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**POST OFFICE  
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**TECHNICAL PAMPHLETS  
FOR  
WORKMEN**

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*Subject :*

**Elementary Principles of  
Telephony.**

ENGINEER-IN-CHIEF'S OFFICE

1919

=====  
**LIST OF**  
**Technical Pamphlets for Workmen**  
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**GROUP A.**

1. Magnetism and Electricity.
2. Primary Batteries.
3. Technical Terms.
4. Test Boards.
5. Protective Fittings.
6. Measuring and Testing Instruments.
7. Sensitivity of Apparatus.

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6. Baudot Multiplex.
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1. General Principles of Wireless Transmission and Reception.

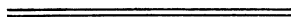
**GROUP D.**

1. Elementary Principles of Telephony.
2. Telephone Transmission. "Loading." Telephone Repeaters and Thermionic Valves.
3. Principles of Telephone Exchange Signalling.
4. Magneto Exchanges—Non-Multiple Type.
5. Magneto Exchanges—Multiple Type.
6. C.B.S. Exchanges—Non-Multiple Type.
7. C.B.S. Exchanges—Multiple Type.
8. C.B. Exchanges—No. 9 Type.
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18. Distribution Cases, M.D.F. and I.D.F.
19. Cord Repairs.
20. Superposed Circuits, Transformers, etc.
21. Call Offices.

*[Continued on page iii. of Cover.]*

# ELEMENTARY PRINCIPLES OF TELEPHONY.

(D.1.)



*The following pamphlets in this series are of kindred  
interest :—*

- A1. Magnetism and Electricity.**
- A2. Primary Batteries.**
- A3. Technical Terms.**
- A5. Protective Fittings.**
- D3. Principles of Telephone Exchange Signalling.**

# ELEMENTARY PRINCIPLES OF TELEPHONY.

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# ELEMENTARY PRINCIPLES OF TELEPHONY.

## ACOUSTICS.

Sounds are caused by vibration of the sounding bodies. If a tuning-fork be struck it can be seen that its prongs are in a state of rapid vibration. The movement of the prongs sets up vibrations in the air in the immediate neighbourhood. These vibrations travel outwards at the rate of 1,120 ft. per second, and they produce in the ear the sensation which we recognise as *sound*. Sound travels by a "to-and-fro" or *wave motion* of the particles of air, and not by a bodily movement of the air from one place to another. An illustration of wave motion is provided when wind passes over a cornfield. Waves appear to travel continuously over the cornfield, but the illusion of forward motion is created simply by the rise and fall of the heads of corn swinging in the wind.

Page 3. Delete 2nd para. Insert new para. :—

Sound waves actually consist of alternate compressions and rarefactions of the air, and audible sound waves vary from  $\cdot 7$  of an inch to approximately 70 feet in length.

The intensity of the vibrations. The **volume** is determined by the energy in the vibrations, which is proportional to the square of the amplitude. Sounds of equal pitch and loudness differ from each other in **quality**—for example, the note of a flute differs in quality from that of a violin, this being due to differences in the relative frequencies, amplitudes, or phases of the overtones present in the two cases.

To transmit speech from one place to another, other than directly through air or similar sound-conducting substance, we may employ a contrivance consisting of :—

(a) An instrument which is actuated by the sound waves and converts the energy of these into the energy of vibrations of a different form, or which, when actuated by the sound waves, brings into use energy from another source.

(b) A medium in conjunction with the above instrument along which the converted energy, or the energy brought into use, can travel.

(c) A second instrument which reconverts the transmitted energy into sound waves similar to those originally produced.

The simplest form of the contrivance referred to in the foregoing paragraphs is illustrated in Fig. 1. It consists of a couple of tin cylinders. Across one end of each cylinder is stretched a flexible diaphragm, the centres being connected by a stretched string. In this case speech is transmitted from one diaphragm to the other by mechanical vibrations in the string.

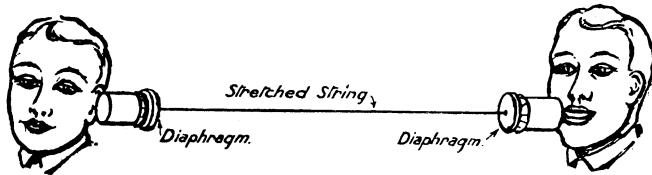


Fig. 1.

In an electric telephone speech is transmitted by means of electrical current, and the simplest way in which this can be done is by the use of two telephone receivers connected through a line circuit.

### ELECTRICAL TRANSMISSION OF SPEECH.

A telephone receiver consists of a permanent horseshoe magnet with soft iron pole-pieces, on which are wound coils of insulated copper wire. In front of these pole-pieces is placed a soft iron (or ferro-type) diaphragm, as indicated in Fig. 2. Some of the magnetic lines of force pass from one pole-piece *through the diaphragm* to the other pole-piece. Some, however, take a direct path *through the air space* between the pole-pieces. If a sound wave causes the diaphragm to move *inwards* towards the pole-pieces, some of the lines of force which passed directly between the pole-pieces will now pass through the diaphragm. Similarly,

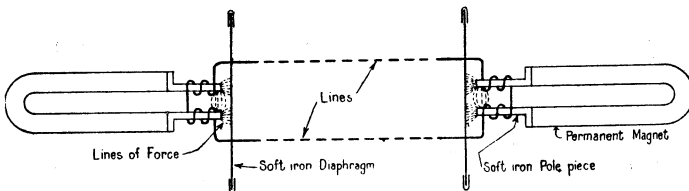


Fig. 2.

if the diaphragm moves *outwards*, some of the lines of force, which normally pass through the diaphragm in a position of rest, will pass through the air. The result of these movements of the diaphragm in the magnetic field is that the lines of force are

redistributed. Whenever a change occurs in the distribution of lines of magnetic force cutting a conductor an E.M.F. is induced in that conductor, and if the circuit is closed a current flows. Consequently currents varying precisely with the movements of the diaphragm are set up in the transmitting receiver circuit. These currents passing through the connecting line set up variations in the magnetic field of a similar receiver at the other end of the line, and reproduce motions of the diaphragm like those set up in the transmitting receiver by the sound waves.

The movement of the diaphragm in the transmitting instrument is produced by the energy of the sound waves, and there is considerable loss when this sound energy is converted into electrical energy, transmitted over a line, and finally changed from electrical energy into the resulting sound waves. This method of transmission by means of two receivers can be used over very short distances only, owing to the weakness of the telephone receiver as a "transmitter," and to the consequent smallness of the received sound.

In practice telephone *receivers*, as the name implies, are used only for receiving speech, and *transmitters* of a more sensitive and efficient type are used for speaking purposes.

### PRACTICAL RECEIVERS.

In some of the earlier forms of receiver, in which the permanent magnet was fixed to the end of an ebonite case, variations in receiver-speech occurred in hot and cold weather owing to the expansion or contraction of the magnet causing variations in the distance between the magnet and the diaphragm.

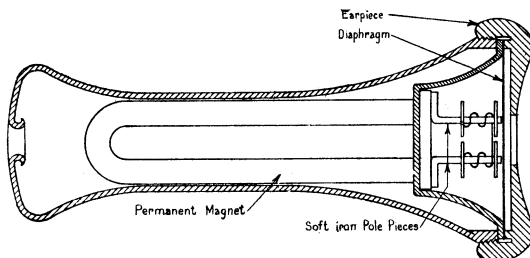


Fig. 3.

The receiver used in connection with the Common Battery telephone system (Fig. 3) is contained in a brass case coated with ebonite and furnished with an ear cap which clamps the diaphragm round its edges. The magnet and pole-pieces are fixed to a small dish-shaped bowl, which, in turn, is clamped



beneath the ear-piece. The outer ends of the pole-pieces and the diaphragm move practically together, with the alterations in length of the brass case of the receiver due to changes of temperature; consequently, variations in the distance between them is reduced to a minimum. The resistance of the coils is 60 $\omega$ .

Another type of receiver which is used on micro-telephones and on operators' headgear apparatus is illustrated in Fig. 4. The magnet is circular in form, and has "consequent poles." This term indicates that a bar or ring is so magnetised that similar poles meet at a point or points in the magnet. In the case of the ring magnet of the receiver, similar poles come together at two points which are at the opposite ends of a

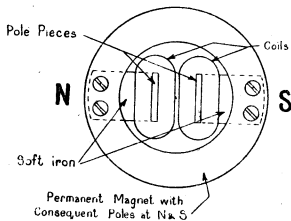


Fig. 4.

diameter of the ring as shown in Fig. 4. *The ring is thus equivalent to two horseshoe magnets with similar poles placed together*, the junction of each pair of similar poles being furnished with a soft iron pole-piece on which a coil of wire is wound. For diaphragms the new magnetic alloy known as "stalloy" (a mixture of silicon, aluminium and iron) is now extensively employed instead of soft iron. The magnetic properties of

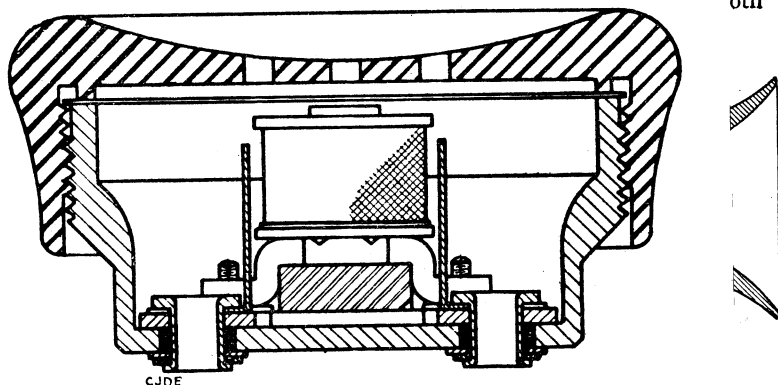
this alloy are equal to those of soft iron, but its "specific resistance" is very high, which reduces the "eddy" currents induced in it when moving in a magnetic field, and thus also reduces the amount of energy wasted. Hence a receiver with a stalloy diaphragm gives somewhat louder received speech than one fitted with a soft iron diaphragm.

## TRANSMITTERS.

Practical telephone transmitters are all of the carbon granule type. The "inset" transmitter is made in the form of an airtight nickel-plated brass capsule. It contains a round, grooved carbon block with carbon granules held between the block and the carbon diaphragm by a couple of turns of flannel surrounding the carbon block and glued to the diaphragm. A small disc of frayed flannel is fixed in the centre of the diaphragm. Movement of the carbon diaphragm *inwards* presses the granules together and the *resistance* between the carbon diaphragm and the carbon electrode is *reduced*. When the diaphragm moves *outwards* the pressure on the granules is reduced, and the *resistance increases*. This effect is due to changes in the area

of contact between the granules, and may be illustrated by

Insert new Fig. 5:



6).  
fact  
oth

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instead of a point, a *contact area* of some extent is created. The resistance between the two spheres will, therefore, vary from a maximum when they are just touching to a minimum when they are heavily pressed together. Movement is greatest at the centre of the diaphragm, and least at the circumference where it is clamped. The granules are, therefore, placed at the centre of the diaphragm so that movements due to sound waves may



Fig. 6.

produce large changes in resistance. A corrugated form of carbon electrode is adopted to prevent the granules from becoming "packed"; because, in this condition, little variation of resistance would occur with movement of the diaphragm, and the instrument would become inefficient. If the back electrode were equal in diameter to the diaphragm, and the space between them filled with granules, there would have been an unvarying resistance between the outer or more or less immovable parts of the diaphragm and the carbon electrode. This would resemble, in effect, a "shunt" across the transmitter, and would very greatly reduce its efficiency.

Page 8, line 1, amend to read :

The solid-back transmitter is illustrated in Fig. 8. This transmitter was the standard type for many years, but it is now being superseded by the inset transmitter. 9/35

carbon block is rigidly attached to the aluminium diaphragm. The front electrode moves bodily with the movements of the centre of the diaphragm, where the maximum motion due to sound waves occurs. The diaphragm is mounted with rubber

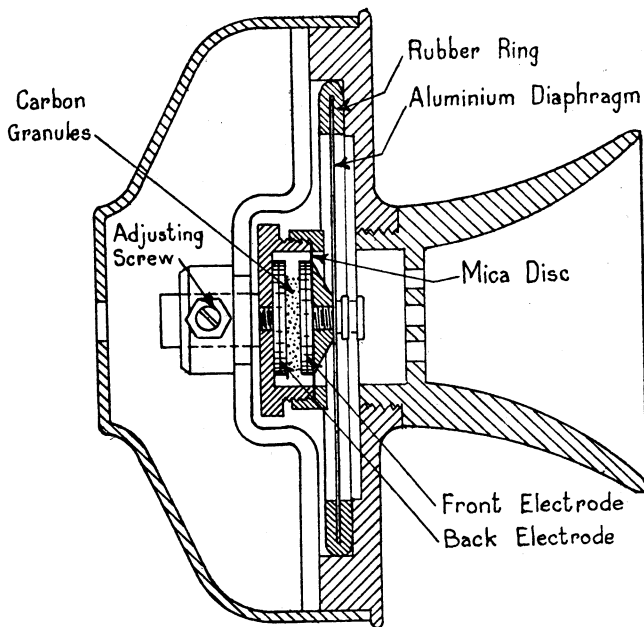


Fig. 7.—SOLID BACK TRANSMITTER.

around its edge, and two rubber-tipped springs also bear upon it in order to deaden or "damp out" persistent vibration, and thus to ensure that the movements of the diaphragm answer to the sound waves as closely as possible. This point can, perhaps, best be illustrated by considering the behaviour of a tuning-fork. The tuning-fork, having been struck, continues to vibrate long afterwards. A telephone diaphragm which had similar properties would seriously distort speech, since the effects of one set of waves would not have died out before another

set impinged upon it. Moreover, sounds which happened to have the same rate of vibration as the natural rate of the diaphragm would be unduly loud as compared with sounds of a different pitch.

Page 9. *Insert new paragraph :*

The standard transmitter used in the latest type of microtelephone is illustrated in Fig. 9. It has a single corrugated aluminium cone diaphragm having a small aluminium cylinder fixed to its centre. This cylinder projects into the granule chamber and carries the moving carbon electrode. The other carbon electrode is fixed to the base of the transmitter case, the faces of the two electrodes being 75-81 mils apart at about the centre of the granule chamber. Rings of silk, forming sliding feet on the cylinder attached to the diaphragm, are clamped in the granule chamber to prevent leakage of the granules. With this arrangement the electrodes are almost completely immersed in granules in whatever position the transmitter may be held.

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... if a particular sound wave causes an alteration of  $1^w$  in the resistance of a transmitter, and the resistance of the transmitter, battery, lines, and receiver amounts to, say,  $100^w$ , the effect on the receiver is due to 1 per cent. variation in the current. If, however, the resistance of the circuit amounted to  $1,000^w$ , the current variation would amount only to one-tenth of 1 per cent., *i.e.*, the received speech would

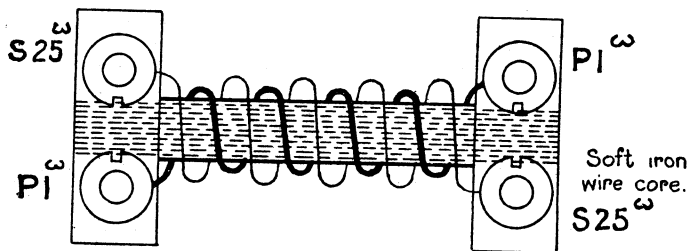
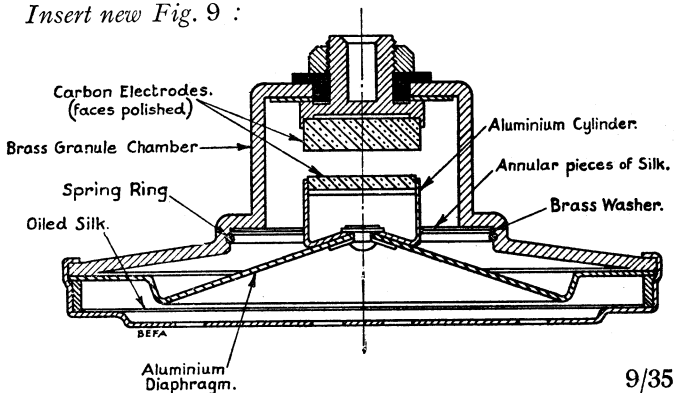


Fig. 8.

be of one-tenth the volume only. In other words, the variations in the resistance of the transmitter would be swamped by the large unvarying resistance added to it.

Induction coils are used with primary battery telephones to eliminate the effect of large external resistances, and also to ensure the maximum variations of resistance in the "speaking

Insert new Fig. 9 :



3

After Fig. 9 insert new paragraph :

There is a tendency for the granules in transmitters to bind together under certain conditions. This is known as "packing" and is more prevalent in the inset type of transmitter. Packing is also associated with the "breathing" effect in microphones, which is due to alternate heating and cooling when switching on and off the feeding current, and to barometric changes operating upon the diaphragm from the exterior. To counteract the latter action a breathing hole of 15 mils diameter is drilled in the outer container of inset transmitters. The hole is sufficient for the purpose and is minute enough to exclude impurities from the air.

Contact is made by a plug and socket for one connexion, and by springs making contact with the transmitter case for the other.

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E.M.F. applied to the primary coil, as the number of turns in the secondary coil is greater than the number of turns in the primary coil. Hence, if 2 volts be applied to a primary coil of 100 turns, an E.M.F. of 200 volts will be induced if the secondary turns number 10,000. The *current* in the secondary coil will, however, be very much smaller than that in the primary, since the power in the secondary is equal to the power in the primary (product of the E.M.F. and current), less internal losses in the arrangement.

The secondary winding is of comparatively high resistance in order that it may contain a comparatively large number of turns of wire and thus provide a relatively high E.M.F. for transmission over the circuit.

The transmitter, battery, and primary of the induction coil are joined in series. If the total resistance of this circuit amounts to  $20^{\omega}$ , a  $1^{\omega}$  variation in the resistance of the transmitter produces a variation of 5 per cent. in the current flowing through the primary circuit. These variations induce similarly varying secondary currents, which pass along the lines, through the distant secondary and receiver, back to the transmitting station. The induction coil necessarily entails a loss of energy in transformation, but this is of small consequence in comparison with the improved overall efficiency of the transmitter system.

Since the current through the primary circuit is always in the same direction, and comparatively large, it is essential that an *open magnetic circuit*, i.e., a magnetic circuit in which air is a portion of the path of the magnetic flux and definite poles are formed, must be employed. Demagnetization on cessation of the current is due to the action of the poles through the core. With alternating currents a closed ring of iron on which the coils are wound would suffice, since demagnetization would be effected at each reversal of the current.

~~It should be noticed that this induction coil (Fig. 8) is furnished with bushes, so arranged that when the coil is screwed into position the primary and secondary windings cannot be reversed.~~

Page 11, lines 38-42, amend to read :

In the old type microtelephone, a lever in the handle of the instrument is employed to complete the circuit of the transmitter, and this lever is kept depressed during speech. In the pedestal pattern and the later pattern microtelephone, the closing of the transmitter circuit is effected by the switch, when this is released by the removal of the receiver.

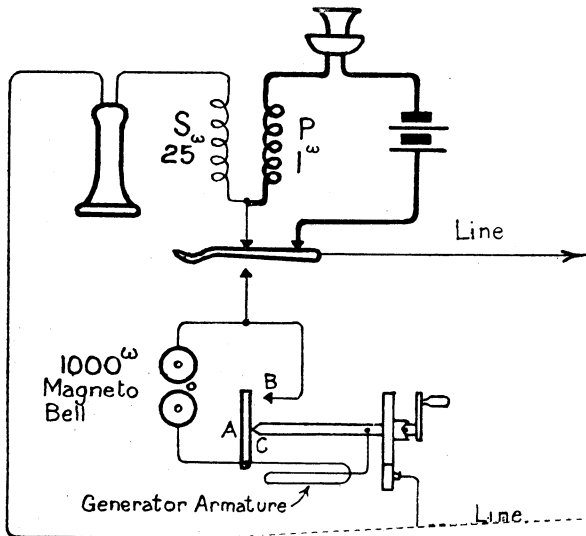
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~~nana micro-telephone a lever in the handle of the instrument is employed to complete the circuit of the transmitter, and this lever is kept depressed during speech. In the fixed transmitter types, such as the pedestal pattern, the closing of the transmitter circuit is effected by the receiver-hook switch when released by the removal of the receiver.~~

The change over from signalling to speaking conditions is brought about by a hook or cradle switch. The receiver, or micro-telephone, normally depresses this switch against the tension of a spring, and in this position the signalling apparatus

is connected. The ~~remover~~<sup>remover</sup> of the receiver or telephone releases the switch and establishes speaking conditions (Fig. 9) (Fig. 11)

The magneto generator usually consists of three permanent magnets furnished with soft iron pole-pieces, between which a Siemens "H" armature wound with fine copper wire is revolved. From Fig. 12a, it will be observed that in the first position the whole of the lines of force pass through the web, whilst in the second position they pass through the ends of the armature. These changes in the magnetic field threading the



Page 12, lines 16-18, delete "the object when making a call,"  
insert new paragraph:

The object of this device is to disconnect the coil of the generator for received rings, and to cut out the bell when originating a call.

With the advent of automatic telephone systems, it has become necessary to provide through-clearing facilities to such exchanges under certain conditions on junction calls. To provide this facility, i.e., a disconnexion when the receiver is on the gravity switch, a condenser is connected in series with the magneto bell, thus alternating current for ringing the bell can flow, but direct current cannot flow until the receiver is removed from the gravity switch. A magneto system providing these facilities is said to be "condensed."

polarity, and a current through the coils of the instrument causes one end of the armature to be attracted and the other to be repelled. Reversal of the current moves the armature in the opposite direction. Attached to this armature is a striker, which

Page 13. Delete existing Fig. 10. Substitute :—

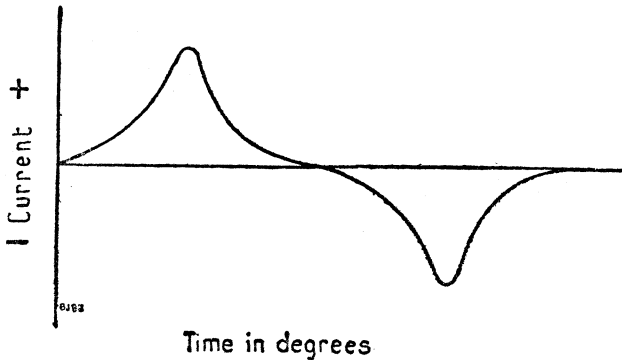


Fig. 10.

It is important to distinguish between the *primary*, *secondary*, and *signalling* circuits. The **primary circuit** comprises the battery, the transmitter, the primary winding of the induction coil, and the leads necessary to complete this circuit when the apparatus is in use. The station portion of the **secondary** or *line circuit* consists of the secondary winding of the induction coil and the receiver, together with the leads necessary to join these to one another and to the external line. When

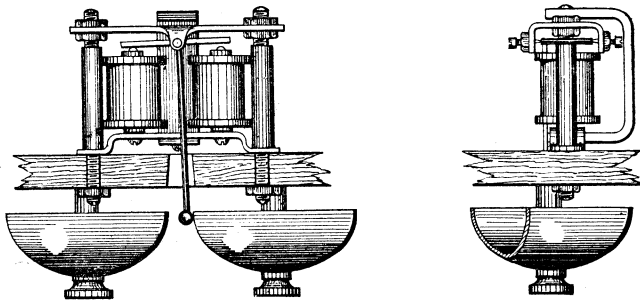
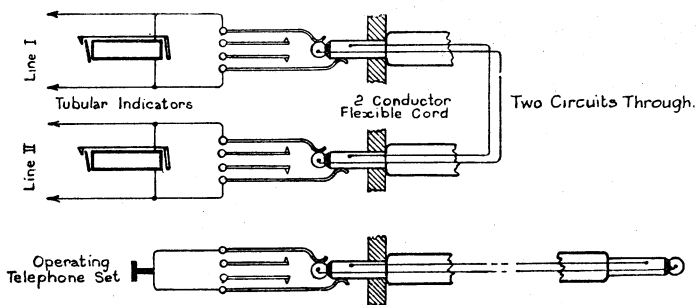


Fig. 11.—MAGNETO BELL.



two receivers are used, they are joined *in parallel*. The station portion of the **signalling circuit** may be divided into that part used to send out a ring and that part used to receive a ring. **Careful consideration of the various circuits and their relation to each other greatly simplifies the tracing of faults.** For example, the case in which it is possible to signal in both directions and to hear speech but not to transmit it, points at once to a disconnection in the primary circuit. It is true that a short-circuit in the secondary winding of the induction coil would produce similar results, but this rarely happens.

The lines of a 2-wire circuit are known as the **A and B wires** respectively, and such a circuit is termed metallic to distinguish it from a single wire circuit in which the earth is used as the return path. In order to prevent overhearing between circuits which run parallel and close to one another, the *A* and *B* wires are, in cables, twisted together, and on open routes, are "revolved together" or crossed at certain intervals, depending on the number of circuits on the route. The result in any of the



Plug in Operating Jack  
Fig. 12.

cases is that an E.M.F. induced in the one wire may be opposed or neutralised by an equal E.M.F. induced in the other wire.\*

### MAGNETO EXCHANGES.

In studying the electrical details of the various telephone switchboards and circuits, the path of the student is easier if he will first make sure that he is familiar with the way in which the apparatus or switchboard is operated.

The simplest case to be dealt with is that in which five or six stations require to be connected to a central switchboard so that any one of them can be spoken to from the central point, and any two can be connected so as to be able to communicate with one another. An indicator is connected across each line which terminates upon a *jack*. These jacks consist of springs

\* This subject is more fully dealt with in Pamphlets A.1 and H.2.

shaped somewhat as indicated in Fig. 12. The indicator consists of an iron-clad electromagnet provided with an armature, which, when attracted, permits a tilted hinged shutter to fall forward by its own weight (Fig. 13). A local contact is usually added so that the circuit of an electric bell may be completed, thus giving an audible signal. An extra jack on the switch-board is connected to the telephone used for operating purposes.

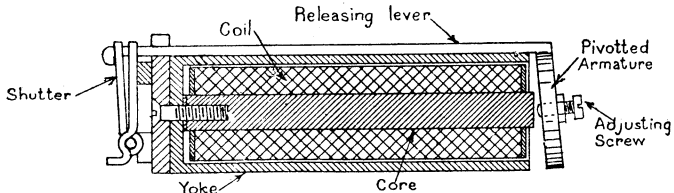


Fig. 13.—SHUTTER INDICATOR.

The procedure is that one of the stations, by turning the handle of his generator, projects the indicator at the Exchange. The attendant, with the aid of a pair of two-way plugs connected together by a two-conductor flexible cord, joins up the operating instrument to the calling line and ascertains which station is required. She then connects the operating instrument to the wanted (or called) line and rings that station. Having obtained a reply she withdraws the operating plug and connects the two stations by means of a pair of cords. The conversation having finished, the subscribers "ring-off" and both indicators fall. The operator then withdraws the plugs and restores the indicator to the normal position.

Since the indicators are connected across the circuit whilst conversations are taking place, it is essential that there should be as little magnetic leakage as possible between any two indicators, in order to prevent overhearing between the various circuits. The iron-clad indicator effectually provides this. The only air gap in the magnetic circuit is that between the pole-piece and the armature and between the armature and the soft iron tube which surrounds the windings. The resistance of the indicator is usually  $1,000^{\omega}$  so as to shunt as little of the speaking current as possible.

**Single Cord Board.**—Similar facilities are readily arranged by connecting each line to a flexible cord and plug, the indicator being connected between the inner springs at the jack (Fig. 14).

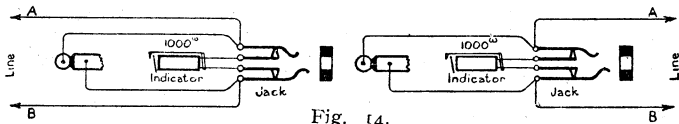


Fig. 14.

The insertion of the plug cuts out the "called" subscriber's indicator, and there is therefore only one indicator across the line. The principal advantage of this board over that previously described is that the calls can be supervised by using the operating plug.

**50 and 100-Line Boards.**—When the number of circuits require it, a 50 or a 100-line board is employed. Separate calling and clearing indicators are provided, and keys for ringing and speaking purposes are added. The lines are connected to the long or line springs of 5-point jacks, the inner springs being connected to the calling indicator. For a 50-line board, ten pairs of plugs and cords are fitted. Each pair is provided with a combined ringing and speaking key, which, in one position, connects the operator's speaking apparatus across the cord, and in the other position sends out a ringing current on the calling plug (Fig. 15). The ring-off indicator is of 1,000<sup>w</sup> tubular type (*i.e.*, shielded to prevent overhearing from magnetic induction); it is in circuit whilst conversations are taking place.

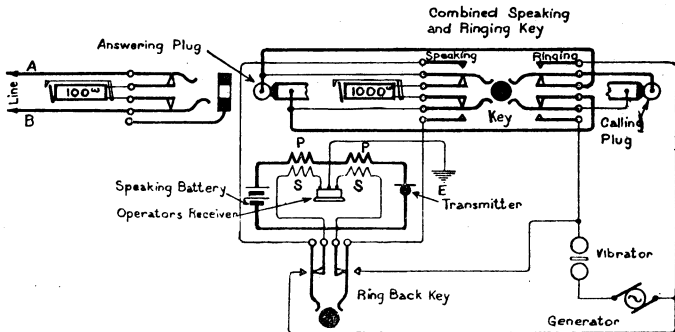


Fig. 15.

The operator's speaking apparatus usually consists of a head-gear receiver and breast-plate transmitter and is connected to the switchboard by a 4-pin plug and flexible cord, the induction coil being located inside the keyboard.

The operations involved in connecting two subscribers together are:—

1. On receipt of the call the operator plugs in with the "answering plug," moves the speaking key to the speaking position, and ascertains the number of the "called" subscriber.

2. The "calling plug" is inserted in the jack of the "called" subscriber and the key is held in the ringing position. A ring is then sent out either by revolving the handle of the switchboard generator or, where the exchange or switchboard is large enough to have warranted the installation of automatic ringing

apparatus in the form of a motor generator or ringing vibrator, connection is made between this and the called subscriber's line by holding the key in the ringing position.

3. The "called" subscriber having answered, the speaking key is placed in the normal position, and this connects the ring-off indicator across the circuit. Should it happen that the calling subscriber has left his telephone, a ring can be given on this plug by putting the speaking key into the speaking position and depressing the ring-back key, which cuts out the operator's speaking apparatus and joins up the generator.

4. The subscribers, having completed their conversation, ring off, and thus project the clearing indicator. The operator then withdraws the plugs and restores the ring-off or clearing indicator to its normal position.

### MAGNETO MULTIPLE.

Where several hundred subscribers are connected to an exchange, a number of operators are required to attend to the calls. If the subscribers are distributed on, say, six positions, it is necessary to make arrangements by which subscribers on one position may be connected to those upon another. This can be effected by "transfer" circuits between the various switchboards, but the arrangement is cumbrous and slow. The

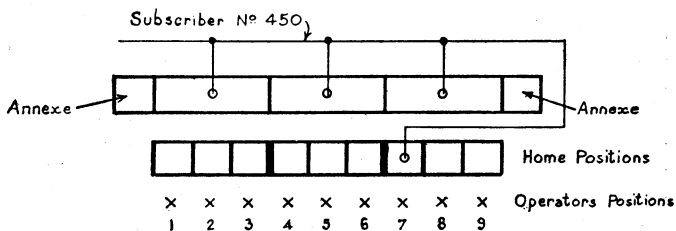


Fig. 16.

difficulty is obviated by "multiplying" the jacks in connection with each subscriber's line at suitable intervals along the switchboard, in such a way that every operator has access to every line connected to the exchange. The principle of this arrangement is illustrated in Fig. 16, where subscriber No. 450 is shown terminating on the seventh operator's position, and connected to the multiple. Operator No. 2 can reach the multiple jacks placed above the operators on either side, but at the beginning and end of the suite of sections the portion of the multiple above operator 3 and that above operator 7 must be repeated. This addition to the multiple is termed the "annexe."

The multiplying of the subscribers' circuits round the exchange necessitates an *engaged test*. It is possible to connect any

given subscriber to other subscribers at each point where the line is repeated on the multiple, and it is, therefore, essential that, a connection having been established, other operators requiring this line shall receive an indication that it is already *engaged*. This is accomplished by the third point of the connecting plug, to which a small battery (one pole of which is earthed) is connected. The insertion of the plug in the jack connects this earthed battery to the bushes of that particular subscriber's line throughout the exchange. The wire connecting the barrel of each subscriber's jack is termed the "test wire." Before an operator makes a connection on the multiple she taps the barrel of the wanted or called subscriber's jack with the tip of her plug. If the line is engaged the earthed battery sends a current through one coil of her receiver and induction coil and produces a click. The absence of a click indicates that the subscriber is free.

The earth connections necessary on the operator's telephone must be symmetrical with respect to the two lines of the circuit, and therefore the induction coil is wound in two equal sections, and the earth is applied at the central point of the operator's receiver. In this way the earth connection does not unbalance the line.

The subscriber's circuit is connected to the long springs of the first multiple jack, and passes *via* the inner springs to the long springs of the next position of the multiple, and so on until finally it terminates on the line springs of the home position, the "home position" being the position on which the line appears for calling purposes. A multiple arranged in this way is termed a "series multiple," and the fact that the circuits are formed through the contacts of the jacks is indicated by saying that "break jacks" are employed. In later systems it will be seen that the line springs of all the multiple jacks for each subscriber's number are joined in parallel, there being very definite objection to the use of a large number of jacks in series.\*

### COMMON BATTERY SIGNALLING.

The Magneto system is gradually being superseded by the Common Battery Signalling system for small exchanges. In this system the act of removing the receiver gives a calling signal at the exchange. The two supervisory indicators on each pair of cords show whether the calling subscriber and the called subscriber have their telephones on the switch-hook or not. On receipt of a call the operator plugs in with the answering plug, and the calling indicator is thereby disconnected from the line. (The supervisory indicator on the answering side of the plug is not affected because the calling subscriber has his receiver off his

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\*Magneto Exchanges are dealt with more extensively in Pamphlets D.4 and D.5.

switch-hook.) Having ascertained the number wanted, the operator plugs in and rings the called subscriber. The supervisory indicator on the called side of the cord is actuated until such time as the subscriber removes his receiver to reply. The conversation having finished, both subscribers replace their receivers, and both the answering and calling supervisory indicators are actuated; the operator then removes the plugs without *entering the circuit to ask if the conversation is finished*. It will therefore be seen that the calling and clearing signals are automatic, as is the case with the Common Battery system (p. 20).

The subscribers' lines are connected to five-point jacks, the inner springs being joined in series to a 1,000<sup>w</sup> bull's-eye indicator and a 24-volt earthed battery (Fig. 17). This indicator consists

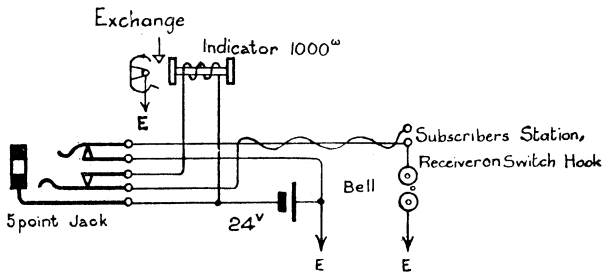


Fig. 17.

of an electromagnet with an armature so shaped that when fully attracted a painted disc is revolved to occupy an aperture in the front part of the strip carrying the indicator.

The subscribers' apparatus is similar to the magneto apparatus already described, but with the generator omitted and the bell normally connected between the *A* line and earth. A current from an earthed generator is sent over the *A* line of the circuit to call the subscriber, whilst the Exchange is called by the subscriber lifting his receiver and looping the *A* and *B* lines of the circuit through his speaking apparatus, thus causing the calling indicator to be actuated (Fig. 17).

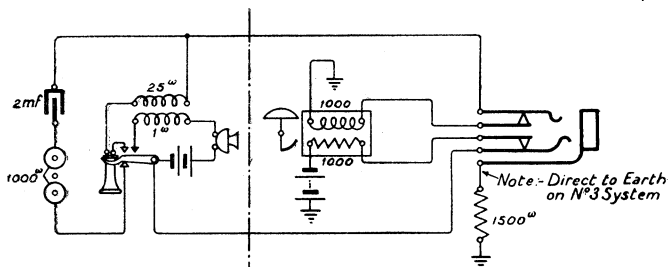
The cord circuit is shown in principle in Fig. 18. The two sides of the cord are connected together by condensers. These condensers permit the passage of the ordinary speaking currents, but, for direct currents, divide the cords into two parts, thus enabling the two clearing indicators to act independently of each other. The two clearing indicators are of the bull's-eye type, and when plugs are inserted in the jacks the 24-volt earthed battery is connected by the barrel of the jack and

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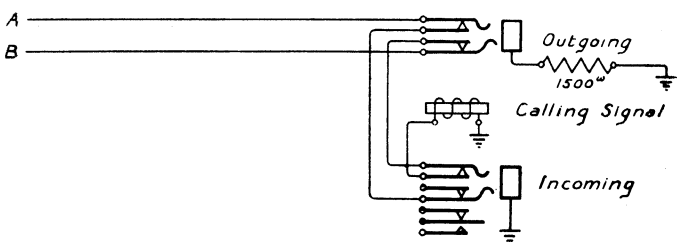
**P.W.-D.1.**

Page 20. Amendment 1/27. Replace Figs. 18a, 18b, 18c and 18d by the following new diagrams.

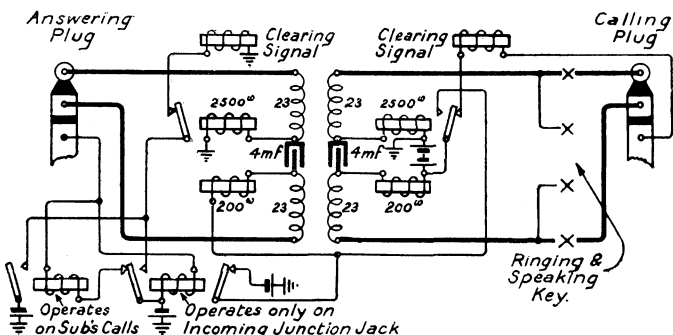
1/29



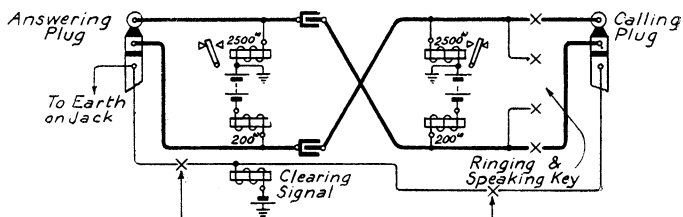
Subscribers' Instrument and Exchange Termination  
C.B.S. N°2 and 3 Systems.



Bothway Junction Circuit  
C.B.S. N° 2 System.



Cord Circuit C.B.S. N°2 System.



Cord Circuit C.B.S. N°3 System.

diagrammatically in Fig. 19. The 22-volt battery is connected between the centres of the four sets of windings of the repeating coil. This repeating coil consists of a circular ring of fine iron wires, upon which the four windings are disposed. Currents passing round windings 1 and 2 induce similar currents in windings 3 and 4, and in this way speech is transmitted between two sides of the pair of cords.

When the subscriber at *A* raises his receiver, current flows through repeating coil winding No. 1, the 17<sup>w</sup> primary winding of the induction coil, the transmitter and repeating coil winding No. 2, back to the battery. Variations in the resistance of the

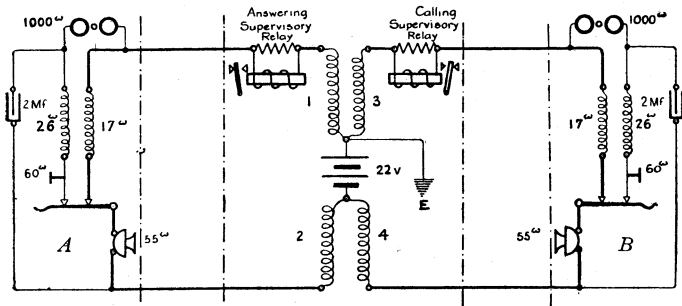


Fig. 19.



the intervention of the condenser and induction coil, the heavy current flowing would reduce the efficiency of the receiver very seriously, and would render factory adjustment before issue extremely difficult and uncertain.

In Fig. 19, the connections of the subscriber's apparatus are shown in skeleton. When the receiver rests upon the switch-hook, the 1,000<sup>ohm</sup> magneto bell and condenser only are connected between the A and B lines; generator rings from the exchange are employed for calling the subscriber, the circuit meanwhile being open (uncompleted) for direct current round the loop. The line relay at the exchange, by means of which the subscriber attracts the attention of the operator when wishing to make a call, is joined in series with the 22-volt battery and the lines, and the raising of the receiver completes the circuit through the subscriber's speaking apparatus, so actuating the line relay and lighting the calling lamp. The insertion of the answering and calling plugs cuts out the line relay of both the calling and called subscribers and establishes the conditions illustrated in Fig. 19.

The supervisory relays, which are connected in circuit with the cords, are heavily shunted by non-inductive resistance. This is because the coils of the supervisory relays have considerable self-inductance, and so offer a good deal of impedance to the passage of speech currents; the non-inductive resistances afford a much easier path for the currents.

It will now be possible to trace the operation of a call.

The removal of the subscriber's receiver completes a circuit of the 22-volt battery through the line relay, the line and the subscriber's speaking apparatus. The line relay, on being energized, lights the calling lamp.

The operator plugs into the jack of the calling line. The 22-volt battery is now connected to the barrel or bush of the jack. This at once puts the engaged test on this subscriber's circuit and disconnects the line relay, and the calling lamp therefore ceases to glow. The supervisory relay on the answering side of the pair of cords is energized by the current which passes out through the repeater and subscriber's speaking apparatus; this prevents the lighting of the supervisory or clearing lamp. The operator now places the calling plug in the jack of the called subscriber's line (if disengaged) and rings. The supervisory lamp on the calling plug side glows until it is darkened by the current which flows round the loop as the result of the removal of the called subscriber's receiver. C.B. working may be arranged in a number of different ways, but the consideration of these details will be obtained from the pamphlets dealing with the various systems.\*

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\* See Pamphlets D, 8, 9, 10, 11 and 12.

## JUNCTION CIRCUITS.

Large towns are usually served by a series of exchanges, and in order that a subscriber on any one exchange may be connected to subscribers on the other exchanges it is necessary to link the various exchanges together by "Junction" circuits. The term "Trunk line" is used to denote circuits connecting different telephone areas, that is, different towns or groups of towns.

In the case of a couple of very small exchanges, such as would be served by 50-line magneto boards, the junction circuit may be of the type illustrated in Fig. 20. The circuit terminates upon an 8-point jack at each switchboard, condensers being interposed at each end in order that the currents from the junction signalling battery may not affect subscribers' circuits connected to the junction. A pair of bridging coils is placed across the circuit at each end, and, with the aid of an indicator, battery and the three upper springs of the 8-point jacks, signalling is provided. The insertion of a plug joins up the battery through the indicator used for both calling and clearing to the centre of the bridging coils. The current divides between the two lines of the circuit

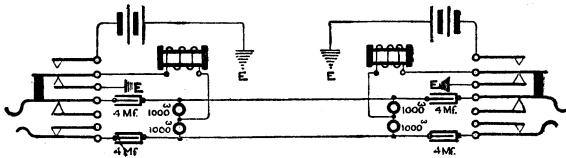


Fig. 20.

and reunites to flow through the indicator at the distant end. In this way the insertion of a plug produces a call at the distant exchange. The distant operator, on plugging in, connects up an opposing battery which neutralises the incoming current, and both indicators return to the normal position. On completion of the conversation the subscribers ring off, thus dropping the cord circuit ring-off indicators. The operator at the end where the call originated withdraws the calling plug from the junction jack, and both junction indicators are actuated until the operator at the other end has withdrawn the answering plug, when both junction clearing signals are restored to normal. A junction circuit of this character would be termed "both-way ringing junction" from the fact that the junction circuit is used both for calls to and from each exchange, and that demands for connections are made over the junction circuit itself, as distinct from those junctions in which the request for the connections of a particular subscriber is made by *order wire*.

In large exchanges having multiple switchboards it is essential that each *A* operator (*i.e.*, the operator accepting calls

directly from subscribers on the exchange, and controlling the large majority of calls thus originated) shall be able to obtain access to the junction circuits serving the various exchanges in the area. It, therefore, becomes necessary to multiple the junction circuits round the exchange in a similar fashion to that in which the subscribers' circuits are multiplied. This junction multiple is placed above the lamps and jacks of subscribers on each home position and beneath the multiple of other subscribers in the exchange. These circuits are termed "**outgoing**" junction circuits, since they are used only for the completion of calls made by subscribers on the home positions to subscribers on other exchanges. The multiplied junction terminates at the distant exchange in a cord and plug, thirty of these circuits being allotted to each *B* or "**incoming junction**" operator. With the aid of an engaged test somewhat similar to that used in the case of subscribers' circuits the *A* operator is able to ascertain which junction circuit is disengaged, and by suitable signalling arrangements the insertion of the calling plug in an outgoing junction jack calls the distant exchange, where the operator, on entering the circuit, ascertains the number of the subscriber required.

Where there is a large group of junction circuits between the same exchange this process is slow and cumbrous, and in order to avoid the difficulty a special call wire circuit known as an "**order wire**" is provided between the two exchanges. A key marked with the name of the distant exchange enables each operator to connect her speaking apparatus to this circuit, which terminates at the distant exchange on the speaking apparatus of the *B* operator in charge of the incoming end of these junctions.

Requests for connections are passed by the operator depressing the order wire key and giving the number of the wanted subscriber. The operator in charge of the incoming junction circuit sees at once which junction circuits are not in use (since the plugs connected to disengaged circuits are, of course, not inserted in jacks), and then nominates the number of the junction circuit to be used; speaking apparatus is not provided on the incoming junctions themselves in an order wire group.

The signalling arrangements on a junction circuit of this character are such that, taking the case of two C.B. exchanges, the two supervisory lamps at the calling end represent the conditions of the calling and called subscribers at the "home" and distant exchanges respectively. When both these lamps light, the operator at the home position withdraws both plugs. This gives a clearing signal at the incoming end of the junction circuit, and the *B* operator breaks down the connection.

This junction circuit is illustrated only as a typical example of the arrangements necessary. Various complications arise owing to C.B. exchanges having to be connected to C.B.S. or Magneto exchanges. Moreover, ringing junctions and both-way junctions require special treatment. For example, it may happen that in the case of a large exchange, only two junction circuits are justified to a small exchange in the vicinity, and, consequently, order wires are not provided. These junctions are used "both-way," and terminate both on the outgoing junction multiple and on the incoming position, special signalling arrangements being required to ensure the proper use of the circuits.

In some cases arrangements are made whereby the insertion of the incoming junction plug in the subscribers' multiple automatically rings the wanted subscriber without the intervention of the *B* operator, and the clearing or supervisory lamp darkens only when the called subscriber replies.

A large exchange, therefore, consists of a number of *A* positions, on which the subscribers connected to that exchange terminate, and in addition, a number of *B* positions, on which the incoming junction circuits from the various exchanges are terminated. The *B* positions are provided with a subscribers' multiple in the same way as an *A* position, since these operators require to be able to make connection to any subscriber on their exchange. The practical limit to the size of a manual exchange is controlled by the length of the operator's arm, and in practice it is found that 10,000 subscribers represent the limit of the number of subscribers' multiple jacks which can be placed within the reach of each operator.

## TRUNK LINE WORKING.

A trunk line may be defined as a line connecting different telephone areas. In the case of these lines special arrangements are necessary, and in very large offices there is a separate trunk exchange. Between the trunk and local exchanges junction circuits are required. Also, a number of transfer circuits are necessary between the various trunk sections for through calls from one trunk line to another.

At the end of a trunk circuit in a small exchange a combined switch-spring and indicator is employed, as shown in Fig. 21.

A current passing through the indicator causes the armature to be attracted and allows the disc of the indicator to fall forward, thus showing that attention is required. The insertion

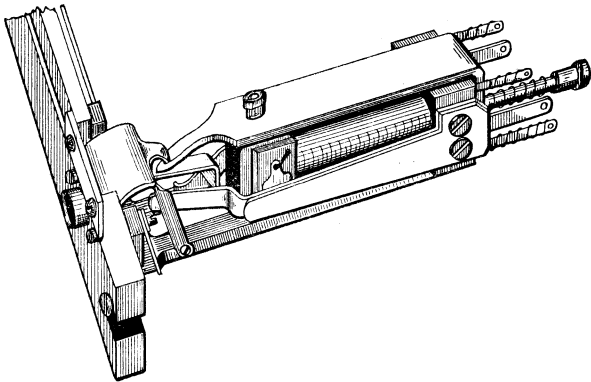


Fig. 21.—SWITCH SPRING INDICATOR,

of a plug in the jack mechanically restores this disc to its normal position and, at the same time, cuts out the whole of the apparatus connected to the inner springs (Fig. 22). A condenser is placed in series with the indicator, the object being to prevent the passage of steady currents while allowing the alternating ringing current to pass through and actuate the indicator. A 24-volt battery earthed in the centre is connected *via* two  $200^w$  bridging coils to the inner springs of the jack. The function of this arrangement is to provide an automatic

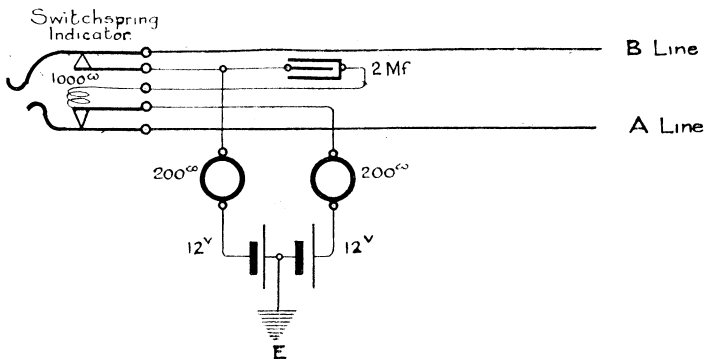


Fig. 22.

clearing signal on withdrawal of the plug. To call this station, the trunk exchange at the other end of the line rings with the generator. On completion of the conversation, the withdrawal of the plug from the jack, and the consequent application to the line (through the inner springs of the jack) of the 24-volt battery, gives a clearing signal on the cord circuit at the trunk exchange at the distant end.

At large trunk exchanges relays and lamps are employed for calling and clearing. Two keys, each having two positions, are provided on each cord circuit to enable the operator to speak on either the answering or the calling side of the cords, or to speak to both stations at once without removing the plugs from the jacks, and also to ring with the generator on either side.

It is impracticable here to describe the various arrangements necessary for a trunk exchange, but it will perhaps be useful to describe here the method of "putting through" a trunk call. Suppose subscriber 150, on Exchange "Y" requires subscriber 1600 on Exchange "Z" in a different area. Subscriber 150 raises his receiver, and his home operator plugs in and receives a request for "trunks." She immediately connects him to a "record circuit" to the trunk Exchange, which terminates in an operator's headset. This operator prepares a ticket giving the number (150) and exchange ("Y") of the calling subscriber and those of the wanted subscriber (1600, "Z" exchange). The record operator informs the subscriber that he will be rung up later and gives a clearing signal. This connection is then broken down. The ticket is taken to the section on which the trunk line to "Z" is located. The trunk operator deals with these tickets in turn. When the turn of his call arrives the trunk operator obtains subscriber 150 "Y" through a junction circuit to the local exchange. The distant trunk station is then rung by generator current, and the wanted subscriber is there connected to the trunk line. On completion of the conversation, or at the end of the allotted time, the originating trunk operator withdraws the plugs; a clearing signal is automatically given to the distant exchange and to local exchange and the connection is severed.

Latterly it has become necessary to work the shorter trunk lines on the same principle as junctions, terminating them on the B boards at larger exchanges, the ordinary junction arrangements being used.

==== LIST OF ====

# Technical Pamphlets for Workmen.

(Continued.)

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## GROUP E.

1. Automatic Telephone Systems

## GROUP F.

1. Subscribers' Apparatus C.B.
2. Subscribers' Apparatus C.B.S.
3. Subscribers' Apparatus Magneto.
4. Private Branch Exchange—C.B.
5. Private Branch Exchange—C.B. Multiple, No. 9.
6. Private Branch Exchange—Magneto.
7. House Telephones.
8. Wiring of Subscribers' Premises.

## GROUP G.

1. Secondary Cells, Maintenance of.
2. Power Plant for Telegraph and Telephone Purposes.
3. Maintenance of Power Plant for Telegraph and Telephone Purposes.
4. Telegraph Battery Power Distribution Boards.

## GROUP H.

1. Open Line Construction, Part I.
2. Open Line Construction, Part II.
3. Open Line Maintenance.
4. Underground Construction, Part I.
5. Underground Construction, Part II.
6. Underground Maintenance.
7. Cable Balancing.
8. Power Circuit Guarding.
9. Electrolytic Action on Cable Sheaths, etc.
10. Constants of Conductors used for Telegraph and Telephone Purposes.

## GROUP I.

1. Submarine Cables.

## GROUP K.

1. Electric Lighting.
2. Lifts.
3. Heating Systems.
4. Pneumatic Tube Systems.
5. Gas and Petrol Engines.

## GROUP L.

1. "Safety First" for P.O. Engineering Workers