for which the presence of a vehicle standing by cannot be justified.

Trailer Pump.

Attention has been directed recently to the necessity for providing pumps of high capacity which shall be capable of clearing rapidly accumulations of water from manholes and joint boxes and which shall also be capable of rapid transportation to the scene of operations. The present type of motor pump on 4-wheeled trolley satisfies these requirements but poorly, much time being lost in an emergency in waiting for a gang to arrive to load the pump on to a lorry, and in unloading it to free the lorry on arrival.

An attempt to satisfy these two conditions was made with the experimental introduction of a centrifugal pump,[1] mounted on a light base, the whole being light enough to be lifted by two men. Centrifugal pumps have in the past been found unsatisfactory for sump and manhole drainage due to loss of priming, and entry of grit, but there is reason to believe that these troubles have been overcome in the particular pump of this type at present on trial.

The latest attempt to meet the conditions has taken a different form, and a 4″ diaphragm pump driven by enclosed worm gear from a 2 H.P. Petter air-cooled petrol engine is employed. A diaphragm pump was selected as it is simple and foolproof and is the most suitable type for dealing with sump drainage without risk of stoppage by intrusion of grit. It is capable of delivering 4,200 gallons per hour at 20 ft. suction head and 5,600 gallons per hour at 15 ft. head.

The pump, gear, and engine are mounted on a common bedplate of substantial dimensions and this is bolted to longitudinal bearers on a "Gibson" trailer, Figs. 3 and 4. The trailer is of the type employed for mounting the handcarts, and is exactly as described above except that it is of standard dimensions (5′ 6″ × 3′ 6″) and has special leather-lined brackets to carry two lengths of suction hose (25 ft. total), and one (10 ft.) length of delivery hose. All hoses are 4″ diameter and are of the wire-bound rubber type, the longer length of suction hose being fitted with foot valve and strainer.

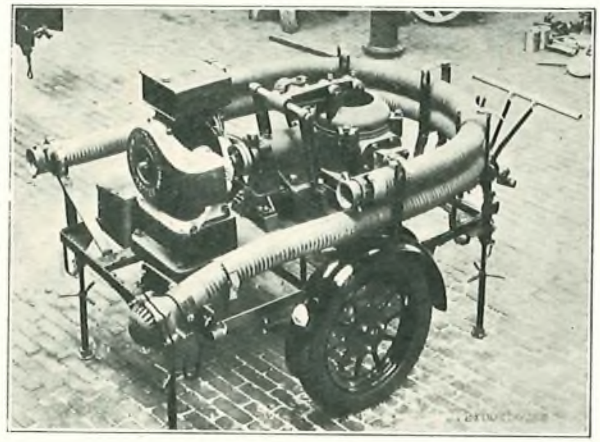


FIG. 3.—TRAILER PUMP.

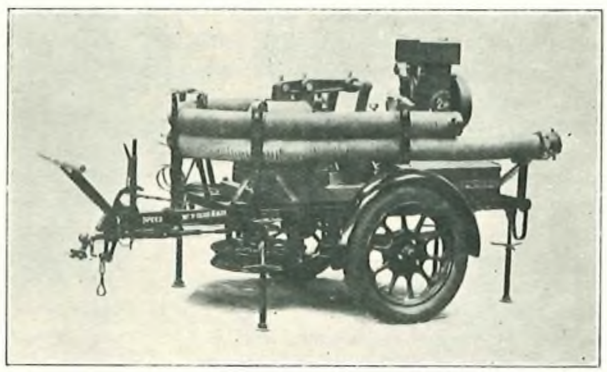


FIG. 4.—SIDE VIEW OF TRAILER PUMP.

With the ball and socket type of towing hitch employed, a small downward load on the ball portion is desirable, but this must be kept as small as possible to ensure easy handling when the trailer is being manœuvred from the handle. As a com-

[1] *P.O.E.E. Journal*, Jan., 1933.

promise a downward load of 20 lb. was agreed, and the position of the pump bedplate was adjusted to give this figure.

The trailer chassis is equipped at each corner with a screw-type jack which can be swung back under the chassis members and locked in position for travelling. With the weight taken by these jacks, the set is extremely steady and needs no attention when the pump engine is running.

As this equipment carries its own spanners, couplings, hoses, etc., and has a legal maximum trailing speed of 16 m.p.h., it is an extremely handy mobile unit and is likely to prove of particular value for cable breakdowns. In such cases the first essential is to get a pump working as quickly as possible to clear manholes and as soon as the pump has been brought to the scene of operations it can be set to carry out this work whilst the vehicle is released to pick up stores and equipment of other members of the gang if necessary and possibly also to trail out the gang's handcart.

There is therefore with these trailers the probability of considerable increase in efficiency in the use of existing motor vehicles and experience with them will show whether it is practicable and economical for other mechanical aids, *e.g.*, winches, desiccators, to be provided in trailer form, or whether the self-mobile type of unit is more advantageous.

Privacy Systems for Radio Telephony

A. J. Gill, B.Sc., M.I.E.E., M.I.R.E.

The use of radio telephony has created a demand for systems whereby the speech transmitted over the radio link is modified in a manner such as to render its interpretation by an unauthorized listener extremely difficult and expensive.

While one would hesitate to claim that a system impregnable to unauthorized decipherment could be devised it is certainly possible to devise systems sufficiently complex that deciphering would be so tedious and require such elaborate and expensive equipment that for all practical purposes the system could be regarded as secret.

Overseas radio telephone services operated by the Post Office are provided with privacy equipment on all channels where the necessary deciphering equipment is provided at the distant end. Systems suitable for commercial services must meet certain requirements which need not apply in the case of radio telephony links not connected to the public telephone network. In the first case the talkers are for the most part infrequent users of the radio circuit and it is essential that the use of privacy working shall not introduce strange or abnormal characteristics in the channel which require getting used to; secondly, the system of privacy should not introduce any delay in transmission since the radio channel is frequently extended by long wire circuits at each end which means that the circuit is working near the limit of transmission time. If the time of transmission exceeds about ½ sec., it means that 1 second must elapse after one speaker has finished talking before he can receive any reply. If both speakers start talking again in this interval neither is aware of the fact that the other is talking since each speaker blocks his receiving path so that talkers inexperienced with the equipment are continually locking the circuit, thus wasting time. The proportion of time lost by this locking up of the circuit increases very rapidly with increase in transmission time over the circuit.

The maximum total transmission time which can be tolerated on a public telephone circuit has not been authoritatively laid down. The limit for good commercial circuits is probably of the order of ½ second. In many cases of long distance telephony in the future the transmission time over the actual circuits will probably approach this limiting value so that little or no additional delay, introduced by a privacy system, can be tolerated.

In the case of a radio channel not used for public service the same talkers would be continually using the circuit and would soon become familiar with its characteristics.

It may be of interest to describe a few of the systems which have been proposed for the purpose of effecting privacy or which have been proposed for other reasons, but possess a degree of privacy.

The systems can be divided primarily into two classes, viz. :—

(1) Systems in which the privacy is effected in the audio frequencies and which can be utilised for line telephony.

(2) Systems which depend on radio frequency characteristics.

Equipment for systems (2) must be installed at the radio transmitting and receiving stations, while equipment for systems (1) can be installed at a central position connected to the transmitting and receiving stations by land lines.

Class (1) systems can be subdivided at two groups as follows :—

1.1. Systems which do not introduce delay.

1.2. Systems which introduce delay.

Systems of Class 1.1 and 2 are suitable for all kinds of services, while class 1.2 systems are only suitable for services not connected to the public telephone network if the delay introduced is appreciable.

Systems may be compounded of two or more of the same or different classes, but if such compounded systems include examples of (1.2) which introduce appreciable delay they become unsuitable for commercial services.

Class 1.1 Systems.

1.11. *Switched channel system.*

This is probably the simplest privacy system which can be devised. If we have a number of channels or circuits between two points, as for example in a telephone cable, each channel carrying a separate conversation then by means of synchronous switching at each end it would be possible to switch a conversation from one channel to another at definite intervals. If these intervals were short a person illicitly listening on one channel would hear only a few syllables of many different conversations. It would be possible to decipher the conversations by recording all the channels on say dictaphone or gramophone records and then sorting out the conversations afterwards, but this would be sufficiently difficult to discourage all but the most determined eavesdropper.

In order that such a system may operate successfully four requirements must be fulfilled, viz. :—

(*a*) There must be a plurality of channels available (say three or four) having similar transmission characteristics.

(*b*) The switching must be practically instantaneous and synchronous at each end.

(*c*) The switching operation must be practically silent and not introduce clicking noises in the circuit.

(*d*) The sequence of switching should change.

Regarding (*a*) this requirement could be readily fulfilled on line telephony, but in only one instance at the present time on radio telephony. On the Trans-Atlantic telephone service there are four channels, three short wave and one long wave. The characteristics of the short wave channels are liable to vary considerably from minute to minute and throughout the day so that it would be difficult to apply this system.

Regarding (*b*) it would be possible to ensure precise synchronism either by the use of a pilot channel or by the use of controlled oscillators at each end. Both these methods are in successful use for picture transmission.

Requirement (*c*) could be fulfilled by the use of suitable circuits. It is being done at present on voice-operated devices in use for radio telephony.

With regard to (*d*) it would be possible to devise some non-recurrent method of switching so that the sequence of changes was repeated only after a long interval.

Generally speaking, the system is not suitable for radio telephony, but would be suitable for line telephony where a number of conversations were being carried simultaneously. In order to safeguard the system at times when only one or two conversations were being carried it would be necessary to occupy the idle channels with conversation or noise from records or some other source.

1.12. *Masking speech by other noises.*

It has often been proposed to achieve privacy in telephony by adding sounds to the speech at the sending end of the circuit and filtering out these added sounds at the receiving end of the circuit.

Fortunately for the art and unfortunately for this proposal the amount of interfering noise which can be tolerated before a conversation becomes unintelligible is very great. When the interference is in the form of random noises (such as atmospherics) speech does not become hopelessly unintelligible until the energy of the noise exceeds the energy of the speech. On the other hand, when the interference is in the form of one or more tones of definite frequencies the energy of the interfering noise can be several thousand times the energy of the speech before a serious lowering of intelligibility occurs. This can be observed when a person is singing to an orchestral accompaniment. The accompaniment may be much louder than the singer's voice, yet the words of the song are readily identified.

Table I. shows the percentage word intelligibility when single frequency tones at various levels are added to speech at reference volume (which is approximately 1 milliwatt). It will be noticed that even when the added tone is 41 decibles above speech (*i.e.*, 12,500 times the energy of speech) the intelligibility is not less than 30%.

TABLE I.

Frequency of Added Tone. Cycles per sec.	Level of added time in decibels above 1 milliwatt with speech at reference volume.				
	9 db.	19 db.	27 db.	35 db.	41 db.
800	91.2	85.6	71.2	48.8	36.8
1000	94.2	82.7	75.7	52	30.0
1100	96.0	87.2	82.4	58	36.0
1500	93.2	84.8	82.4	69	42.8
2000	97.7	94.2	93.8	79.3	48.0

In order that noise artificially injected may subsequently be filtered out it is essential that this noise be confined to definite frequencies to suit the filters. This makes the system impracticable for radio telephony as the power of the transmitter would have to be increased by about one hundred thousand times in order to handle the noise.

The same difficulty would also arise in applying the system to loaded and repeatered land line circuits.

For these reasons this proposal can be ruled out as impracticable.

1.13. *Frequency transposing Systems.*

We now come to a group of systems for privacy in which a transposition sufficient to produce unintelligibility is made in the frequencies of the original speech currents.

The systems are largely the outcome of the development of single sideband suppressed carrier system of the Western Electric Company.

It is well known that when the amplitude of an alternating current of a given frequency is varied sinusoidally at another frequency the modulated current is identically equivalent to the sum of three alternating currents of different frequencies but of constant amplitude.

The frequencies of the three components are (1) the original frequency, (2) the original frequency plus the modulating frequency and (3) the original frequency minus the modulating frequency. The first is known as the carrier component while the others are known as the upper and lower sideband frequencies respectively.

When, instead of modulating the carrier frequency by a single frequency, we modulate it by a large number of different frequencies simultaneously, such as speech currents, we obtain in the output the carrier together with two bands of frequencies on each side of the carrier, each band equal in width to the original modulating band.

In Fig. 1(*a*), A represents a spectrum of speech current say from 0 to 5000 cycles per second which is used to modulate a carrier B, while C and D represent the two sidebands produced in the output of the modulator. The positions of points on the sidebands can readily be determined as follows: If f_c is the frequency of the carrier B and f_x is the frequency of any point on the original modulating band then $f_c + f_x$ and $f_c - f_x$ will be the two points in the upper and lower sidebands respectively, corresponding to the original frequency f_x.

By filters or other means, it is possible to isolate one of these sidebands, say C. If this sideband is then used to modulate another carrier frequency, say E, Fig. 1(*b*), we obtain two new sidebands, F and G. It might perhaps be more correct to represent F in the position F1 to the left of zero frequency, as this gives a better picture of what really happens and also depicts the two sidebands equally spaced from the carrier. If we had isolated the other sideband D and modulated it by another frequency H, we should have obtained two other sidebands J and K, Fig. 1(*c*).

In each case it will be noticed that the new lower sideband has appeared in the same range of frequencies as the original speech but has been reversed or inverted, while the new upper sideband is at a much higher frequency, inverted in one case and erect in the other. If in the case of Fig. 1(*b*) the new carrier instead of being placed close to the sideband had been put still lower (Fig. 1(*d*)) the new lower sideband F1 would still have been inverted but would have been displaced to a higher range, while the new upper sideband G1 would have been brought to a lower range.

If again E had been placed on the upper side of C but removed from it the resulting sidebands would have been as shown in Fig. 1(*e*)—the lower sideband F2 erect but displaced from zero frequency and the upper sideband inverted.

In all these examples it will be observed that if the

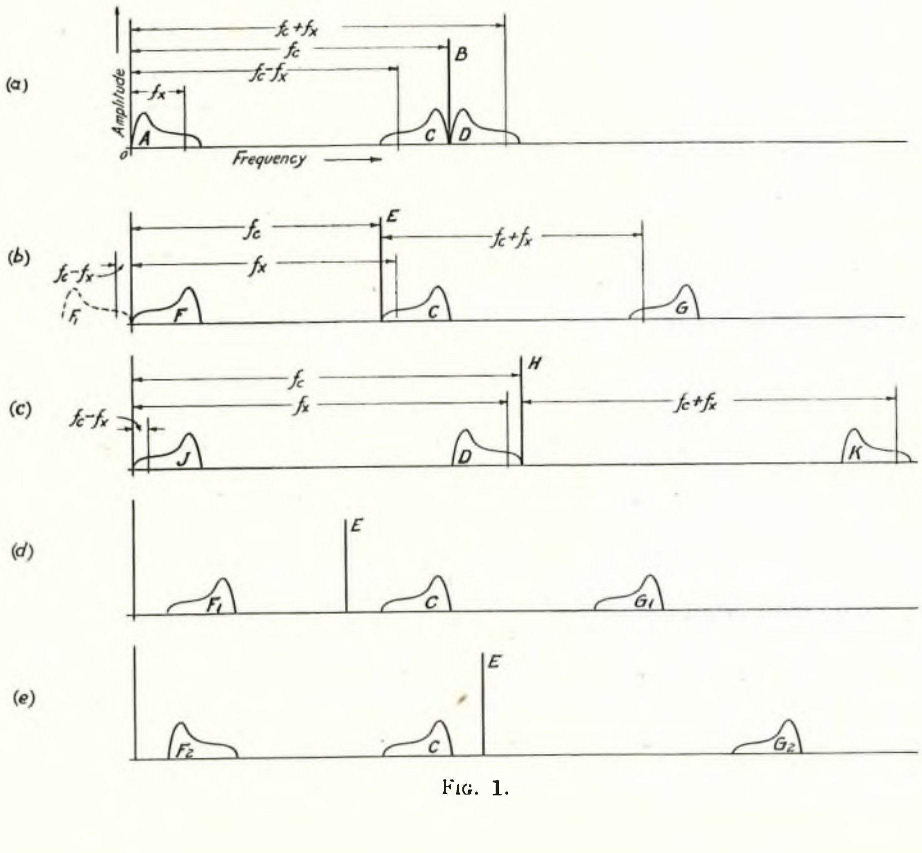


FIG. 1.

carrier is higher in frequency than the modulating band (as in 1*a*, 1*c* and 1*e*) the upper sideband is erect while the lower sideband is inverted with re-respect to the modulating band. If, on the other hand, the carrier is lower in frequency than the modulating band (as in 1*b* and 1*d*), then both side-bands are erect as compared with the modulating band.

It will thus be seen that by two modulating processes it is possible by appropriate choice of carrier frequencies to take a speech band and invert it in its original range or place it inverted or erect in any position of the frequency spectrum.

A method of depicting these changes is shown in Fig. **2**(*a*), which shows the change in frequency in the lower sideband F and J, produced by the processes Fig. **1**(*b*) and Fig. **1**(*c*) respectively.

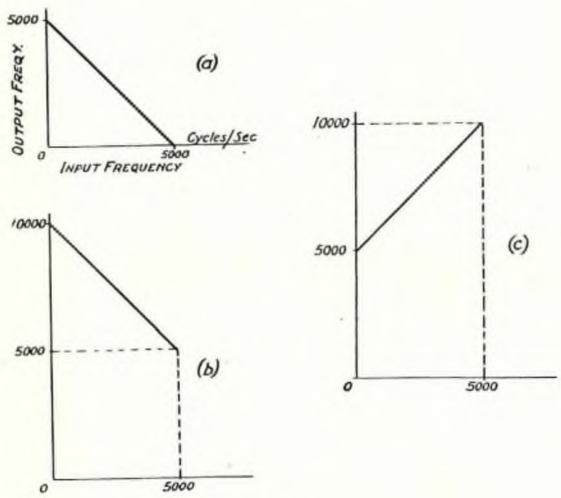


Fig. 2.

Fig. **2**(*b*) shows the frequency change in the lower sideband F1 in Fig. **1**(*d*) while Fig. **2**(*c*) shows the frequency in the lower sideband F2 of Fig. **1**(*e*).

The changes shown in Fig. **2**(*a*), (*b*) and (*c*) produces in each case a result which is unintelligible. Processes Fig. **2**(*b*) and Fig. **2**(*c*) can be used to provide a second channel on line telephony. The output of either of these processes can be used to modulate a radio transmitter and the transmission when picked up by an ordinary radio receiver is unintelligible.

1.131. *Plain Inversion.* (Brit. Patent 179016).

In this system the speech frequencies are inverted as in Fig. **2**(*a*). In the diagram the inversion is depicted over a range of 0 to 5000 cycles per second. The range used in actual practice will depend on the band of frequencies to be transmitted. In this connexion it should be pointed out that when inverted speech is transmitted over land lines the effect of " cut-off " on the land lines is to remove the upper ranges of inverted speech which means that the lower ranges are missing after re-inversion. As stated above, the result is unintelligible and a similar operation has to be applied at the distant terminal to re-invert the speech. The processes are complementary so that the same equipment can be used for coding and deciphering if suitable arrangements are made at the terminal point for the inverter equipment to be connected to the transmitting or receiving line as required by means of voice operated switches.

Plain inversion has one disadvantage for radio telephony, namely, that if an oscillating receiver is used it is possible by careful adjustment to set the receiver on the outer edge of one of the inverted sidebands and obtain a certain degree of intelligibility. This is prevented if the carrier frequency of the transmitter is given a slight wobble or periodic change in frequency (Brit. Pat. 215164).

There is another and probably better method of impeding unauthorized reception, and that is, to give a slight periodic variation to one of the carriers used in the inverting equipment. Referring to Fig. **3**(*a*),

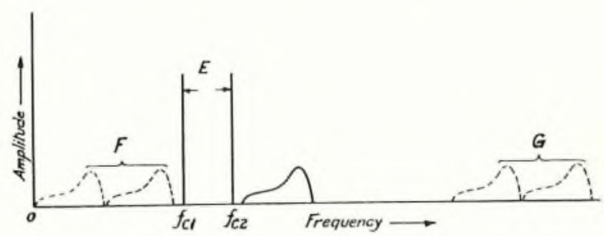


Fig. 3.

which is a modification of Fig. **1**(*b*), if the carrier E (which is used to produce the inverted band F), instead of remaining at a fixed frequency, is given a slow periodic variation of frequency between the limits fc1 and fc2 the sidebands will move backwards and forwards in frequency in unison with the carrier as indicated by the dotted outlines at F and G. The lower inverted sideband F can then be used to modulate the transmitter. On reception it will be necessary to vary one of the re-inverting carriers in synchronism and by the same amount as in the inverter.

1.132. *Spread Sideband system.*

In this system the transmitter is modulated by speech which has undergone transformations represented by F1 and F2 in Figs. **1**(*d*) and **1**(*e*) respectively.

The process of coding and decoding is not complementary, so that two items of equipment are necessary at each terminal, one for transmitting and one for receiving.

This system also suffers the defect of being deciphered by a carefully adjusted oscillatory receiver. The remedy of wobbling the radio frequency carrier can, however, also be used in this case or, alternatively, the scheme of wobbling the inverting and re-inverting carriers synchronously can be applied.

1.133. *Split band systems.* (Scrambling.)

We have seen how the whole speech band can be taken and placed either erect or inverted in another part of the frequency spectrum. Providing we have filters sufficiently sharp this can also be done with a portion of the speech band. In Fig. **4**(*a*) if we modulate the carrier E with the speech band A we obtain the two sidebands B and C. Suppose we now have a band-pass filter which will only pass the band f_1 to f_2 we can isolate—erect—that portion of the sideband corresponding to the portion of the speech band marked between the limits f_x and f_y. Alternatively, by setting the carrier E at a higher frequency and using the same filter we can isolate—inverted—the portion of the sideband corresponding to the portion f_x to f_y of the speech band, Fig. **4**(*b*).

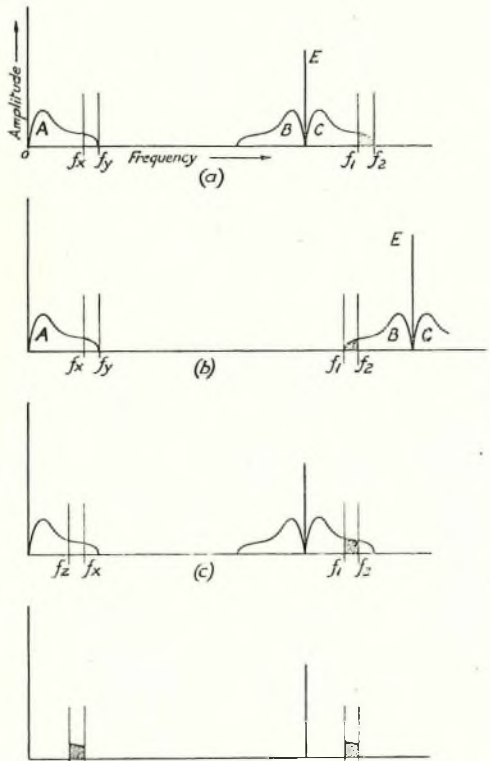


Fig. **4**.

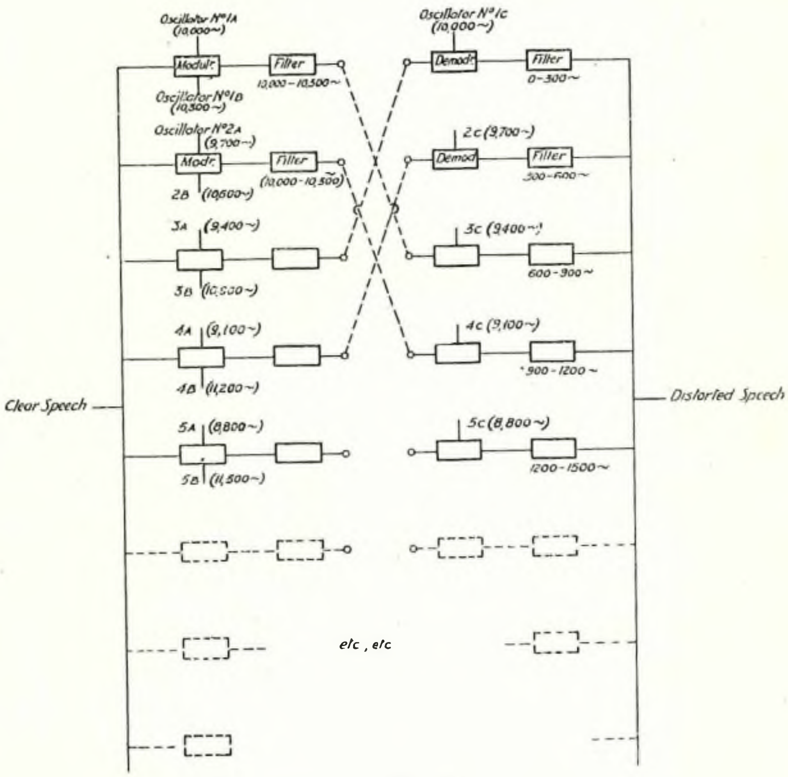


Fig. **5**.

equipment to deal with a speech band of 0 to 3000 cycles and suppose a pass band of 10,000 to 10,300 is selected. Then the first modulator will take a portion of the sideband corresponding to 0-300 cycles in the speech band to the frequency 10,000 to 10,300. If oscillator 1A is used the band will be erect and if oscillator 1B is used the band will be inverted; the first demodulator with its oscillator 1C will bring this sideband portion down to speech frequency 0-300 cycles. As the outputs from all the modulators and the inputs to all the demodulators are comprised within the same band of frequencies the output from any modulator can be connected to the input of any demodulator. For example, if the output of No. 1 modulator is connected to the input of No. 3 demodulator the portion of the original speech

In a similar way we can bring other portions of the speech band (either erect or inverted) to the same sideband frequencies f_1 to f_2 and isolate them by a filter, Fig. **4**(*c*). Thus with sufficient equipment the whole of the speech band can be split into a number of narrow sections a few hundred cycles wide either erect or inverted and transposed to a common frequency band f_1 and f_2.

By a reverse process of demodulation each of the portions of sideband so isolated can be brought back to its appropriate position in the speech band. Fig. **4**(*d*). The arrangement is shown schematically in Fig. **5**. Suppose, for example, we have ten sets of which lay between 0 and 300 cycles would appear in the output of the demodulator at 600 to 900 cycles.

If on the other hand oscillator No. 1B had been used inversion would have occurred and zero frequency in the original speech would be 900 cycles and 300 cycles in the original speech would be 600 cycles. In Fig. **5** possible cross connexions between the first four groups are shown in dotted lines. Assuming oscillators 1B, 2A, 3B and 4A are used the resulting frequency changes are shown in Fig. **6**.

It is impossible in the scope of this article to go into details of this system, but it can be seen from the foregoing that the combinations possible are

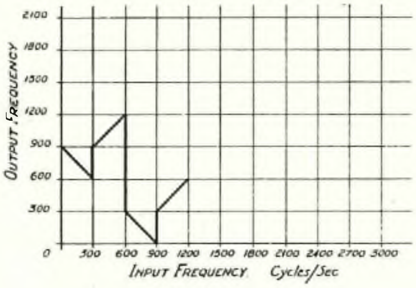


FIG. 6.

very numerous if a sufficient number of bands are chosen. Moreover if a system of synchronous switching is adopted whereby the combinations are changed simultaneously at each end illicit detection becomes still more difficult.

1.2. *Systems introducing delay.*

The principle involved was first disclosed by Tigerstedt (Brit. Pat. 133704). He proposed to record the speech on a steel wire and to pick up the speech from the wire in an order different from that in which it was recorded. A similar arrangement would be used at the receiving end whereby the original order of the sounds would be restored. The scheme is simply illustrated by Fig. 7. For example,

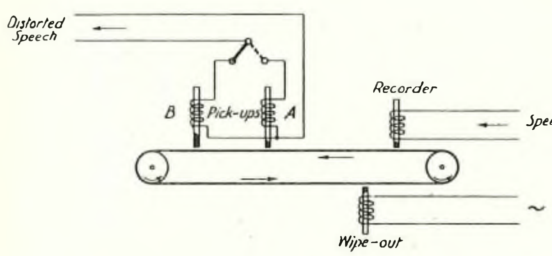


FIG. 7.

suppose the sound " London " was recorded on the tape and further suppose that when the tape carrying the record reached pick-up A the switch was connected to B until the first syllable passed A the sound picked up by A would be the second syllable " don " the switch would then move to A and the first syllable " lon " would be recorded. The sound sent to line would then be " don " " lon."

An electrical equivalent to this scheme can be devised as shown in Fig. 8, where delay circuits are used in conjunction with synchronously operated switches at each end. The overall delay in the circuit is the same with the switches in either position and the period of the cycle of switching must correspond to the delay. Thus if the delay circuit introduced 1 second delay the switches would all go to the upper position for $\frac{1}{2}$ second, then to the lower position for $\frac{1}{2}$ sec. and again then back to the upper position and so on. By this time the speech put into the delay circuit would be reappearing at the outlet.

Speech would appear on the line or radio link between the two stations transposed by $\frac{1}{2}$ second intervals while the total delay would be 1 second.

The delay circuits could be electrical networks or high quality telephone transmitters and microphones connected by a suitable length of tubing containing air or some other elastic fluid.

1.21. *Systems introducing variable delay.*

Modifications of the above system have been proposed by various inventors. Carr (Brit. Pat. No. 287673) describes a system in which the recording electromagnets or pick-ups move. By this means the frequency of the sounds are changed and if the pick-up moves faster than the tape the order of the speech is reversed.

Exceedingly complex systems can be built up in this way, and while they may be suitable for special purposes they are unsuitable for commercial telephony if the additional transmission time introduced by the device is appreciable.

2. *Systems which depend on radio frequency characteristics.*

Proposals have been made from time to time for signalling by change of phase in the carrier wave instead of by change in amplitude. Other proposals have been put forward for systems in which modulation changes the frequency of the carrier instead of its amplitude. Claims have sometimes been put forward that these systems possess some elements of secrecy, but as far as is known it has never been established either by mathematical reasoning or by experimental trial that systems operating in these principles do not contain components sufficient to provide a measure of intelligibility when the emissions are picked up by an ordinary receiver.

The chief obstacle to the use of such systems is that the emissions require a larger frequency band for the transmission of a given audio frequency band than systems working on amplitude modulation.

2.1. *Periodic Variation of Carrier Frequency.*

It has often been proposed to vary the frequency of the emitted carrier over a wide range and to vary synchronously the tuning of the receiving station. The congestion of the æther renders this scheme impracticable owing to the disturbance and interference which would be caused to other services.

The scheme, however, must not be confused with the slight wobble or

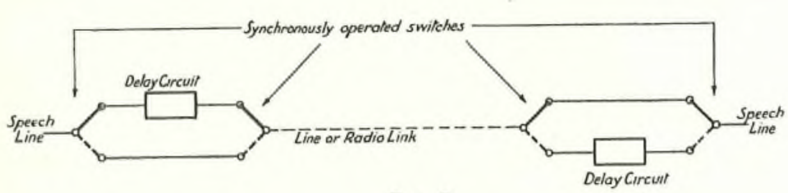


FIG. 8.

variation which is imparted to the carrier in some cases to augment the efficacy of inversion (1.131); this wobble of itself is quite insufficient to provide secrecy or to cause disturbance to other services.

2.1. *Single sideband systems.*

Single sideband transmission with suppressed carrier uses an emission from the transmitter which is unintelligible when picked up on an ordinary receiving set. This unintelligibility is due to the fact that the carrier frequency is missing so that the only audio frequency tones delivered by the receiver are intermodulation products between the various high frequency sideband components. The emission is equivalent to the band marked (G) in Fig. 1(*b*).

In order to receive intelligible speech it is necessary to simulate the carrier frequency at the receiver by means of a locally generated frequency. This local frequency need not be of exactly the same frequency and phase as the original carrier but for good intelligibility it must be within about $\pm$ 20 cycles of that frequency. It thus becomes a matter of some little difficulty accurately to inject this local frequency unless some agreed procedure is adopted between the transmitting and receiving stations and unless a stable frequency type of oscillator is used the adjustment when made will not be maintained.

The difficulty becomes greater as the frequency used increases and while it is possible to adjust an oscillator at the receiving station by trial and error within the necessary proximity when the frequency used is about 60,000 cycles per second it would be practically impossible to do so on short waves when the frequency is often as much as 20,000,000 cycles per second.

On the other hand, the application of the single sideband suppressed carrier system to short waves demands a frequency constancy in the equipment at the transmitting and receiving stations greater than is practicable in present day commercial plant and, although the necessary degree of frequency constancy is at present attainable in laboratory equipment, some time will elapse before this system is applied to short wave services. A system has been successfully demonstrated for short waves using a single sideband without carrier in which a pilot frequency provided by the transmitter is utilized in the receiver to control the frequency of the local oscillator. This system does not demand an abnormally high frequency constancy in the transmitting and receiving equipment; the equipment used in each case, however, would be too complex and expensive for a casual eavesdropper to provide. It should be made clear, however, that the reasons for employing, or desiring to employ, single sideband suppressed carrier working are not primarily those of privacy. Its chief recommendations are economy of power and reduction of frequency band necessary on long waves and economy of power and reduction of selective fading on short waves.

2.2. *Quiescent Carrier Systems.*

Quiescent carrier working is particularly applicable to short wave services and implies the suppression of the carrier at all times except when the transmitter is being modulated. The emission of the carrier is controlled by voice operated thermionic switches and ceases immediately the local speaker stops talking. This system again by itself has very little value for purposes of privacy but it can be of great utility in combination with other systems. The quiescent carrier system has other important advantages, particularly that of economy, since the consumption of power is reduced to about 10 or 12 per cent compared with the ordinary continuous carrier system as used for broadcasting; also, since the transmitter is not radiating during reception, it facilitates locating a transmitter close to its complementary receiver, such as is necessary on board ship.

The use of suppressed carrier or quiescent carrier can add considerably to the privacy value of other systems, such as plain inversion (1.131) or spread sideband (1.132), as owing to the shortness of the periods during which modulation appears an eavesdropper would have considerable difficulty in adjusting his apparatus, and the absence of the carrier would remove any indication of the presence of a radio channel during periods of quiescence.

Conclusion.

In addition to the use of special devices of the types mentioned, other factors may contribute to impede unauthorized interception of services.

The actual signals used for commercial services at the point of reception are at times infinitely smaller than those used for broadcasting services, and only by the use of highly sensitive receivers located at noise-free localities and fed from directive antenna systems can such services be maintained during the less favourable periods of transmission conditions. The lower limit of signal strength for a broadcasting service is usually regarded as somewhere in the region of about 1,000 microvolts per metre, whereas a first class commercial service is often maintained with a signal of less than 0.5 microvolts per metre, *i.e.*, a difference of 66 decibels. Then again the use of short waves imposes limitations on unauthorized reception because of skip distance effects and also because of the possible unsuitability of the waves for directions and distances in other than the chosen route. The use of directivity at the transmitter assists signals along the desired path at the expense of radiation in other direction and thus adds its toll to the difficulties of reception in directions other than that of the actual beam.

In many cases unauthorized reception would be limited at most to one side of a conversation, this, taken in conjunction with weak signals, fading and the use of privacy equipment, makes any attempt at organized interception a fairly hopeless proposition.

Notes and Comments

Dr. H. De Forest Arnold

HAROLD DE FOREST ARNOLD, Director of Research of Bell Telephone Laboratories, died early in the morning of July 10th, of a heart attack. Dr. Arnold was born in Woodstock, Conn., on September 3rd, 1883, and received his undergraduate training at Wesleyan University (Conn.). After further graduate work at the University of Chicago, under Professor R. A. Millikan, and a year as a professor at Mt. Allison University, he received the degree of Doctor of Philosophy from Chicago in 1911. Then entering the Research Laboratories of the Bell System, he was one of the scientists who laid the foundation for what is now Bell Telephone Laboratories, Inc. His contributions to knowledge have been in the field of telephone transmission, thermionics, and magnetics. In the field of thermionics he was one of the earliest scientific workers and was the first to appreciate the necessity for a high vacuum in the three-element thermionic valve. Other contributions to this art were the development and application of methods for obtaining such a vacuum, recognition of the existence and the importance of the space charge effect of electrons in such a device and the calculation of the magnitude of this effect and methods for its adaptation to commercial purposes. He developed designs for valves and methods for their manufacture, so that they could be made to meet the telephonic requirements of reliability and ease of maintenance This work included the development, under his immediate direction and at his suggestion, of an oxide-coated filament as a source of electrons within the valve. He had charge of the adaptation of valves to the telephonic problem of long-distance wire telephony and also of radio telephony. In recognition of these achievements, Dr. Arnold was awarded the John Scott Medal in 1928.

The stimulating guidance and personal contributions of Dr. Arnold were also responsible for the development in Bell Telephone Laboratories of the magnetic alloys, permalloy and perminvar. The first of these has an exceptionally high susceptibility to magnetism, many times that of the various materials previously available. In the form of a continuously-applied loading to submarine telegraph cables, it has increased their message-carrying capacity more than five-fold; whilst its application to magnetic structures such as telephone receivers and transformers has been of great value in the undistorted transmission of sound. The alloy, perminvar, has the additional characteristic of being but little affected by superposed steady magnetizing forces so that it finds an important field of application in the cores of loading coils whose windings carry direct currents as well as the alternating currents of telephony.

As the research activities of the Bell System broadened, his responsibilities were likewise broadened in scope with corresponding increase in staff for whose work he has been responsible. Under his efficient direction, not to mention his very definite contribution of ideas, fundamental research work upon many phases of the communication art has been carried on. These have notably advanced the whole telephone art, both wire and radio; they have made available new methods in land wire telegraphy; in submarine cable telegraphy they have furnished a new type of cable with appropriately modified methods of operation; they have given new methods of recording sounds, making possible improved phonograph records and making practical the so-called talking movie; and finally, not to extend the statement further, this work finds more or less direct application to the problem of those with impaired hearing.

Dr. Arnold was a member of Phi Beta Kappa, Sigma Xi, and Gamma Alpha Fraternities, and of the Franklin Institute, the American Chemical Society, and the American Association for the Advancement of Science. He was a Fellow of the American Institute of Electrical Engineers, of the American Physical Society, and of the Acoustical Society of America; a member of the last-named society's Executive Council and its representative on the Governing Board of the American Institute of Physics.

Dr. Arnold is survived by his widow, Mrs. Leila Beeman Arnold, and two daughters, Mrs. Ludwig G. Browman and Mrs. M. R. White, both of Chicago.

C. D. Crommelin

The news of the death of Mr. C. D. Crommelin, owing to an accident in the Lake District, was a shock to all who knew him. Mr. Crommelin, who was in his 34th year, was the son of Dr. A. C. Crommelin, the distinguished astronomer. At Trinity Hall, Cambridge, he had a successful career, gaining a second class mathematical tripos. Subsequently he spent seven years with the Western Electric Co. (now Messrs. Standard Telephones and Cables, Ltd.) and one and a half years with Messrs. Siemens Bros. & Co., Ltd. In both firms, he was engaged on work of a special nature, requiring mathematical knowledge of a high order. Although he had been engaged on research entailing the mathematical theory of acoustic transformers and similar matters, he is perhaps best known in the Post Office for his work on the traffic capacity of switches in Automatic Telephony. On this subject, his works include an article which appeared in Vol. 25 (page 41) of this Journal and a further article which will be published in the next issue, whilst he had a book in preparation on the same subject at the time of his death.

Behind his somewhat retiring and unassuming disposition, Mr. Crommelin concealed a very friendly and determined personality, as well as an intellect of no mean order. His death at such an early age is a loss not only to his personal friends, but also to the Telephone industry at large.

Royal Signals Quarterly Journal

For some time past there has been a feeling that there should be a Journal dealing with subjects of a technical and military nature connected with the Royal Corps of Signals. The *Royal Signals Quarterly* has now made its appearance to fill this long-felt want, and the first number was published in July last. The contents include an article by R. J. Halsey, B.Sc., on the Simplified Carrier System developed by the Post Office Engineering Research Section; an article on the training of Territorial Army Recruits, by Lt.-Col. M. E. Holdsworth; and the first part of an historical account of the Signal Service in the Palestine Campaign, from the pen of Major-General Sir M. G. E. Bowman-Manifold, K.B.E., C.B., C.M.G., D.S.O.

The Journal is excellently produced and we wish the Editorial Committee every success in their venture. Copies of the Journal may be obtained from the Signals Association, 95, Belgrave Road, London, S.W.1, price 2/6 (10/- per annum).

The "Post Office Magazine"

The Postmaster-General has approved a proposal to publish a monthly journal for circulation among the staff of the Post Office. Its objects will be to keep the staff more fully informed of the main activities of the Post Office, and to maintain and further encourage *esprit de corps*, and the sense of a common interest in providing the public with a service of the highest efficiency.

The journal will be known as "The Post Office Magazine." Its price (to members of the staff) will probably be one penny a month.

The magazine will be freely illustrated. A large part of its contents will consist of local news, including suitable items of personal news and records of social activities among the staff: and a Correspondent will be appointed in each Department and District in order to keep the editor in close touch with local developments.

It is hoped to publish the first number in January next. The "Post Office Magazine" is in the nature of an experiment, but the Postmaster-General has every hope that its circulation will be so great as to justify the very low price at which it is to be sold.

Electrical and Radio Publicity Service

Mr. Bernard C. Holding, formerly editor of "The Electrician," and until recently European Director of Publicity for the International Standard Electric Corporation, has now set up in business as an incorporated advertisement consultant, in partnership with Mr. Michael C. W. Thomas, formerly Publicity Manager of Standard Telephones & Cables, Ltd. The new firm is styled the Electrical & Radio Publicity Service, with offices at 7, Southampton Row, W.C.1. (Telephone Holborn 0762).

Inductive Interference from E.H.T. Lines

A letter from Mr. H. J. Joseph in connexion with Mr. Jackman's article, published in the July issue, and the author's reply appear below.

Chemical Laboratory,
Research Section,
Dollis Hill.

The Managing Editor.
Dear Sir,

The publication, in the July (1933) issue of the P.O.E.E.J., of a paper entitled "Inductive Interference from Fault Currents on E.H.T., Power Lines," by Mr. A. J. Jackman, draws attention to the "equivalent earth-plane theory," as a simple basis for interference calculations. Therein, it is stated that Pollaczek's formulæ for the mutual induction M (which involves Bessel functions), may be reduced to a simple algebraic formula (page 102) involving the depth of an "equivalent earth-plane" below the conductors. From his investigations Mr. Jackman concludes (page 102) that, if the depth of the equivalent earth-plane could be arrived at in any particular case, the simple formula would give calculated results of the same practical value as the results of the more complex Pollaczek formulæ, advocated by the C.C.I., in 1929.

The problem suggested by Mr. Jackman is, therefore, to deduce an expression for the depth of the equivalent earth-plane in terms of the conductivity and frequency. This letter contains an analysis of the problem.

The first requirement is to deduce from Maxwell's electromagnetic field equations, the set of partial differential equations, together with their general solutions, that describe the equivalent earth-plane theory. For the purpose of analysis the equivalent earth-plane will be treated as a surface of conductive discontinuity, at a depth d below the surface of the earth, as shown in Fig. 2 (page 100).

Maxwell's equations are applicable to the problem in the form :

$$(1)\ldots\ldots\ldots \quad \left.\begin{aligned} \text{curl } H &= \frac{4\pi}{C}\sigma E \\ \text{curl } E &= -j\frac{\omega}{C} H \end{aligned}\right\}$$

where H and E are the magnetic and electric intensities : σ the conductivity and C the velocity of light. ω is 2π times the frequency and j the $\sqrt{(-1)}$. The permeability and dielectric constant of the earth are both assumed to be unity. The x axis will be taken on the surface of the earth perpendicular to a vertical plane containing the two conductors. The z axis will be taken in the direction of the conductors, whilst the current in the earthed power line will be taken as the real part of I exp ($j\omega t$). Referring to Fig. 2, of Mr. Jackman's paper, let region 1 be the space between the ground line and the equivalent earth-plane and let region 2 be the space containing the " image " below this plane. Let region 1 have a conductivity σ_1 and region 2 a conductivity σ_2. These conditions, together with the fact that in this case, $E_x = E_y = H_z = 0$, enable the set of equations embodied in (1) to be transformed into the form,

$$(2)\ldots\ldots\ldots \quad \frac{\partial^2 E_k}{\partial x_1^{\,2}} + \frac{\partial^2 E_k}{\partial y_1^{\,2}} = jN_l E_k$$

$$(K = 0, 1, 2.)$$
$$(N_l = 0, 1, \sigma_2/\sigma_1)$$

with the surface conditions,

$$(3)\ldots\ldots\ldots \quad \left.\begin{aligned} y_1 = 0;\ E_0 = E_1;\ \frac{\partial E_0}{\partial y_1} &= \frac{\partial E_1}{\partial y_1} \\ y_1 = -d_1;\ E_1 = E_2;\ \frac{\partial E_1}{\partial y_1} &= \frac{\partial E_2}{\partial y_1} \end{aligned}\right\}$$

where x_1 is x/y and y is $C/\sqrt{(4\pi\omega\sigma_1)}$: likewise for y_1 and d_1.

From equations (2) and (3) we obtain by transformation the Bessel solution,

$$(4)\ldots\ldots \quad E_0 = \frac{I}{\pi\sigma_1 x^2}\left\{ 1 - a\sqrt{j\omega}K_1[a\sqrt{j\omega}] + C_m(1 - N_2)e^{-d|K|}I_1\left[\frac{a}{\sqrt{j\omega}}\right]\right\}$$

where a is $\sqrt{(4\pi\sigma_1 x^2)}$; $|K|$ is $\sqrt{(4\pi\sigma_1\omega)}$, and x the separation between the two lines : the Bessel functions are in Watson's notation.

Equations (2), (3) and (4) are the fundamental equations of the equivalent earth-plane theory, and have been deduced from Maxwell's equations (1). Now Maxwell's electromagnetic theory is the fundamental basis of all electrical science. It is the focal point from which all correctly established electrical principles must be derived. Consequently from the above equations a rigorous examination of the equivalent earth-plane theory can be made. For the purpose of analysis the equivalent earth-plane has been treated as a surface of conductive discontinuity, such as $\sigma_2 \rightarrow \sigma_1$ in the limit. From this condition we find that d is given by a null function and cannot be expressed in terms of any of the variables that enter the interference problem. This means that the expression for depth given on page 101, is quite meaningless when viewed from the accepted theory of electromagnetism. It also follows that the formula (page 102) given by Mr. Jackman to replace Pollaczek's formulæ, reduces to zero. The foregoing analysis shows that the equivalent earth-plane theory is wrong in conceptions and principles.

In conclusion it is to be noted that in the limit ($\sigma_2 \rightarrow \sigma_1$) the preceding equations may be transformed into the Pollaczek formulæ : this fact is an illustration of the wisdom of the C.C.I., in recommending the adoption of the Pollaczek formulæ as the fundamental basis for interference calculations.

Yours faithfully,

H. J. Josephs.

Construction Section,
Engineer-in-Chief's Office.

The Managing Editor.

Dear Sir,

The letter from Mr. H. J. Josephs is an important addition to the many mathematical treatments of the problem of inductive interference from earth-fault currents in that it exposes the unsoundness of the elementary earth-plane theory when investigated by mathematical analysis.

Extensive application of this equivalent earth-plane theory to field problems was made by the Californian Railroad Commission in a series of investigations between 1914 and 1918. The theory was elaborated in Technological Reports Nos. 64 and 65 of a voluminous publication which they issued in 1919 [see also Summary (to 1925) of European and American Data on Interference. J.I.E.E. 68, pp. 587-641 (1930)]. In the article in the July issue of the P.O.E.E. Journal, however, the theory was introduced simply to give " an elementary conception . . . . in non-mathematical terms " (page 100) and the methods of calculation subsequently explained were based on Pollaczek's formula in accordance with the recommendations of the C.C.I.

Many engineers will desire to have an easily comprehended picture of the main characteristics of inductive interference apart from a rigorous mathematical treatment. Such an illustration is provided by the equivalent ground plane and image conductor in the manner explained. The curves given on page 101 (which, of course, agree with the formula on page 102) show that this illustration will not lead one very far from the true values in any practical problem. It is thought therefore that the elementary theory might still be used to illustrate the general nature of the problem, although it is not satisfactory to the principles of physics.

The expression for depth on page 101 which Mr. Josephs demonstrates to be insupportable is a deduction from the work of Haberland given in the Summary of Recent Information (1926-1929) by Mr. W. G. Radley in the J.I.E.E. 69, pp. 1117-1148 (1931).

This opportunity must be taken to correct a misprint in the formula on page 102 which should be

$$M = \log h \left[1 + \left(\frac{2D}{S} \right)^2 \right] \text{henries} \times 10^{-4} \text{ per km.}$$

Yours faithfully,
A. J. JACKMAN.

Erratum

On page 143 of the July issue, the titles of Figures 5 and 6 should be transposed.

District Notes

London Engineering District

MILEAGE STATISTICS.

During the three months ended 30th June, 1933, the following changes occurred :—

Telephone Exchange. Net increase in overhead and underground respectively of 580 and 30,594 miles.

Telephone Trunks. Net decrease in overhead, 152 miles. Net increase underground, 1,449 miles.

Telegraphs. Net decrease in overhead, 1,310 miles. Net decrease in underground, 95 miles.

The total single wire mileage at the end of the period under review was :—

Telephone Exchange	3,596,442
Trunks	199,885
Telegraphs	44,378
Spares	157,708
	3,997,078

Gerrard Exchange.—The work of replacing the present manual Gerrard Exchange by an automatic exchange on the same site has called for some unusual arrangements. It is necessary to demolish the present building completely and build a new one. The upper parts of the existing building are occupied by the Gerrard Manual Exchange, the recovery of which will be made possible by the temporary transfer of the subscribers to a second automatic unit in the Whitehall building.

The retention of a main frame on the Gerrard site during the reconstruction of the building is necessary to facilitate the ultimate transfer of the subscribers back to the new automatic exchange. While Gerrard Exchange is working at Whitehall, the lines will be routed *via* this frame.

The ground floor has been reconstructed inside the main walls of the old building, but detached therefrom, and the new main frame erected thereon. To protect the frame from dirt and dust during the demolition of the old building and the erection of the new and from the weather, it has been completely enclosed in a steel structure covered on the outside with corrugated iron and lined on the inside with asbestos sheet.

Trunk Exchange.—A further step in the reconstruction of the London Trunk Exchange was taken on Saturday, August 12th, when a suite of 45 positions was opened in the 3rd floor Annexe (South side) G.P.O. South. This suite is known as Inland Exchange and is designed to deal with traffic from the Provinces to London and elsewhere.

The positions are equipped with cord circuits of the "sleeve control" type as is the case on the other recently-opened Trunk Suites. The multiples are fitted with Visual Idle circuit Indicating Equipment and make provision for Trunk, Toll and Junction circuits. There are also service and other circuit multiples, and many of the circuits are common to other suites in the Trunk Exchange.

The opening on the 12th August was the first stage of the opening of Inland Exchange and the following circuits were brought into use :—

Circuits teed to the Outgoing Junction Multiple on other floors	186
New Outgoing Junctions	161
Trunks transferred from Provincial Exchange	100
Trunks transferred from Third Floor main (old Trunk Suite)	10

Further circuits will be transferred in September, after which the old Trunk Exchange on the Third Floor (Main) will be recovered preparatory to the installation of additional Demand Suites.

Voice Frequency Telegraphs.—A considerable portion of the Voice Frequency Telegraph equipment at the Central Telegraph Office has been completed and brought into service. The circuit arrangement and apparatus are of the latest type and will comprise, ultimately, 33 bays of 6 channels per bay. Up to the present 84 channels of the new system have been completed and made available for service, and of these 60 channels are carrying telegraph traffic to the North of England, Scotland and Northern Ireland. It will be appreciated that as each system of 18 channels utilises an ordinary 4-wire trunk telephone circuit, a considerable saving of physical circuits has been effected .

Panel-mounted Telegraph Equipment.—The installation in the C.T.O. of the Panel Telegraph system is proceeding apace and three-quarters of the instrument room accommodation on the third floor has been modified. Briefly this entails the withdrawal of all auxiliary apparatus from the instrument tables and placing its equivalent on racks in a space under the control of the Testing and Maintenance Staff, leaving on the instrument tables, which are of a new double width type with band conveyor down the centre, the teleprinter and milliampere-meters for indicating the sending and receiving currents. The band conveyors are displacing the low vacuum pneumatic house tubes in the building.

G.P.O. North.—A new electric lift has been fitted in substitution of the old hydraulic lift at the north-east entrance of G.P.O North.

Radiolympia. — At the National Radio Exhibition held at Olympia from August 15th to 24th a stand adjacent to the B.B.C. Theatre was equipped by the Post Office for the exhibition of Radio apparatus, telephone switchboards and instruments, teleprinters and working models illustrating many phases of communication engineering. The resources of the staff of 36 engineering demonstrators ably assisted by ladies from the L.T.S. were fully extended in entertaining the many visitors attracted to the display. The " Heart Beat " exhibit proved to be most popular. An interesting link with the past was the Electrophone table and receivers which may be regarded as the forerunner of broadcasting. The model of a cable manhole containing a section of a cable with the joint open showing the special screened wires used for long distance transmission of music attracted considerable attention. The short lectures on radio interference were well attended, the capacity of the theatre on the stand was fully taxed at every session, and it is estimated that 1000 complete demonstrations were given on the automatic demonstraton set.

FIG. 1.—MECHANICAL TRENCH EXCAVATOR.

Scotland East

A NEW MECHANICAL TRENCH EXCAVATOR FOR LAYING ARMOURED CABLES.

A new form of mechanical trench excavator proposed by the Assistant Superintending Engineer of Scotland East District is illustrated in the accompanying photographs. This machine is specially adapted to excavate trenches for the laying of armoured cables in grass margins or in footway. A special feature of the machine is that it is a side-cutter. The depth of trench relative to the roadway surface therefore remains constant and independent of variations in the height of the margin or footway. Another important feature is that the width of the trench cut is only between 4 and 5 inches—just sufficient to permit of the cable being laid in the trench without difficulty. Filling-in and reinstatement are therefore reduced to a minimum. The cutting of the trench and the forward movement of the vehicle are controlled by the driver, who can vary the rate of travel to suit soil conditions. In suitable grass margin the rate of cutting a trench 2 feet deep relative to the roadway surface is about 100 yards per hour.

The machine shown in the photographs has been designed and constructed by Messrs. W. G. Brown & Sons, 216, Old Shettlestone Road, Glasgow, E.2, to the order of Messrs. Standard Telephones & Cables, Ltd.

FIG. 2.—TRENCH EXCAVATOR IN ACTION.

Northern District

INTRODUCTION OF VOICE FREQUENCY TELEGRAPH WORKING AND THE

RE-ARRANGEMENT OF THE TELEGRAPH INSTRUMENT ROOM AT NEWCASTLE-ON-TYNE.

Two multi-channel voice frequency telegraph equipments have been installed at Newcastle, one of which provides for 18 circuits each to TS and Leeds. The TS equipment was brought into operation on the 24/6/33 and provides for the following circuits :—

6 circuits Newcastle to London.
1 circuit Middlesborough to London.
1 ,, Newcastle to Glasgow.

(This circuit is connected at London to a circuit on the TS-GW V.F. channel.)

One extension to London of the Oslo submarine cable circuit (TSF 79).

The Leeds equipment makes provision for circuits to Leeds, Grimsby, Edinburgh, Aberdeen, Hull, Manchester, Bristol, Cardiff and Bradford (Private Wire Circuit). Facilities for a Middlesborough-Leeds circuit are given also, the extension from Newcastle to Middlesborough being on a D.C. basis. The system was opened for commercial traffic on the 3/6/33.

The modernization of the telegraph instrument room and phonogram room is proceeding rapidly. The new phonogram and telephone-telegram equipment was successfully brought into operation on the 14/8/33, four suites being provided consisting of 20 T.T. positions and 20 phonogram positions. The opening of these suites has brought about the complete abolition of Morse working in the Newcastle telegraph zone. The modifications in the instrument room consisting of the installation of the modern type of panel equipment both for V.F. and D.C. operation, and of conveyor equipment will be complete within two months. The whole of the telephone and telegraph plant in the City of Newcastle will then be brought into line with up-to-date standards.

This work is being carried out under difficult circumstances, involving as it does the shifting of the telegraphs to where the phonograms were previously, the demolition and reconstruction of partitioning walls, together with the shifting of the street tubes to another position.

Only working to a carefully-designed schedule has enabled the work to proceed with the minimum discomfort to the staff.

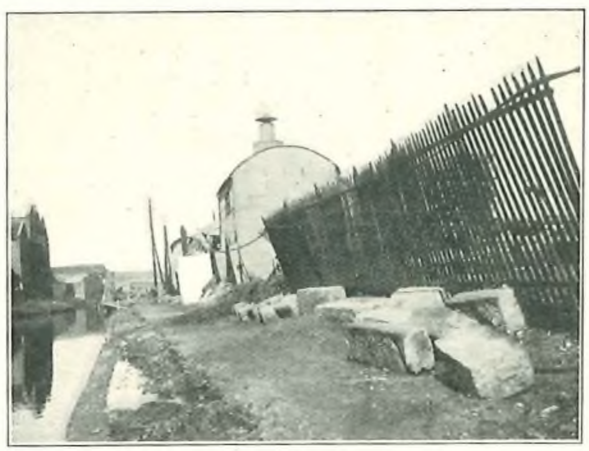
In 1931, automatic telephony came to Newcastle, replacing in many cases magneto exchanges of antiquated design; in February of 1933, Trunk demand service was offered to the public; October, 1933, will see the advent of a greatly improved telegraph service. It is a regrettable fact that the depression in the great industries of Tyneside will not yet allow of full advantage being taken of these improvements in the science of communication.

North Wales

BIRMINGHAM — FIRE DAMAGE TO MAIN LINE ON CANAL.

A destructive fire occurred at the Great Western Railway Sidings at Small Heath, Birmingham, on Sunday, the 7th August. The destruction included nearly 50 loaded goods trucks and wagons, thousands of squares of sawn timber, and sawmills and

tractors. In the immediate vicinity is a huge storage station of the Shell-Mex Company where many thousands of gallons of petrol are stored. The trucks involved in the fire included two storage tanks, also containing thousands of gallons of petrol.



Fortunately the storage station was saved. The fire extended over an area 100 yards long by 50 yards wide, bounded on the one side by the G.W.R. Company's main line to London and on the other by the Birmingham and Warwick Canal. Along the canal line runs one of the Department's heavy trunk routes carrying circuits to the South, including the lines between Birmingham and Daventry used by the B.B.C. Owing to the terrific heat from the fire, two of the poles and the whole of the spare wires were completely burnt up. Due to dangerous conditions, it was not possible to examine the extent of the damage to the route until the following morning (Bank Holiday). It was then apparent that only a temporary restoration could be effected, as the major portion of the towing path had been washed away by the volume of water used to quench the fire.

A breakdown gang was assembled and the route restored by means of interruption cable, the whole of the circuits being made good by 10.0 p.m. the same day.

Thanks are due to the men called upon for cheerfully responding to the call, as many of them had arranged to take their wives and families out for the day. It was only by their co-operation and zeal that speedy clearance of the faults was effected.

The Institution of Post Office Electrical Engineers

Prize Essays. Members of the Institution do not appear to be generally aware that the Prize Essays are held in the Library and are available on request to the Librarian, Alder House. The following list gives the library numbers and titles of the Prize Essays from the inception of the Essay Competition to 1926-27. In requisitioning the essays, members should quote the number and prefix letter as shown in the List.

LIST OF PRIZE ESSAYS HELD IN THE LIBRARY.

1923-24.

E1 New ways of doing old jobs with a view to time saving.—V. Smith.
E2 A Practical Analysis of characteristic faults in an automatic exchange.—F. J. Gibbs.
E3 Cable Balancing.—G. Mower.
E4 The Lineman and the Subscriber.—H. Creed.
E5 U.G. Telegraph and Telephone Cables.—F. W. Belfit.
E6 The merits and de-merits of Modern C.B. subscribers' apparatus.—A. J. Allinson.

1924-25.

E7 Telephone Repeaters in practice.—F. J. Gibbs.
E8 Fault Locating in local underground cables.—S. H. Johnson.
E9 Small matters that need reform in the P.O.E.D.—A. F. Strudwick.
E10 Making a local development survey.—H. S. Twort.
E11 The extension of large Multiples.—H. C. A. Linck.

1925-26.

E12 The Technical Certificates: Why and how to acquire them.—S. H. Johnson.
E13 The Vacuum Tube Amplifier and its application to telephone repeater circuits.—C. A. Maggs.
E14 Secondary Batteries.—A. W. T. Baldwin.
E15 Telephone Development in Rural Districts.—A. E. W. Maslin.
E16 Insulating Materials.—J. E. Wright.

1926-27.

E17 The modern conception of Structure of Matter.—J. S. Dennis.
E18 The Fundamental Principles and Characteristics of the W.E. Telephone Repeaters.—J. Bingham.
E19 Transmission Testing Sets.—F. V. Padgham.
E20 The Arc Transmitter.—R. L. Ryan.
E21 Photo-telegraphy and television.—E. H. Jeynes.
E22 The Secondary Cell.—S. E. Price.
E23 Automatic Exchanges, Non-Director Areas.—N. V. Knight.
E24 Management of oil engines in Telephone Repeater Stations.—J. H. Sundewall.
E25 Local Line Records.—W. F. Goodman.
E26 The changeover of the M.D.F. at Birmingham H.P.O.—W. G. Johnson.

Junior Section Notes

Annual Award of Prizes for Best Papers Read by Members

Twenty-three papers were submitted by Local Centres; as we go to Press we learn that the Judging Committee have completed their examination of the papers and that the result of their adjudication is as follows :—

(1) " Television," by Mr. S. T. Stevens, Birmingham.
(2) " An Introduction to Telephone Repeater Working," by Mr. W. J. Boyd, Belfast.
(3) " Thermionic Valves," by F. W. Allan, Halifax.
(4) " The Auto-Auto Relay-set Routiner," by Mr. R. C. Such, Southend-on-Sea.
(5) " The Preparation of Underground Development Schemes," by Mr. A. C. Benzies, Glasgow.

London Centre

The Annual General Meeting, held on 10th May, 1933, was a fitting conclusion to a very satisfactory year. The Committee's report reminded the membership that a rather ambitious programme of Lectures and Discussions had been undertaken, but it had been fully justified by the high standard of excellence attained in the papers and the ready response of the members in the discussions. The membership was steadily increasing and had reached the substantial total of 478.

Mr. Kraushaar, in moving a vote of thanks to the retiring members of the Committee, specially mentioned the help given by the Chairman (Mr. E. P. Neate, M.I.E.E., Sectional Engineer) in the most difficult period of the Section's history. Mr. Wadeson seconded the motion which was received with acclamation.

The meeting was followed by a paper from Mr. Birch (Senior Section), entitled " The Development of Trunk Working." An excellent paper, delivered with mastery, it had the reception it deserved and concluded the first chapter in the life of the Centre.

Turning to the new year, members have already been privileged to spend an interesting and instructive afternoon at the Baldock Radio Station and our sincere thanks are tendered to those who spent their Saturday afternoon so ably conducting us round.

Further visits are being arranged to the Department's Cable Ship, The British Broadcasting Corporation's Station at Brookmans Park, and Battersea Power Station, while the following topics give promise of a varied and attractive series of meetings: "Commercial Applications of Auto Switching Plant," "The Replacement Section," and "The By-Path System."

Lastly, our membership has now increased above the 500 mark.

Cambridge Centre

The task of preparing programmes for the ensuing Session has been made easy, thanks to the splendid number of offers to read papers received from members. The subjects cover a wide field, and promise to be very interesting and instructive.

Over 20 members travelled by coach to London on the 22nd July, when the afternoon was spent at Faraday House by kind permission of Mr. Gomersall. The visit was most instructive; members found much to interest them, especially in the International Exchange. Much credit is due to the Secretary, Mr. H. Kitteridge, in making all arrangements in connexion with the outing.

Preston Centre

We are confident of a most successful Session and an interesting programme has been promised. The following officers have been elected for the 1933-34 Session:—

Chairman—Mr. J. W. Gould.
Vice-Chairman—Mr. H. Crook.
Committee—Messrs. J. Seed, R. E. Porter, T. Singleton, C. L. Hall (Secretary), W. S. Whitehead (Treasurer).

MEMBERS OF THE PRESTON JUNIOR SECTION CENTRE.

On July 29th, a visit was paid to the North Regional Transmitting Station, at Moorside Edge. The visit was most interesting and instructive, and was thoroughly enjoyed by the members.

Manchester Centre

The effective membership at the close of the Session was 110, but it is hoped to considerably augment this during the coming Session.

The past Session has proved very successful and the programme of six papers and five visits to places of interest has been no mean contribution to the educational facilities open to the staff. It is felt that we are performing a useful work in creating and sustaining in the minds of the younger members a keen desire to keep abreast with the rapid modern developments in the realm of communication engineering.

Present indications augur well for the future progress of the MR Centre.

Gloucester Centre

The high hopes of success entertained at the inauguration of the Gloucester Centre have been fully justified, and the interest, discussions, and attendance have been well maintained throughout the 1932-33 Session.

The complete list of papers for 1933-34 Session are as follows:—

October. "Telephone Repeaters." Mr. R. A. Kibly.
November. "U.G. Cable Construction." Mr. A. J. Hyett.
December. "Armoured Cable laying and jointing." Mr. L. V. S. Middleton.

All members are looking forward to a stimulating and helpful Session.

Blackburn Centre

At the time of writing, the programme for the Session has been arranged as follows:—

Oct. 9, 1933. "Blackburn Police Signalling System. Mr. W. Butcher.
Feb., 1934. "Clerical Procedure." Capt. T. G. Halsall.

Papers have also been promised by Messrs. A. Jackson, G. R. Houldsworth, and A. E. Wilson.

Birmingham Centre

The first Session of the Centre ended on April 5th, 1933, and conclusively proved that the high hopes of success entertained at the first meeting may be claimed as having been fully justified and that those who wish to interest themselves in the activities of the Centre obtain full value for their modest subscription (2/6 per annum).

The Committee have been earnestly engaged during the recess and the programme for the coming Session is as follows:—

1933.
Oct. 10. Exhibition of Films.
Nov. 14. "Power Equipment," by Mr. H. E. Perks.
Dec. 2. Annual Dinner.
" 12. "Teleprinters," by Mr. L. Oliver.

Bolton Centre

If the same enthusiasm which was shown last year is again displayed, a very successful Session is assured. Last year nine papers were read and a slightly reduced programme for next Session is considered advisable, although none will be refused.

The array of talent displayed last year will be evident from a glance at the following list of papers given:—1. Cable balancing; 2. Teleprinters; 3. Induction A/C Motors; 4. Auto Unit No. 4; 5. Internal Combustion Engines; 6. Electron theory; 7. Wayleaves; 8. Radio interferences; 9. Youths-in-training.

Book Reviews

" Theory of Thermionic Vacuum Tubes." By E. L. Chaffee, Ph.D. London, McGraw Hill Book Co. Pp. 652. Price 36/- net.

In spite of the vast amount of literature that has appeared on radio and allied subjects during the last twenty years comparatively little of moment has been produced on thermionic valves. Only one work of first class importance exclusively devoted to the subject has hitherto been published in English, viz., Van der Bijl's " Thermionic Vacuum Tube," which was first issued in 1920.

In view of the great advancement of technique and of knowledge on the subject which has taken place in recent years a new and comprehensive work has long been overdue and can be heartily welcomed.

The present book is by a professor of physics at Harvard University and is based on the author's notes for a course of lectures.

The author has endeavoured to present only the fundamental principles of the subject, avoiding discussion of the multifarious circuits in which the vacuum tube may be used. Owing to the extent of the subject it has only been possible to deal with the theory of the operation of vacuum tubes of low power in the present work, the theory of power amplifiers and oscillators, gas content tubes, rectifiers, etc., will, according to the author's stated intentions, appear in a second volume.

The book can be roughly divided into three main sections—the first dealing with emission, the second with amplifiers, and the third with detectors. A final chapter deals with tetrodes and pentodes. Although the second and third sections contain a large amount of mathematical analysis, the book is not impossible for a non-mathematical reader who is prepared to do a little judicious skipping, as the author has made his text very readable and has been at pains to illustrate his results by numerous graphs, vector diagrams, and pictures of three dimensional space models.

Certain sections, which go into considerable detail and which may, to advantage, be omitted on the first reading of the book, have been starred.

The book is undoubtedly a most comprehensive exposition of the subject and will be recognized as a standard work of reference on the theory of thermionic valves. It is to be hoped that the author's intentions regarding the second work will be carried into effect at an early date. A.J.G.

" Wireless over 30 Years." By R. N. Vyvyan. 256 pages. George Routledge & Sons, Ltd., London. 8/6 net.

The most interesting feature of this book is that portion which is autobiographical, written as it is by an Engineer who has been in close association with Wireless since its first commercial development for communication purposes, and who has been particularly concerned in the part played by the Marconi organization in this country.

A first-hand account of the early difficulties, and successive attempts to establish wireless telegraphy across the Atlantic, from the first transmission of a signal from Poldhu to Newfoundland, in December, 1901, to the opening of a public telegraph wireless service in February, 1908, is given in some detail, with sufficient technical description to give interest to the Engineer as well as the General Reader.

Three chapters are devoted to Wireless in War, on Land, at Sea and in the Air. The part played by Wireless in contributing to Safety of Life at Sea, and its uses for Marine Communications and Aviation are well presented. It is opportune that at a time when the Broadcasting aspect of radio is so much in the forefront, the outstanding importance of its use for these purposes should be emphasized.

An appreciation is given of the British Post Office contribution to Wireless Development and the author's outlook on the future is given in the last three chapters, on " Broadcasting," " Wireless as a Career," and " Research Problems," but it is somewhat surprising that, in a review of this nature, no mention is made of the part played by the Radio Research Board, and the investigations and research it has initiated, leading directly or indirectly to improvements in technique and developments in wireless.

To the young engineer contemplating wireless as a career this book gives an indication of the rewards that may be expected and lays emphasis rather on the scope for creative work and achievement which this profession opens rather than great pecuniary recompense. A.S.A.

" Travelling Waves on Transmission Systems." By L. V. Bewley. Chapman & Hall. 28/- net.

This book has been written for power engineers who have a working knowledge of the methods of the operational calculus. Indeed, such methods appear almost indispensable to the evaluation of the transient effects due to arbitrarily impressed voltage impulses.

In Part I. of the book, the author aims at presenting a generalized fundamental analysis of the characteristics and behaviour of travelling waves. Starting from the well-known ground of the " telegraph equation," reflection at transition points along the line, attenuation and distortion are dealt with. Although the travelling waves principally concerned are those on high tension overhead lines due to lightning discharges, the reading of these chapters should be provocative of useful thought to communication engineers with the necessary mathematical equipment. Cathode-ray oscillograms, which have been obtained of lightning surges during recent years, have shown that they may be generally represented by the difference between two exponentials. This is fortunate, since the effects of travelling waves on terminal equipment are comparatively easy to calculate for waves of this shape. In any case, the exact methematical solution of the practical engineering problem appears impossible, as both the leakance and capacitance increase in an imperfectly known manner with the formation of corona.

Part II. deals with high frequency oscillations and transients in terminal transformers, a useful method of synthesis being used for setting up equivalent circuits for the transformers, etc.

The aim of the book throughout is, however, not to present new methods, but the consolidation of the work of such pioneers as Heaviside, Steinmetz, and K. W. Wagner on travelling waves. As a permanent reference it should be valuable to the power engineer dealing with H.T. lines. W.G.R.

" Communication Agencies and Socail Life." By Malcolm M. Willey and Stuart A. Rice. McGraw-Hill Publishing Co., Ltd., Aldwych House, London, W.C.2. Price 15/- net.

It is often stated that statistics make but dry reading, but the authors, who are Professors of Sociology at the Universities of Minnesota and Pennsylvania, respectively, have succeeded in presenting their data in such an interesting manner as to surround the volumes with an atmosphere of romance—the Romance of Communications. This study of the trends of Communication is one of a number of investigations made by the Research Committee on Socail Trends appointed by the President of the U.S.A.; it is a study of the development and utilization of the media of communication, and their inter-relationships and social effects.

The material is presented in three parts : The first deals with the transportation agencies and their utilization. the second, with the agencies of point-to-point communication; and the third, with the agencies of mass impression. With the exception of broadcasting, electrical communications are treated in the second part, and their effect upon the social life of the American people is dealt with at length. The greater portion of the deductions made could equally be applied to the peoples of other countries possessing comprehensive networks for telegraph and telephone communications, and the volume would prove well worthy of investigation by the Communcation Engineer interested in the effects of modern communications upon the daily life of nations.

" Telephone Theory and Practice; Vol 2, Manual Switching and Substation Equipment; Vol. 3, Automatic Switching and Auxilliary Equipment." By Kempster B. Miller, M.E. McGraw-Hill Publishing Co., Ltd., Aldwych House, London. Price 30/- each volume.

Volume 1 of this work appeared some time ago and has already been reviewed in this Journal. The two volumes now under review complete the author's revision of his earlier work on Telephony.

The first part of Volume 2, consisting of five chapters, deals with the equipment of substations and the various component parts of the apparatus required. Transmitters and receivers are first described, and then the development of substation signalling apparatus is discussed. After a description of the " sign language of telephony," the connexions of subscribers' sets for various types of service are described in detail. The fifth chapter gives a great deal of useful data on the various methods of selective and code ringing for multi-party lines.

The second part consists of six chapters and is devoted to a discussion of manual switchboards. First, the various component parts, such as jacks, lamps, keys, relays, etc., are described, and then follows an account of the equipment and operation of magneto non-multiple switchboards. A separate chapter is devoted to a discussion of the current supply to central battery exchanges, in which the various types of transmission bridge are dealt with and the causes and prevention of cross-talk, machine noise, and switching noises are fully treated. The last three chapters are devoted to non-multiple C.B. switchboards and a description of the equipment and operation of multiple-type switchboards.

Volume 3 opens with a discussion of the machine switching idea, and an explanation of control devices and numbering schemes. The next four chapters deal with the Strowger Step-by-Step System, the Panel System, the Rotary System, and the Relay System. The lucid descriptions of each system are copiously illustrated with diagrams, drawings, and photographs; and the fundamental principles of each system are clearly set forth.

The second portion of the volume deals with auxiliary equipment proper to both manual and automatic systems; power plant, protective apparatus, distribution frames, private branch exchanges, and toll switching each form the subject of a separate chapter and are fully described.

The volumes are succinctly written, but the diagrams would have been more readily followed had they been drawn on the " detached contact " plan. The books are excellently indexed and can be recommended as a very useful addition to the Communication Engineer's library.

" Standard Handbook for Electrical Engineers." Sixth Edition. 2816 pp. McGraw-Hill Publishing Co., Aldwych House, London. 42/-.

This sixth edition of this lavishly illustrated reference book is some 30 per cent. larger than the previous edition. The work is divided into 26 sections of which two—those on electric heating, melting, etc., and on electron tubes and electric wave filters—are new; the greater portion of the other sections have been considerably enlarged and the whole work thoroughly revised by a staff of specialists working under the able editorship of Mr. Frank F. Fowler. The work is excellently printed and bound; and greatly simplified by the comprehensive index and the thumb tabs at the beginning of each section. The prestige gained by the previous edition will be considerably enhanced by this revised edition which should prove of much assistance to electrical engineers.

Staff Changes

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	From.	To.	Date.
Cave-Browne-Cave, Capt. N. F. ...	Asstistant Superintending Engineer, Eastern District.	Superintending Engineer, Eastern District.	23-9-33
Gravill, W. E.	Executive Engineer, London District.	Assistant Suptg. Engineer, Eastern District.	23-9-33
Ritter, E. S.	Executive Engineer, Research Section, E.-in-C.O.	Assistant Staff Engineer, Designs Section, E.-in-C.O.	1-9-33
Morris, A.	Executive Engineer, Radio Section, E.-in-C.O.	Assistant Staff Engineer, Radio Section, E.-in-C.O.	1-10-33
Bowyer, G.	Assistant Engineer, S.W. District.	Executive Engineer, S.W. District.	26-10-33
Rae, R. B.	Assistant Engineer, Scot. E. District.	Executive Engineer, Scot. E. District.	10-11-33
Ashdowne, H. A.	Assistant Engineer, S. Mid. District.	Executive Engineer, S. Mid. District	1-1-34
Smith, W. F.	Assistant Engineer, N. District.	Executive Engineer, N. District.	1-1-34
Gracie, A. J. A.	Assistant Engineer, Radio Section, E.-in-C.O.	Executive Engineer, Radio Section, E.-in-C.O.	1-10-33
Somerville, H. B.	Assistant Engineer, S.E. District.	Executive Engineer, London District.	23-9-33
Jolley, E. H.	Assistant Engineer, N. Mid. District.	Executive Engineer, Research Section, E.-in-C.O.	To be fixed later.
Manning, F. E. A.	Assistant Engineer, Lines Section, E.-in-C.O.	Executive Engineer, Lines Section, E.-in-C.O.	6-10-33
Graham, C.	Assistant Engineer, S.E. District.	Executive Engineer, London District.	1-9-33
Hughes, R. E. S. F.	Chief Inspector, E. District.	Assistant Engineer, Construction Section, E.-in-C.O.	2-8-33
James, F. G. H.	Chief Inspector, S.E. District.	Assistant Engineer, S.E. District.	To be fixed later.
Catto, A. D.	S.W.I., Scot. E. District.	Inspector, Scot. E. District.	5-12-32
Dunkley, L. W.	S.W.I., N. Mid. District.	Inspector, N. Mid. District.	3-2-33
Mann, R. G.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	17-11-32
Atkinson, J.	,, ,,	,, ,,	28-1-33
Marshall, W. J.	,, ,,	,, ,,	21-5-32
Robinson, R. B.	,, ,,	,, ,,	25-6-32
Stride, H. S.	,, ,,	,, ,,	3-10-32
Kingham, M. W. F.	,, ,,	,, ,,	6-3-33
Hull, J. A.	,, ,,	,, ,,	31-12-32
Hogg, F. E.	,, ,,	,, ,,	24-6-33
Hills, A. F.	,, ,,	,, ,,	21-1-33
Chapman, C. W.	S.W.I., S.E. District.	Inspector, S.E. District.	15-7-33
Middleton, A. M.	S.W.I., E.-in-C.O.	Inspector, E.-in-C.O.	1-1-33
Challenger, G.	Unest. Draughtsman, S. Wa.	Draughtsman, Cl. II., S. Wa. District.	15-6-33
Privett, A. J.	Unest. Draughtsman, L.E.D.	Draughtsman, Cl. II., L.E.D.	30-8-33
Waldegrave, R. F.	Unest. Draughtsman, E.-in-C.O.	Draughtsman, Cl. II., E.-in-C.O.	28-7-33

Deaths.

Name.	Rank.	District.	Date.
Pooley, B.	Chief Inspector.	Eastern.	10-7-33
Hardy, B.	Inspector.	N.E.	22-6-33
Waters, S. A.	Inspector.	E.-in-C.O.	9-8-33

Transfers.

Name.	From.	To.	Date.
de Wardt, R. G.	Assistant Staff Engineer, Telegraph Section, E.-in-C.O.	Assistant Superintending Engineer, S.W. District.	1-10-33
Cooper, M. C.	Assistant Engineer, Equipment Section, E.-in-C.O.	Assistant Engineer, N. Ireland District.	25-6-33
Trott, L. J.	Inspector, E.-in-C.O.	Inspector, S.W. District.	1-8-33
Baines, F. G.	Inspector, London District.	Inspector, E.-in-C.O.	1-9-33
Carrette, A. D.	Inspector, E.-in-C.O.	Inspector, N.E. District.	3-9-33

RETIREMENTS.

Name.	Rank.	District.	Date.
Gall, J. R. B.	Staff Engineer	E.-in-C.O.	31-8-33
Cornish, H. V.	Deputy Superintending Engineer.	London.	30-4-33
Mitton, F. E.	Executive Engineer.	London.	31-8-33
Elliott, A.	Assistant Engineer.	S. Wales.	18-8-33
Ellison, J.	Chief Inspector.	N. Wales.	15-7-33
Tremayne, W. C.	,, ,,	S.W.	17-7-33
Duerth, W. S. F.	,, ,,	S.E.	30-7-33
Hardstone, S. A.	,, ,,	Testing Branch.	31-7-33
Rowe, H. G.	,, ,,	N. Mid.	13-8-33
Rowson, E. W.	,, ,,	N. Mid.	11-8-33
Wood, J.	,, ,,	N.	3-8-33
Bailey, C. G.	Inspector.	N.E.	30-6-33
Carron, J. R.	,,	S. Lancs.	30-6-33
Kirkland, J.	,,	Scot. W.	26-7-33
Morgan, C. R.	,,	S.W.	26-7-33
Norman, J.	,,	Scot. W.	8-8-33
Richards, H. J.	,,	London.	31-8-33

CLERICAL GRADES.

PROMOTIONS.

Name.	From.	To.	Date.
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Spears, A. E.	Clerical Officer, London District.	Higher Clerical Officer, London District.	11-8-33
Kimber, E. J.	Clerical Officer, Eastern District.	Higher Clerical Officer, Eastern District.	8-8-33
Farries, L. J.	(Executive Officer, E.-in-C.O.	Acting Staff Officer, E.-in-C.O.	18-8-33
	Acting Staff Officer, E.-in-C.O.	Staff Officer, E.-in-C.O.	4-9-33
Martin, H. E.	Executive Officer, E.-in-C.O.	Acting Staff Officer, E.-in-C.O.	4-9-33
Hughes, J.	Clerical Officer, E.-in-C.O.	Acting Executive Officer, E.-in-C.O.	18-8-33

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Johnston, R. R.	Higher Clerical Officer.	Northern District.	22-7-33
Slate, J. F.	Higher Clerical Officer.	S. Eastern District.	18-7-33
Fletcher, G. E.	Higher Clerical Officer.	S. Eastern District.	31-7-33
Petchey, F. G.	Higher Clerical Officer.	London District.	10-8-33
Hoggarth, H. J.	Staff Officer.	E.-in-C.O.	31-8-33

TRANSFER.

Name.	Rank.	From	To	Date.
Colman, W. A.	Higher Clerical Officer.	N. Mid. District.	S. Eastern District.	19-7-33

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INDEX TO ADVERTISERS.

I.P.O.E.E. PROGRAMME, 1933

PROVISIONAL PROGRAMMES OF LOCAL CENTRES.

1933. LONDON CENTRE.

10 Oct. J. Stratton, A.C.G.F.C., A.M.I.E.E., and W. G. Luxton.
"Modern Developments in Telephone Transmission over Lines."

14 Nov. S. J. Husband.
"Some Notes on Exchange Equipment, Factory Costing and the Economics of Production."

12 Dec. W. H. Brent, B.Sc. (Hons.).
"The Telegraph Pole."

Informal Meetings.

1933.

24 Oct. R. W. Palmer, A.M.I.E.E.
"The Service Aspect of Automatic Telephony."

28 Nov. S. Birch and C. H. Hartwell.
"The Post Office International Telephone Exchange."

1933. EASTERN CENTRE.

26 Sept. Capt. N. F. Cave-Browne-Cave, B.Sc., M.I.E.E.
"Vision and visualization in management."

24 Oct. N. Feather, Ph.D.
"Electrons" (and visits to Cavendish Laboratory, Cambridge).

28 Nov. S. J. Cain, A.M.I.E.E., W. J. Storey and A. H. Wade.
"Chief Inspectors' duties."

19 Dec. R. N. Hamilton, B.Sc. (Eng.).
"The Bypath System of Telephony."

1933. NORTHERN CENTRE.

Opening Meeting.
Prof. E. G. Richardson, D.Sc.
"Acoustics in Telephony."

1933.

Capt. B. S. Cohen, B.Sc., M.I.E.E. (*E.-in-C.O.*).
"Engineering Research in the P.O."

1933. NORTH EASTERN CENTRE.

10 Oct. *To be arranged.*

14 Nov. Major F. E. A. Manning, M.C., B.Sc. (Eng.), A.M.I.M.E., A.M.I.E.E. (*E.-in-C.O.*).
"Recent Repeater Station Installation."

12 Dec. G. Riches.
"Contracts—District Engineers Orders."

1933. NORTH WESTERN CENTRE.

J. Stratton, A.C.G.F.C., A.M.I.E.E. and W. G. Luxton (*E.-in-C.O.*).
"Modern Developments in Telephone Transmission over Lines."

H. O. Ellis and B. Winch (*E.-in-C.O.*).
"Party Lines—History and Recent Developments."

G. Manning, B.Sc. (Eng.).
"The Development of Telephone Communication between England and the Continent of Europe."

1933. NORTH MIDLAND CENTRE.

4 Oct. J. R. Milnes.
"Conveyors."
Followed by a visit to "Boots," Cash Chemists, Factory at Beeston.

13 Nov. H. H. Bell (*B.I. & H.C., Ltd.*).
"Laying, Jointing and Loading a Main Cable."

11 Dec. C. J. Griffiths.
"Trunk Demand."

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