CHAPTER XI: TELEPHONY – PART 1

TELEPHONY being a branch of the science of transmitting sounds to a distant point, it will be appropriate to commence by considering sound waves and some of their properties. When a tuning-fork is caused to vibrate, the surrounding air is disturbed and waves are produced therein, as shown in Fig. 158. When the prongs of the fork move outwards, the air in the immediate neighbourhood is compressed, as shown at a. This compression travels away from the fork, but its prongs have now reached the position shown in b and produced a rarefied condition of the air.

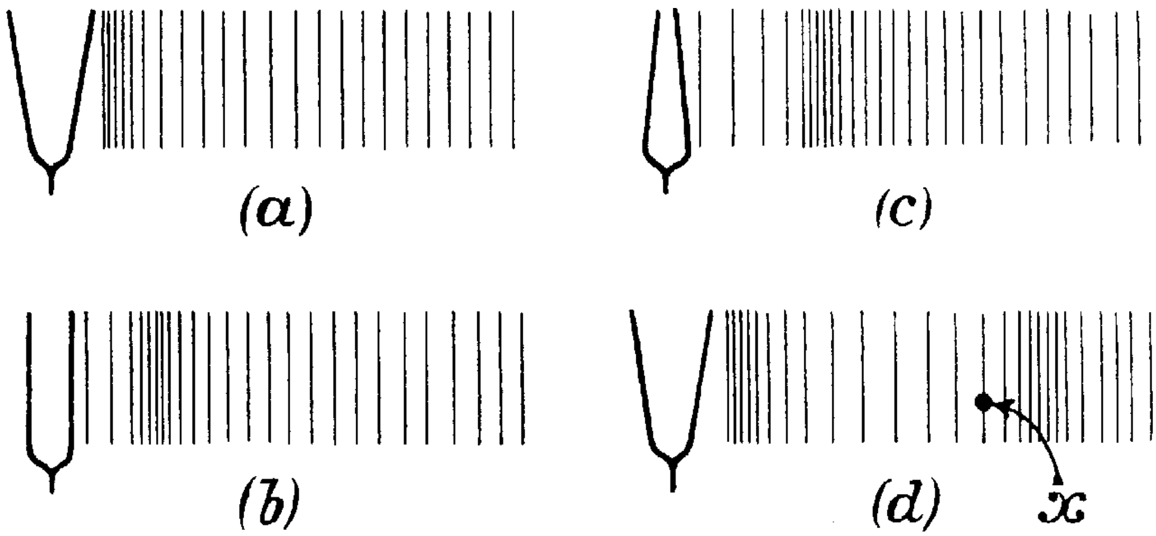

Fig. 158.- Action of Tuning-fork.

This rarefication will proceed to travel similarly to the compression so that when the fork has reached the position shown in c the condition of the air has again changed, as shown. When the fork now returns to the original position a another compression period will be given as at d. During the period when the fork is vibrating, therefore, there is a period of compressions and rarefications travelling in the air, away from the fork. These waves on reaching the human ear cause its drum to move in and out in corresponding fashion. This movement, conveyed to the brain, produces the sensation of sound.

Consider a small portion of air, as at x in d. It will be seen that it moves forwards and backwards with each sound wave. This action gives rise to the name of longitudinal waves, as distinguished from transverse waves, the latter being waves where an up-and-down motion of the particles is produced, as in the case of a rope shaken at one end ; the wave will be seen to travel along the rope, as in Fig. 159, but any particular point in it, as at x, has an up-and-down motion.

If the frequencies of the sound waves reaching the ear-drum are low, a low note will be heard. As the frequency of the vibrations per second increases, the note becomes higher in tone or pitch, until, if' the frequency can be increased sufficiently, the sound ceases to be audible. The average human ear responds to frequencies between about 30 and 15,000 per second, but it is not necessary to be able to transmit the whole of this range to produce intelligent speech in a telephone receiver, the band of frequencies between 300 and 2,800 being sufficient, at any rate for medium distances. On long trunk circuits an increase up to about 3,200 has been found advantageous. As the sound waves consist of movements of the air they possess mechanical energy and can be made to actuate diaphragms or similar devices, and if such movements are reproduced by them the original sounds will be heard. This is the principle of telephone transmission. At the transmitter a thin metal or carbon diaphragm, moving under the action of sound waves, varies the current in an electrical circuit, which includes a receiver having a metal diaphragm, the latter being made to reproduce the movements of the transmitter diaphragm and. hence the sound waves falling thereon. Various losses occur in the circuit, causing the reproduced speech to be weaker than the original.

FIG. 159. - Transverse Waves.

THE TRANSMITTER.

Strictly speaking, sensitive microphones, such as those used in broadcasting, can be classed as transmitters, but for ordinary telephone work, where the extreme upper and lower frequencies are not essential, what is called the carbon granule type of transmitter is universally employed. Its action depends upon the fact that if a quantity of fine carbon granules are compressed, the electrical resistance of the granules decreases as the pressure is increased, and vice versa.

Fig. 160 shows the section of a modern hand-set with an "inset"type of transmitter. The inset is self-contained and fits into the mouthpiece of the transmitter proper, contact with the external connections being made to the pin P, and by the springs S to the case of the inset, which can therefore be easily changed. The carbon granules C are contained in a small circular box B. The open end is practically closed by a carbon plate P1, rigidly fixed to a diaphragm D. A further carbon plate P2 is provided at the back of the box, capable of connecting with pin P.

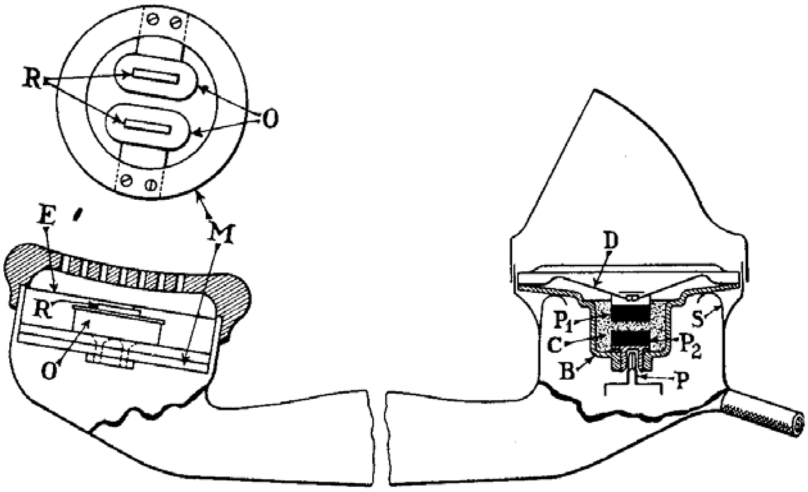

Fig. 160. - Hand-set with Inset Transmitter.

If the carbon plates are connected across a battery a steady current will flow. Sound waves reaching the diaphragm will cause it to move backwards and forwards in sympathy, which will alternately compress and release the carbon granules, the current then varying in proportion to the diaphragm movements. These current variations are passed by the external circuit to the receiver. In this type of transmitter the carbon granules are liable to "pack" together and cause faint or no transmission. This fault is particularly noticeable on instruments with a fixed transmitter, as on wall-type telephones, the carbon granules gradually getting moved until they are all "fitted "together, to the exclusion of any air spaces. The condition can usually be remedied by lightly tapping the inset to rearrange the granules, but occasionally obstinate cases are found and the inset has to be changed.

THE RECEIVER.

This consists essentially of a permanent magnet M (Fig. 160) provided with soft iron pole-pieces R, the difference in the "watch" and "bell" type receivers being only in the shape of the magnet. A soft iron diaphragm E is fitted as shown, the distance between the diaphragm and pole-pieces being approximately 10/1000 to 20/1000 of an inch. Coils O are fitted on each pole-piece connected to the external circuit.

The diaphragm is normally under tension, due to the pull of the permanent magnet. Upon receipt of the current from the transmitter, the diaphragm will either move outwards or farther in, depending upon whether the magnetic field produced by the current in the coils opposes or assists the field of the permanent magnet. The diaphragm will thus reproduce the movements of the transmitter diaphragm and sound waves are produced. Probably the most common fault met with in receivers is a damaged diaphragm. Until recently the receiver caps had one hole in the centre, the diaphragm being liable to become bent or damaged by accidental knocking. Obviously the diaphragm must not touch the pole-pieces, and where a receiver has been in use for a long period the diaphragm may assume a bowed shape and seriously reduce the air gap between it and the pole-pieces. A cure can sometimes be effected by reversing the diaphragm. The existence of the air gap can be judged by the hollow sound emitted when the diaphragm is lightly tapped. In some cases the permanent magnet may be weakened by rough usage. The pull of the magnet upon the diaphragm may be compared with another receiver. If it is found to be appreciably weaker the faulty receiver should be changed. The current variations produced by the transmitter are comparatively small and subject to line conditions, such 5s resistance, leakage, and the impedance o£ the line. To improve the range of transmission the induction coil is used. This is in effect a step-up transformer, its chief asset being that the transmitter circuit is independent of the line resistance.

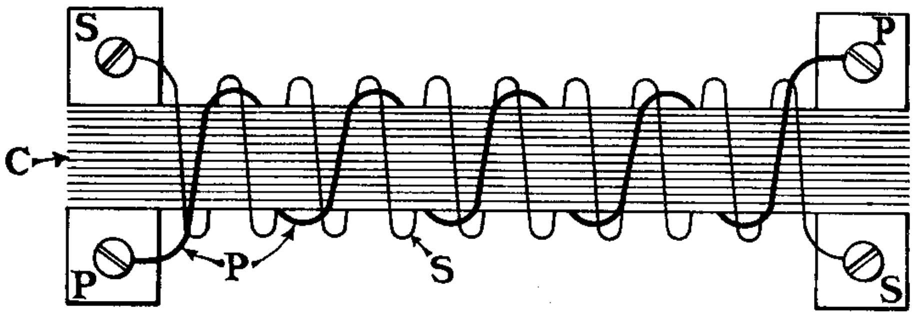

FIG. 161.-Induction Coil.

THE INDUCTION COIL.

This consists essentially of a primary winding P, as seen in Fig. 161, and a secondary winding S, wound over the primary. The core C is often composed of soft iron wires, although stampings, similar to those used in power transformers, are being increasingly. used in modern telephones. With the usual type of local battery telephone, the resistance of the primary is I ohm, and of the secondary 25 ohms ; with central battery telephones the primary may be 17 ohms, and the secondary 26 ohms, but these values vary in different makes. The induction coil on a local battery telephone is connected as shown in Fig. 162 ; the case of the central battery telephone is considered later.

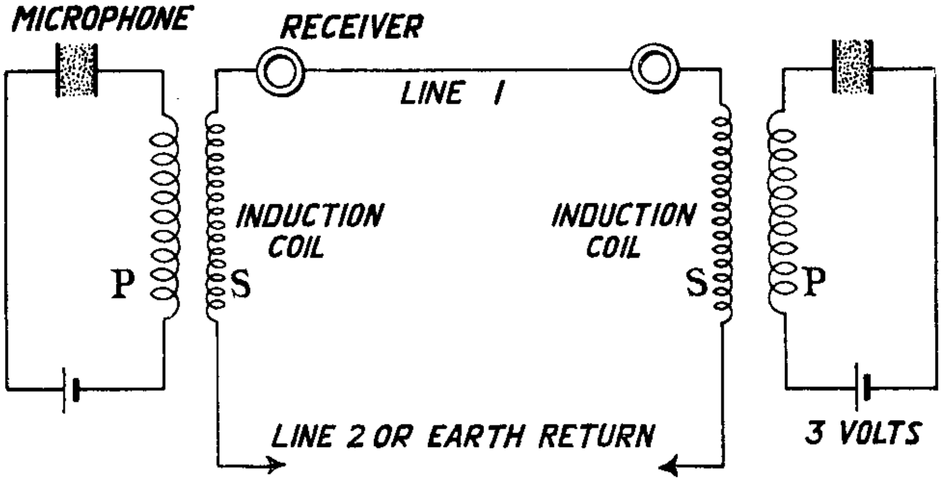

FIG. 162.-Circuit of Local Battery Telephone.

As the primary winding is of low resistance, the maximum current is obtained in the transmitter circuit, with consequent maximum variations produced by the transmitter, such variations being independent of the line resistance. The steady direct current from the transmitter battery through the primary produces a magnetic field, this field being further "concentrated" around the coil windings by the action of the iron core. When, therefore, the primary current varies, an induced voltage is observed at the secondary coil terminals. This voltage variation is much greater than the variation that would be obtained if the transmitter circuit was connected direct to the line. With the arrangement shown in Fig. 162 all speech transmitted is heard in both receivers, with the result that any local room noises would be heard in the receiver, via the transmitter, as well as the received speech. Present-day telephones are usually equipped with an "anti-side tone" circuit, designed to reduce the side-tone, or amount of speech received in the receiver from its own transmitter. The induction coil has two primary and secondary windings, connected as shown in Fig. 163.

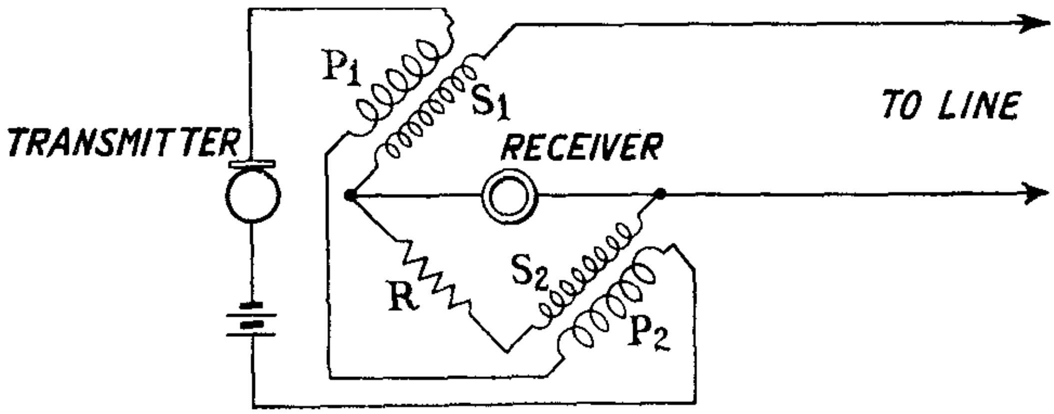

FIG. 163. - Anti-Side Tone-Circuit.

With outgoing speech the currents are balanced, resistance R being equal to that of the line, the receiver being connected to points of the same potential so that no speech is heard. On incoming speech, however, the circuit is unbalanced, the speech being divided between S1, R, S2 and the receiver, and being heard in the latter. For a perfect balance, resistance R should equal the line resistance. As this, of course, is not the same for all stations, an average value of 360 ohms is fitted. The amount of side tone is then not excessive on lines having a resistance slightly above or below this value.

In addition to speaking and receiving apparatus, means must be provided for calling the attention of the desired station when communication is required. The methods of calling are numerous, but mostly consist of ringing a bell by means of a battery or hand generator. In the latter case an alternating current is applied to line, and a so-called "magneto "bell is provided at each station. The alternating current is produced by a hand generator similar in principle to a car magneto, and consists of an armature capable of rotating between the poles of a powerful horseshoe magnet, as in Fig. 164. The armature is rotated by gear-wheels, and the alternating current produced is applied direct to line. The contact C, which moves over directly the handle is turned, disconnects the generator from the line when the former is not in use. The magneto bell is capable of operation by alternating current only, and consists essentially of a pivoted armature A (Fig. 164), provided with a hammer S for striking the gongs G. A permanent magnet M, bent to shape, is fitted as shown, with one pole close to the armature. The latter, due to the magnetism induced in it, will then act as one pole of the magnet and have a similar polarity at each end. Coils are fitted to the soft iron pole pieces P and connected to line. The incoming alternating current will then energise the coil and constantly reverse the polarity of the pole-pieces, so that the armature will rock about its pivot and ring the bell. This type of bell is used extensively at the present time. If a condenser is provided in series with it, battery currents will not influence the bell.

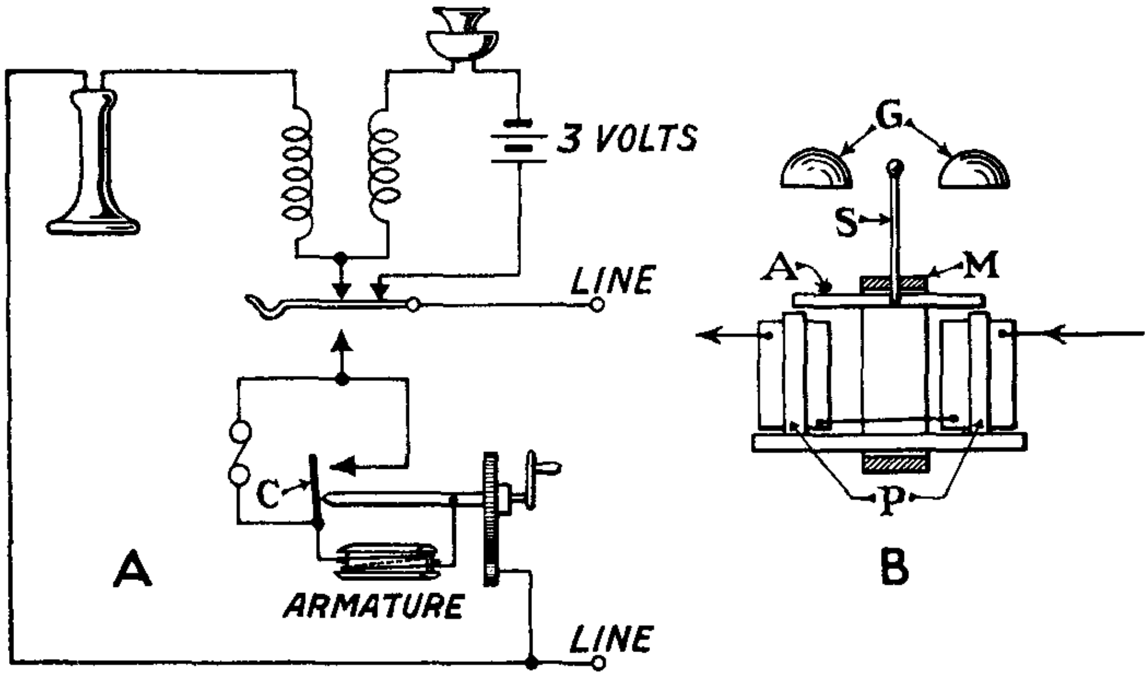

FIG. 164. - Magneto Ringing.

An arrangement, used particularly with automatic systems, is what is called the two-party line system, in which two telephones are connected to one line (Fig. 165), the bell circuits being connected between one line and earth, as shown. A separate number is allocated to each line, and the lines are reversed in the exchange jumper connection to one of the numbers. Ringing current from an automatic exchange is applied to the negative line, and if, therefore, line No. 1 is called, it would pass out on the negative line to Station 1, through the bell circuit to earth, Station No. 2 being unaffected. When Station 2 is called, the ringing current is applied to the negative line, but, owing to the reversed connection, is sent to line on the positive wire, thus ringing the bell at Station 2. The receivers when lifted are connected across the lines in the normal way. Thus both stations have full facilities, except that o£ inter-communication between themselves. Inter-office or "intercommunication "telephones, as they are often called, are usually confined to short distances, as a multiple wire cable is required to each telephone. Various circuits are in use, the apparatus being of a simple type with a switch or key to select the particular line connection required.

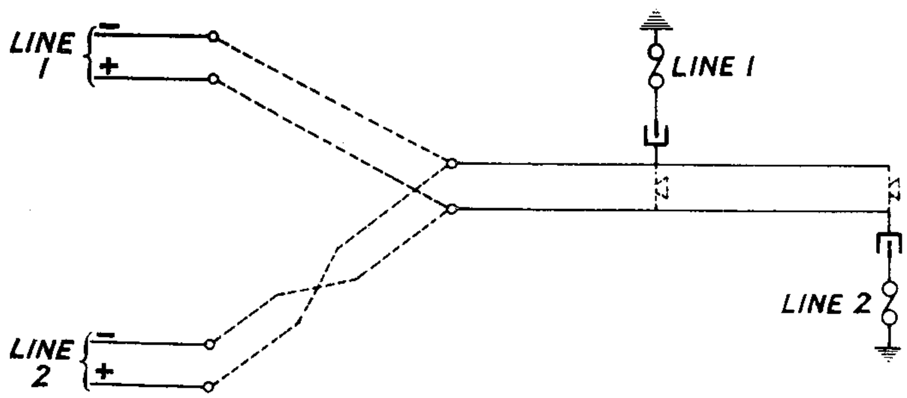

FIG. 165. - Two-party Line Working.

SWITCHBOARDS.

As means of "exchanging" calls between lines a switchboard is provided. In this case all lines terminate on calling devices, placed in front o£ an operator. When a call is received the operator inserts the plug, with a cord connection, into a jack associated with the calling line and, by operating a key, speaks to the caller and ascertains the number required. The operator then inserts another plug with cord connection into the jack of the desired station and rings the latter's bell by operating a ringing key. The two stations are now connected by the plugs and cords, which are fitted in pairs, each pair constituting one connecting circuit. When the stations have finished, a signal is given on the associated cord circuit ; the operator then withdraws the plugs.

The calling devices usually consist of a drop indicator or a lamp signal. The former requires no large battery at the exchange, but requires restoring by hand, and is liable to mechanical failures. The lamp signal is operated by a line relay, the relay being disconnected (and the lamp extinguished) with the insertion of the plug. This arrangement requires a battery (24 volts) at the exchange, but in the central battery (C.B.) system this disadvantage is counterbalanced by using the exchange battery to supply the transmitter current for the stations, no batteries being required at the latter.

The station instrument circuit for this system is shown in Fig. 166 (a, b and c). In addition to the transmitter, receiver, induction coil and magneto bell, a condenser, usually 2 mF., is connected in series with the bell ; thus, when the receiver is on the rest, the line circuit consists of the bell and condenser in series as at a. The bell will then ring on the application of the alternating (ringing) current from the exchange. The transmitter circuit, when the receiver is lifted, is shown at b, the transmitting current being supplied from the exchange. The receiver circuit is shown by the thick lines in c; the incoming speech currents, passing through the primary of the induction coil, induce a current in the secondary and speech is heard in the receiver. The "loop" provided by the transmitter circuit operates the exchange signalling relay, as explained below.

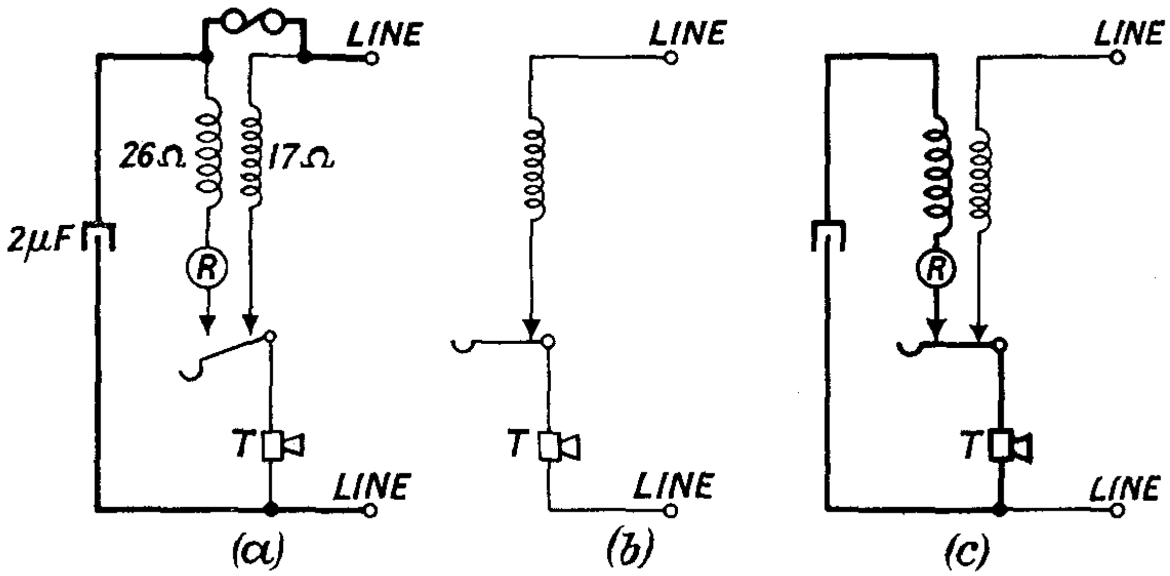

FIG. 166.- Central Battery Working.

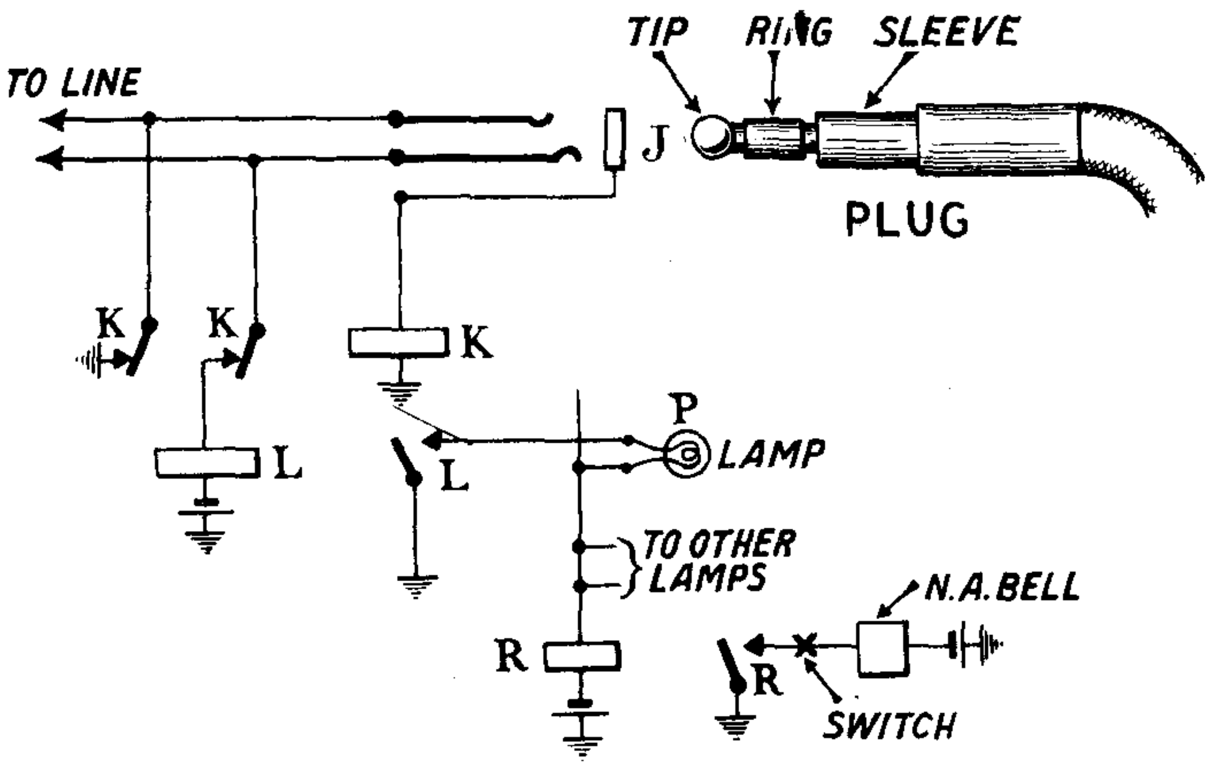

FIG. 167.- Exchange Equipment, Central Battery System.

The exchange line equipment usually consists of a line relay L, connected to line via the contacts of a cut-off relay K (Fig. 167). The operation of the line relay lights the lamp P associated with the station line jack J. The relay, o£ course, will not operate until the receiver is lifted at the station. A choke coil is frequently inserted in the earth connection to "balance "the line and eliminate any overhearing. A second coil wound on relay L is sometimes used for this purpose. Upon a signal being received the operator inserts a plug into the jack and operates the cut-off relay K by means of a third or "sleeve "connection on the plug. The line relay then releases and the lamp is extinguished. The operator then connects to the required station by means of the associated plug, as explained above. A relay H is connected to the line circuit of the cord, as in Fig. 168. This relay will be operated whilst the station receiver is off, and will release when the receiver is replaced. The circuit for this relay for station A is shown by the thick lines in that figure. The relay contact then operates a clearing lamp associated with the cord.

Battery for the clearing lamp is usually provided by a sleeve relay SA, the circuit of the relay coil serving to operate the extension cut-off relay K. The clearing lamps do not, therefore, remain alight when the plugs are withdrawn. A similar circuit is provided on the associated cord for the called station, the pair of cords being connected by condensers C to pass the speech currents. The relays also act as choke coils, preventing the passage of the speech currents to the battery connections and battery. Overhearing would otherwise result, as the battery is common to all circuits. For a similar reason a choke coil E is usually fitted in the positive connection ; this usually consists of a relay similar to the clearing relay, but without contacts. The two coils thus provide a "balanced" condition, essential for good transmission on long lines.

Cords at exchanges become "noisy" after long use, due to the flexible wires fraying and breaking, particularly at the point near the plug, where the maximum movement of the cord is obtained. At old exchanges trouble is also caused by wear on the plugs and jacks, causing the plug points to make poor connection to the jack. At small exchanges keys are substituted for the cords, the keys usually being arranged in two or three rows, one extension having a key in each row, as shown in, Fig: 169.

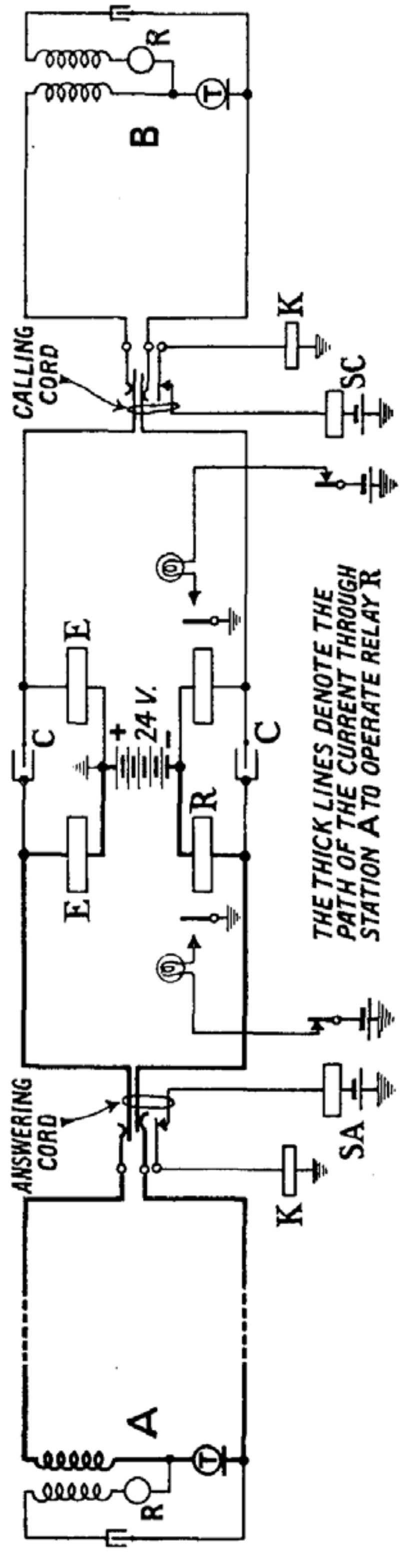

FIG 168. – Central Battery Extensions when Speaking

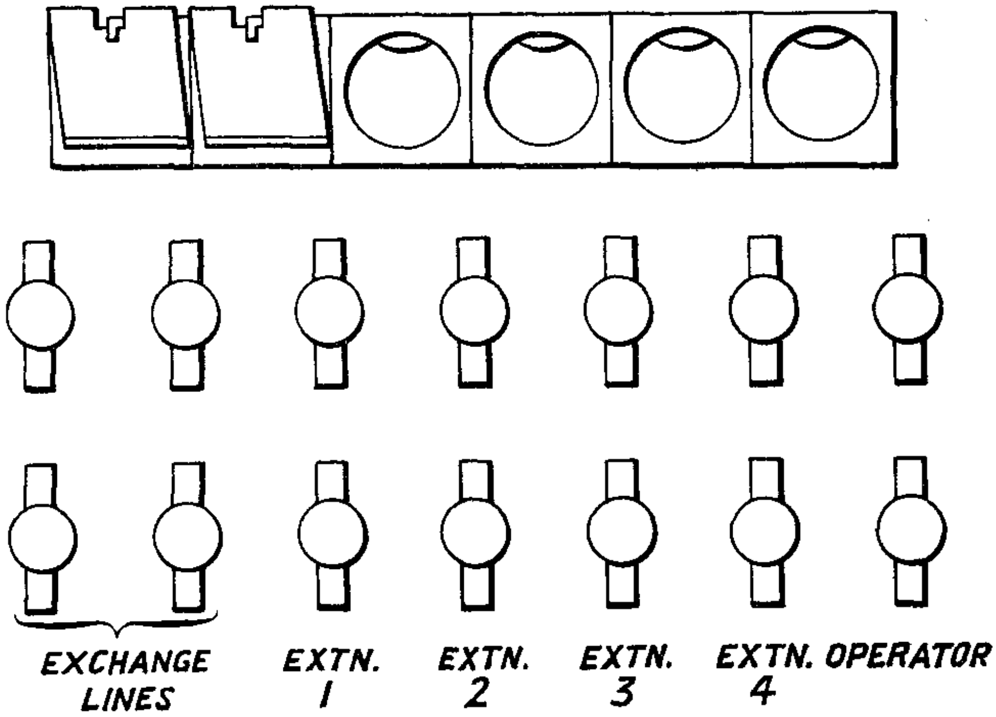

FIG. 169. - Cordless Switchboard.

The operation in the same direction of any two extension keys in the same row will connect the extensions together, via a clearing relay circuit similar to a cord circuit. The "down" position of the lower row of keys is used for ringing purposes. Where calls to the public exchange and, or railway trunk lines are to be handled, special equipment is provided for signalling on these circuits. On public exchange lines a lamp signal is usually provided, the lamp being connected by a relay which operates on receipt of the public exchange ringing current. The Post Office stipulate certain conditions applying to exchange lines, among them being that the "clear" shall be given immediately to the public exchange operator when a person speaking on an extension replaces the receiver, independently of whether or not the private exchange operator removes the plugs; and also that the speaking current for the extension shall be provided by the public exchange line circuit. It is. also required that another incoming call shall be signalled, although the private-exchange operator has not removed the cords from the previous call, and that under these conditions the extension still connected shall not be rung. These arrangements are provided for by numerous circuits beyond the scope of this work.

Trunk-line and omnibus-line equipment varies according to the method of signalling, and may consist of a polarised relay (Fig. 170) and keys for "reverse "battery ringing. The polarised relay provides for the exchange to be called only with the current in one direction, the out-stations being called, by code ringing, with the current in the opposite direction, the exchange thus not being inconvenienced by station-to-station calls. A bell or ,buzzer circuit is provided at exchanges for use when the board is unattended.

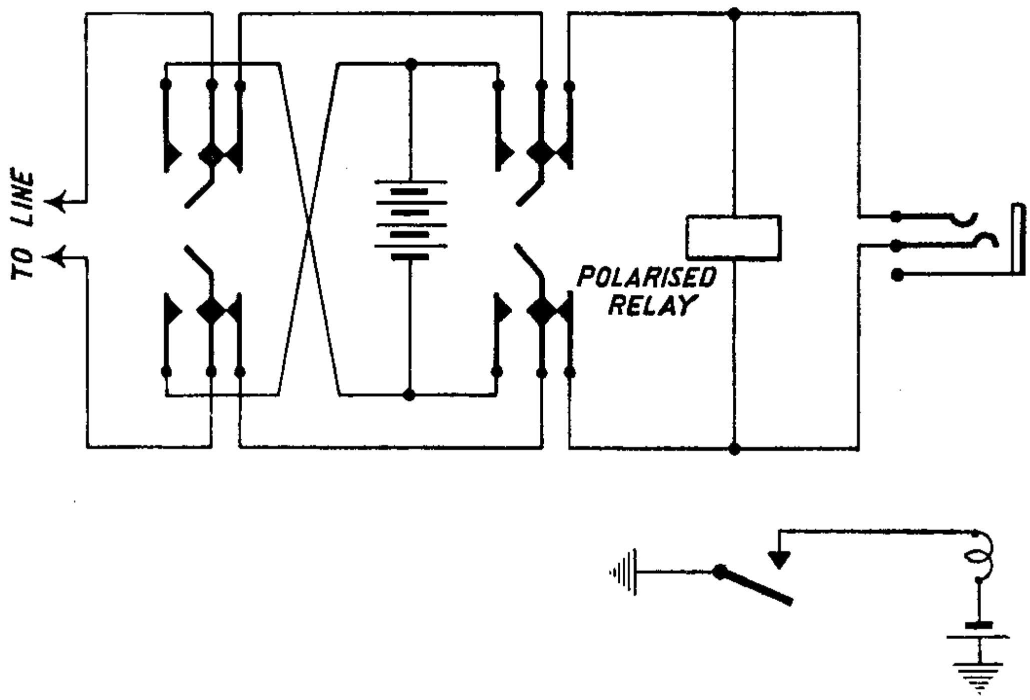

FIG. 170.- Reverse Battery Ringing.

With drop-indicator calling devices the local bell circuit is completed by a contact on the indicator flap. With lamp signalling, the common battery feed to the lamp is taken via "pilot" relay R (Fig. 167). This relay will operate when any lamp circuit is completed, the contact completing the local bell circuit. The relay is usually of 4-ohm resistance, and therefore has no effect upon the lighting of the lamps.

AUTOMATIC TELEPHONY.

Automatic telephones are now used wherever possible. Their advantages are well known, notably the saving in time due to the elimination of operators, and the immediate clearing of the line at the end of a conversation.

A dial is fitted to each telephone and the required number is obtained by lifting the receiver and "dialling" the figures. Connection to the required station is completed as soon as the dial comes to rest, and, if disengaged, a ringing tone can be heard, indicating that the station is being rung. If engaged, an

"engaged" tone is heard. The whole connection is cleared by replacing the receiver. Connection with the operator, for trunk calls, is obtained by dialling 0. The dial itself consists of a mechanism having a cam to "make and break" the line circuit at a definite speed ; the number of "breaks "corresponding to the number dialled, 0 being represented by 10. They are only produced whilst the dial is returning to normal under the action of a coiled spring, a governor being fitted to control the speed to approximately 10 breaks per see. Auxiliary springs are fitted that short-circuit the receiver and transmitter whilst dialling, to prevent unpleasant clicks in the receiver and reduce the loop resist ance. The telephone circuit is of the C.B. type.

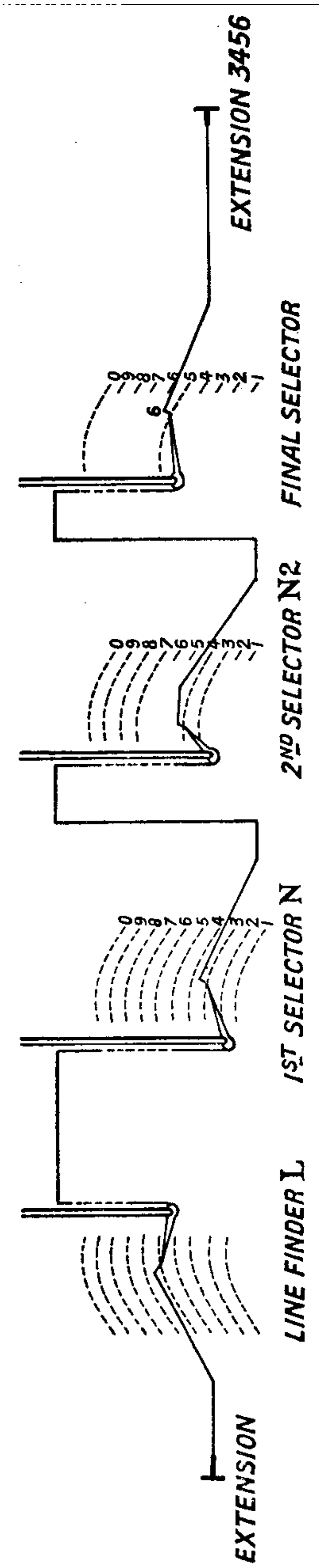

FIG 171- Train of Switches; Four-digit Automatic System

The methods of switching at the exchange are numerous; one system in use in certain London railway exchanges employs relays only, but present-day practice is entirely on what is called the machine-switching system. In this, brushes or "wipers" are mechanically stepped over banks of contacts, their movements being controlled by the dialled impulses. The banks of contacts usually consist of a hundred contacts, arranged in ten rows of ten.

Fig. 171 shows the arrangement of the switches in a four-digit exchange. The extension lines are connected, in groups, to the banks of the line-finder switches L. When the person using an extension removes the receiver a relay circuit steps the line-finder shaft vertically and then rotates it to the contact associated with the extension. The wipers of the line-finder switch are normally connected to what is known as the "first selector" switch N ; therefore, as the wipers of the linefinder are standing upon the extension contacts, the extension will be connected to the first selector switch, and " dial" tone, will be heard in the extension receiver. Assuming that the extension requires to call extension No. 3456, the digit 3 will first be dialled. The first selector switch shaft will then take three vertical steps and automatically rotate to find a free line to the second selector. The banks of this first selector switch are joined to the " second selector " switches, and the wipers of the former will continue rotating on level 3 until a connection to a disengaged second selector switch is encountered. The relay circuit of the first selector switch will then switch the wipers through the second selector switch N2, and when the second digit 4 is dialled the second selector switch will step to level 4 and rotate over the contacts until a connection to a disengaged final selector is encountered. The circuits of the first and second selector switches are similar, providing for the automatic "hunting" over the dialled level for a connection to a disengaged switch. The final selector, however, has both the vertical and rotary stepping controlled by the extension dial, and the contacts of the banks of the final selector are connected to the extensions in numerical order.

The final selector will now step vertically when the extension dials the third digit 5, and upon the fourth and last digit 6 being dialled the switch will take six rotary steps and the wipers will then be standing on the contacts of extension 3456. Relay circuits connect ringing to the wipers, and, when the called extension answers, will connect the two extensions for speaking. When the conversation is finished the switches are restored to normal. Fig. 171 shows the call completed and the wipers in position in the banks.

Telephony Section continues in Part 2 of Chapter XI with

Traffic Control Systems
Line Work
Superimposing
Buzzer Telephones
Carrier Telephony