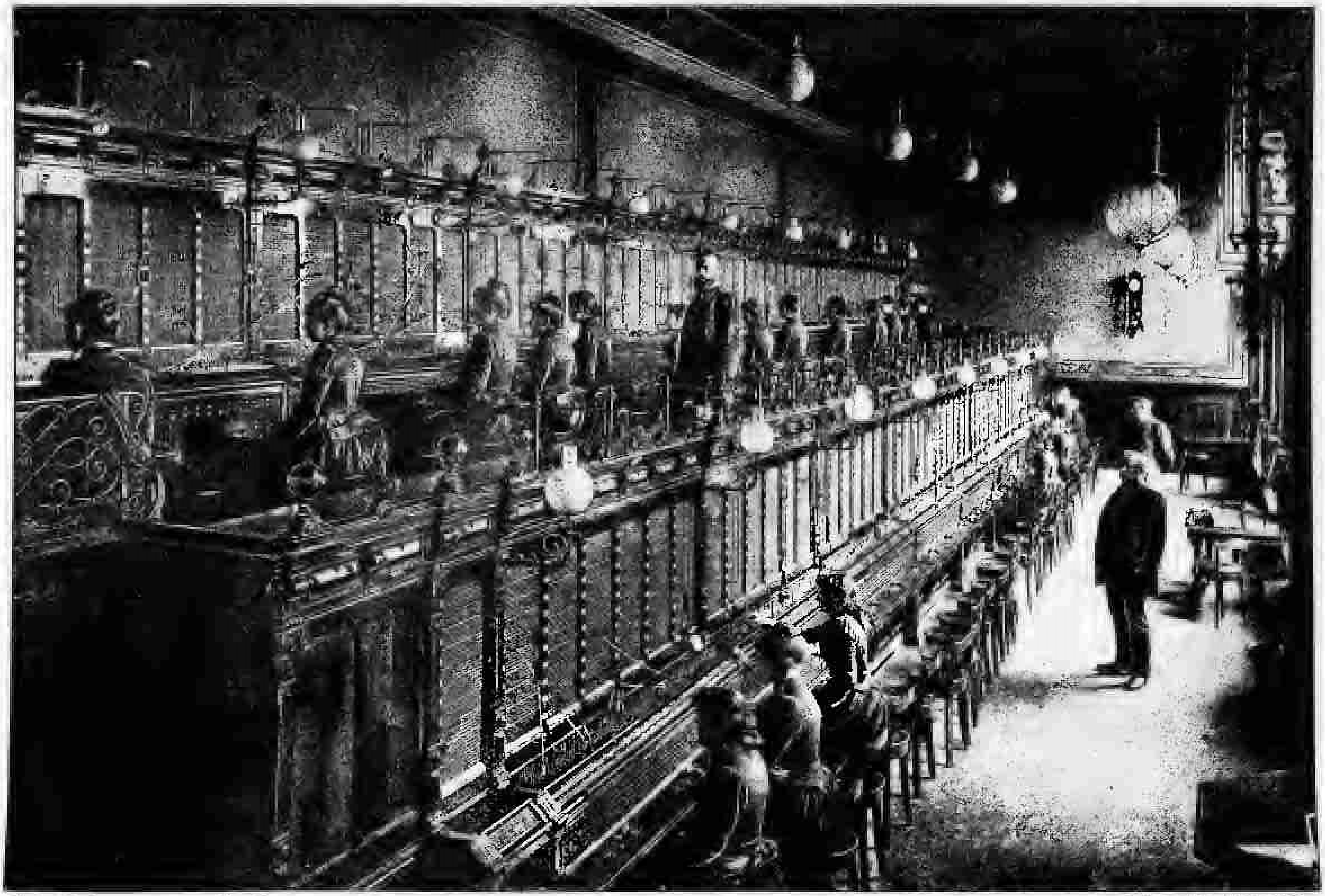
TELEPHONES

THEIR CONSTRUCTION & FITTING

ALLSOP



E. & F. N. Spon, London & New York

THE BERLIN TELEPHONE EXCHANGE.

(Frontispiece.)

TELEPHONES:

THEIR CONSTRUCTION AND FITTING.

A PRACTICAL TREATISE ON
THE FITTING-UP AND MAINTENANCE OF TELEPHONES
AND THE AUXILIARY APPARATUS.

BY

F. C. ALLSOP,

AUTHOR OF 'PRACTICAL ELECTRIC BELL FITTING,' 'ELECTRIC BELL CONSTRUCTION,'
'PRACTICAL ELECTRIC LIGHT FITTING,' ETC.

210 ILLUSTRATIONS.

SECOND EDITION, REVISED AND ENLARGED.

E. & F. N. SPON, 125, STRAND, LONDON.
NEW YORK: 12, CORTLANDT STREET.
1892.

PREFACE TO FIRST EDITION.

THE breaking-up of the telephone monopoly throws open a vast field for development—that of erecting "private lines" between offices and works, residences and stables, different parts of large business establishments, and the thousand and one other places where telephonic communication proves not only an immense convenience, but also a means of saving both time and money. Many persons thus find themselves required to fit up for the first time an instrument with whose construction and working they are totally unacquainted, and whose aptitude for developing "faults" if not properly erected, is oftentimes really marvellous. I have endeavoured, therefore, in the following pages, to give practical instruction on the working and fitting up of telephones, and also such hints as will enable an intelligent fitter with a little practice to readily detect and remove the different "faults" that are liable to appear. Like my former works, the greater portion of this book originally appeared as a series of articles in the 'English Mechanic.'

F. C. ALLSOP,

OF F. C. ALLSOP & CO.,
MANUFACTURING ELECTRICIANS,
165, QUEEN VICTORIA STREET, E.C.

PREFACE TO SECOND EDITION.

THE very rapid exhaustion of the first edition necessitated the immediate production of the second, and advantage has been taken of the opportunity thus afforded to thoroughly revise the whole of the matter and bring it up to date. The book has been greatly enlarged, both by the addition of new illustrations as well as fresh matter, the more prominent of the former being some large folding plate diagrams. Throughout the entire revision I have endeavoured to keep to my original project, viz., to provide a complete and thoroughly practical instruction book for those engaged in the erection or maintenance of telephones.

F. C. ALLSOP,

165, QUEEN VICTORIA STREET, E.C.

CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

LIST OF ILLUSTRATIONS.

TELEPHONES:

THEIR CONSTRUCTION AND FITTING.

CHAPTER I.

RECEIVERS.

A TELEPHONE instrument consists essentially of three parts: we have first the *transmitter*, second the *receiver*, and third the calling and switching apparatus, or *switch-bell* as it is commonly called. The transmitter transforms the vibrations produced by the sound-waves into undulating electric currents, which currents are transformed back by the receiver into sonorous vibrations. The switch-bell sends and receives the signal to call attention, and makes the necessary change of connections from signalling to speaking

The whole combination of line wire, instruments, &c., is generally called a "telephone line," and a telephone line may be either "exchange" or "private." In an "exchange" telephone system one end of each subscriber's wire is taken to a central exchange or switch-room, where, by means of certain switching apparatus, each subscriber can be put into communication with any other subscriber on that exchange, while a "private" line is one erected merely for a person's own use between his office and works, office and residence, or other places between which communication may be desired.

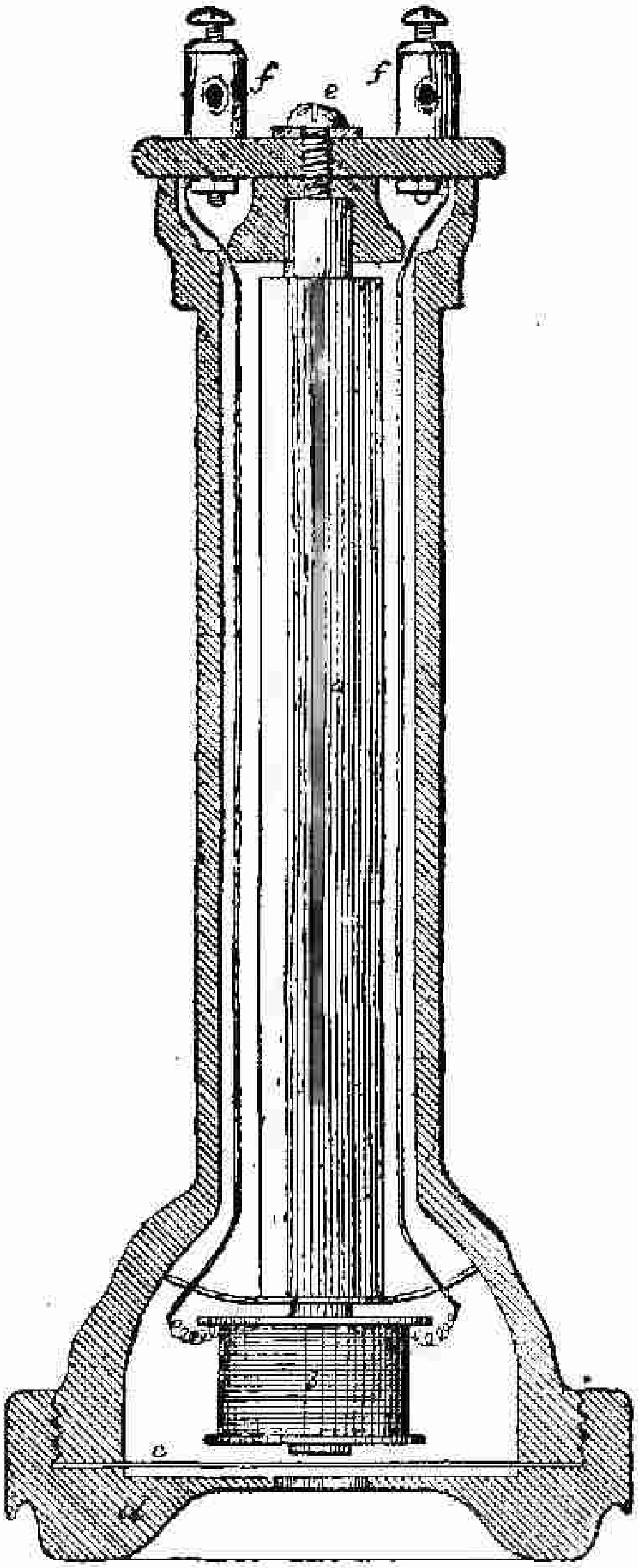
As most forms of receivers can be used also as transmitters, and are in fact for short lines often preferable to a microphone on account of their simplicity, receivers will be described first.

The Bell Receiver.

To Prof. Graham Bell has been ascribed the honour of inventing the first practical magnetic telephone, and Fig. 1 shows in section the most general form of this instrument in use at the present time. A laminated permanent magnet is used, as in this form it is less likely to lose its magnetism. This magnet *a* carries at each end two soft iron pole-pieces, the lower one of which holds the boxwood bobbin *b*, wound with No. 40 B.W.G. silk-covered copper wire, to a resistance of from 70 to 80 ohms. This magnet is contained in an ebonite case of the shape shown, and has opposite its lower end the thin ferrotype iron diaphragm *c*, the diaphragm being held in its position by the lid *d*, which screws on and off. The diaphragm is fixed only at the circumference, and in the centre is free to vibrate to and fro. Into the top pole-piece screws the screw *e* by means of which the distance of the other end of the magnet off the diaphragm is adjusted. On either side of this screw are the terminals *f f*, to which the ends of the bobbin *b* are connected.

The action of the instrument is as follows:—Sound, as is well known, is the sensation produced in the ear by certain vibrations or undulations of the atmosphere. When we speak, air is forced out of the lungs through two delicate membranes situated in the upper part of the throat, called the vocal chords, which set the air as it passes over them in vibration, the number of these vibrations per second determining the pitch of the sound, while their amplitude determines the loudness. If we take two receivers (see Fig. 2), of the form shown in Fig. 1, and connect by means of two insulated wires, the right-hand terminal of the one (A) to the right-hand of the other, and the left-hand of one to left-hand of the other (B), we shall have a complete circuit right through the two receivers. If now we speak in front of one of these receivers,

Fig. 1.



Single-pole Bell Receiver.

the best position being when the lips are about an inch from the mouthpiece, the sound-waves produced impinging on the

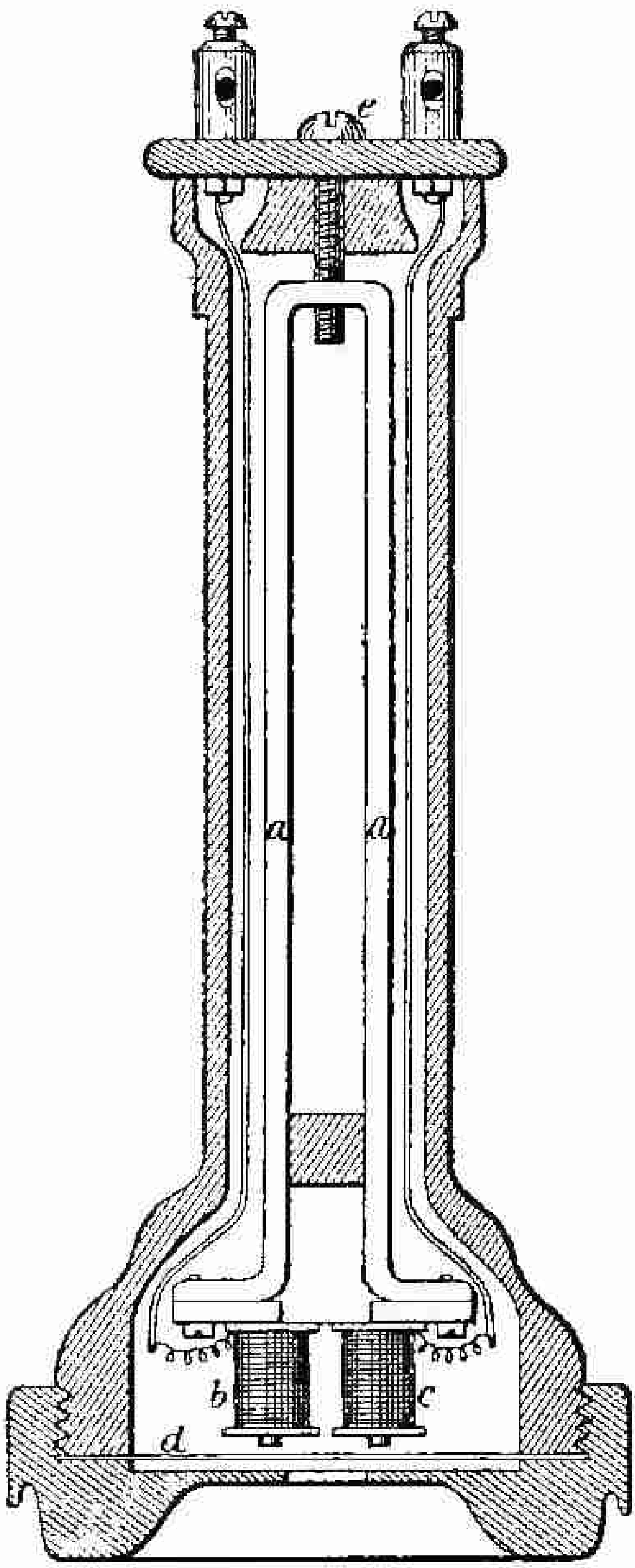
Fig. 2.

Two Receivers connected.

diaphragm *c* cause it to vibrate in unison with them. The diaphragm *c*, vibrating in front of the magnet, varies the number of lines of force that pass through the coil *b*, thus inducing in the coil electric currents which vary rapidly both in direction and electromotive force. These currents flow by means of the insulated wires to the second telephone, and, by passing through its coil, strengthen or weaken the permanent magnet according to their direction, causing it to vary its attraction on the diaphragm in front, which thus vibrates in unison with the diaphragm in telephone No. 1. Words thus spoken to the one receiver are faithfully reproduced in the other, though very much reduced in loudness. Certain sounds are better reproduced than others, the sibilants being the most difficult to reproduce, this being due most probably to the complexity of their vibrations. The Bell receiver shown in the illustration is about three-quarter full size.

A more powerful form of receiver can be obtained by employing a horseshoe magnet, and receivers thus made are known as "double-pole" as differing from the "single-pole" just described. The double-pole Bell receiver is shown in section in Fig. 3. By employing a horseshoe form magnet, both the N and S poles of the magnet are presented to the iron diaphragm, thus bringing it into a more intense magnetic field. The magnet consists of a flat steel rod *a* (bent to the shape shown), on the N and S poles of which are fastened the two oval-shaped bobbins *b* and *c*. The iron cores of the bobbins are screwed to the magnet ends, thus forming soft iron polar extensions of the magnet, the lower ends of the

Fig. 3.



Double-pole Bell Receiver.

cores coming close to the diaphragm *d*. The adjustment is effected as with the single-pole type by the screw *e*, which varies the distance of the two poles off the diaphragm. The two coils are connected in series, and arranged in the usual manner, i. e. so that a current in one direction would give a N to one and a S to the other, and not two N's or two S's. Thus when the rapidly alternating and undulating current from a transmitter passes through the coils it weakens or strengthens the N and S poles, as described for the single-pole type, which thus vary their attraction on the diaphragm.

Fig. 4 shows the external appearance of the "single-pole" and Fig. 5 that of the "double-pole" Bell receiver.

Fig. 4.

Fig. 5.

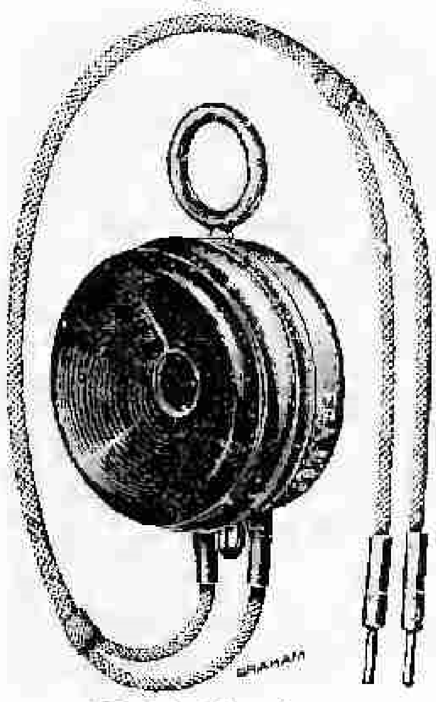
Bell Receivers.

Although by "Bell" receiver is more generally understood the form shown in Figs. 1, 3, 4, and 5, yet nearly every magnetic receiver is a modification or re-arrangement of the original

Bell instrument, certain modifications being introduced by the different inventors, with a view to increase the efficiency or render more compact.

A very compact form of receiver is that shown in Fig. 6, and known as the "watch," owing to its resemblance to that article. It is a double-pole receiver, and consists of a flat horseshoe magnet, similar in shape to that in the Gower (see Fig. 8), with two oval-shaped bobbins on the soft iron polar extensions. The diaphragm, which is of thin ferrotype iron, is clamped between the lid and body of the case, the lid screwing on and off, as shown in the Bell. The receiver is suspended when not in use by the ring at the top, and the terminals are inside the case, the two metal-pointed ends of the receiver cord passing through two holes in the bottom of the case for the purpose of making connection with the terminals. It is not so powerful as the Bell receivers shown in Figs. 1 and 3, but is an exceedingly handy form, and gives very good results on short lines.

Fig. 6.



Watch Receiver.

The Membrane Receiver.

This receiver, which was also invented by Bell, was the one he adopted previous to his bringing out the improved form just described. It had an electro-magnet and goldbeater's skin diaphragm, in the centre of which was fixed a small steel plate. After experimenting with different forms of this instrument, Bell found that better results were obtained if he substituted a thin sheet-iron diaphragm for the goldbeater's skin one, and that also by using a permanent instead of an electro-magnet, he could do away with the necessity of having a battery in circuit. Owing to the details of this first form of Bell's receiver being published in the 'English Mechanic' of August 1879, this form of the receiver is also known as the "English Mechanic" receiver. Some time after patenting his improved form, Bell filed a disclaimer repudiating all claim to his former instrument, so this form of receiver was free to be used and manufactured by any one while Bell's patent was in force, and was the form of transmitter and receiver used during that time by such telephone companies as were not licensed by the United Telephone Company.

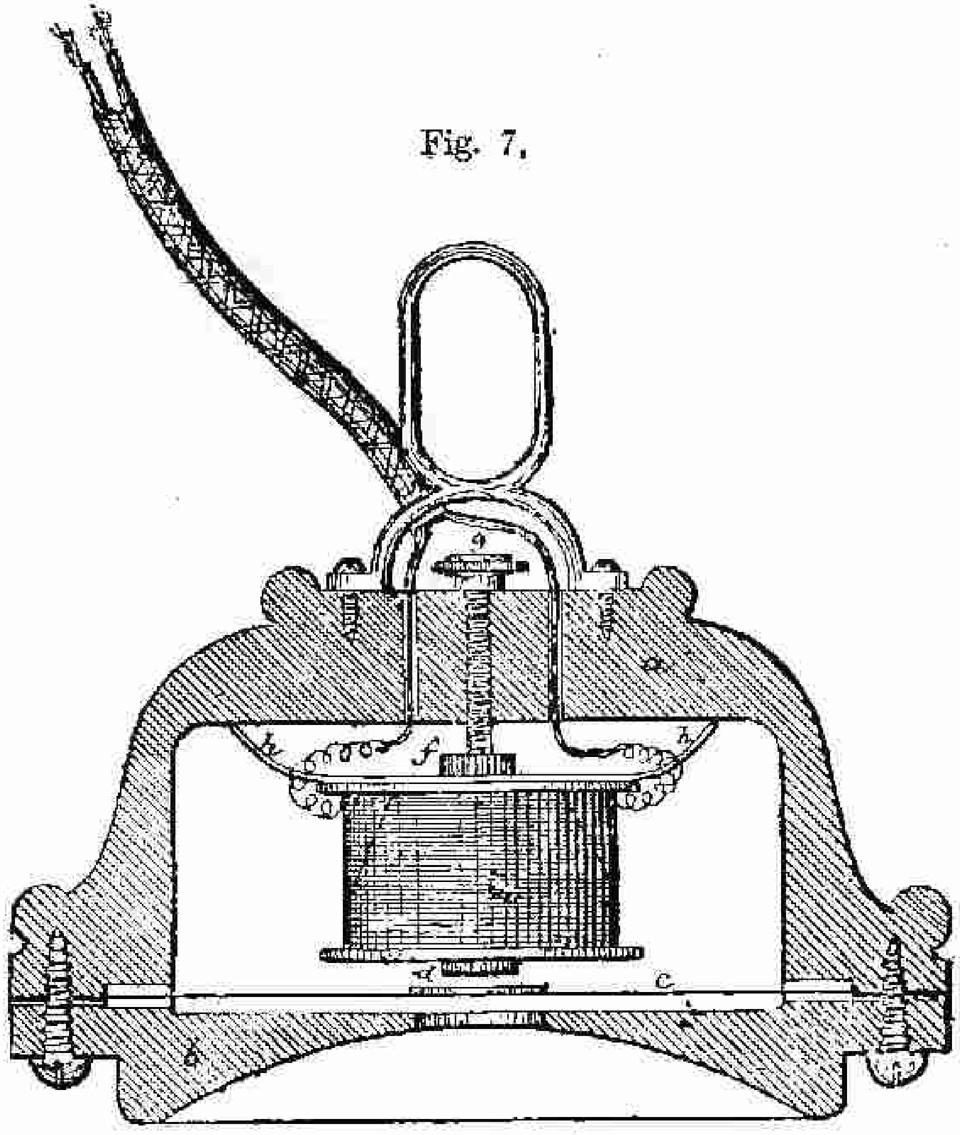
Fig. 7 shows, full size, partly in section, a form of the membrane receiver. It consists, as will be seen, of a boxwood, mahogany, or ebonite case *a*, fitted with a lid *b*, the lid being fastened to it by the screws shown. Between the lid and the case is the diaphragm *c*, which may be of goldbeater's skin, parchment, or any similar material, and preferably one not much affected by atmospheric changes, the diaphragm being stretched on a brass or zinc ring or clamped between two, as shown in the illustration. In the centre of the diaphragm is the disc *d*, of tinned iron, which is affixed to the diaphragm by rubber solution or other similar cementing compound. The adjustment is effected by the screw *g*, which pulls against the spider wheel *h*.

It is in making a diaphragm that will resist the atmospheric changes that the difficult part of a membrane receiver comes in. The first forms introduced proved almost useless on account of their diaphragms, which would be taut one day, while the next perhaps they would be so slack as to quite prevent the transmission of speech. Swinton used a thin sheet of vulcanised fibre for the diaphragm of his receiver, but what seems to have given the best results is celluloid.

With the Bell receiver, owing to the magnet being a permanent one, no battery is required when two receivers are joined up together for the purpose of speaking between two places; but with the "English Mechanic," or other receivers which have an electro-magnet, a battery is, of course, necessary.

The expiration of the Bell patent on Dec. 9, 1890, proved

Fig. 7.



Membrane Receiver.

the death-stroke of the membrane receiver, since it was only employed as a means of avoiding this patent, and is not for a moment to be compared, both as regards convenience and speaking capabilities, to a properly constructed Bell receiver.

The Gower Receiver.

Figs. 8 and 9 show the Gower receiver—the one used by the British Post Office. Fig. 8 is a view from the front with the diaphragm removed, while Fig. 9 is a side view, partly in section and partly in elevation. The permanent magnet *a*, it

Fig. 8.

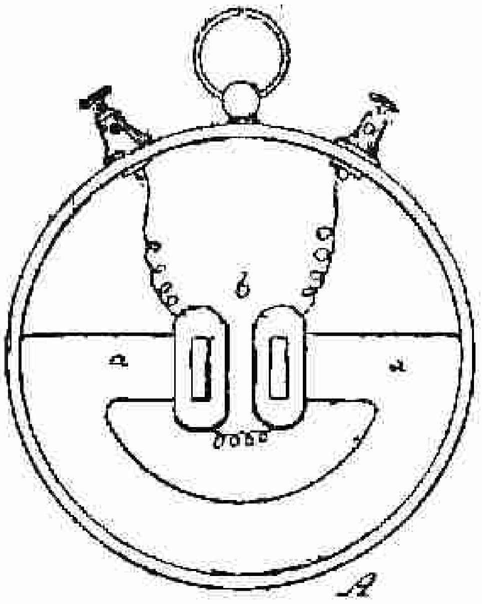
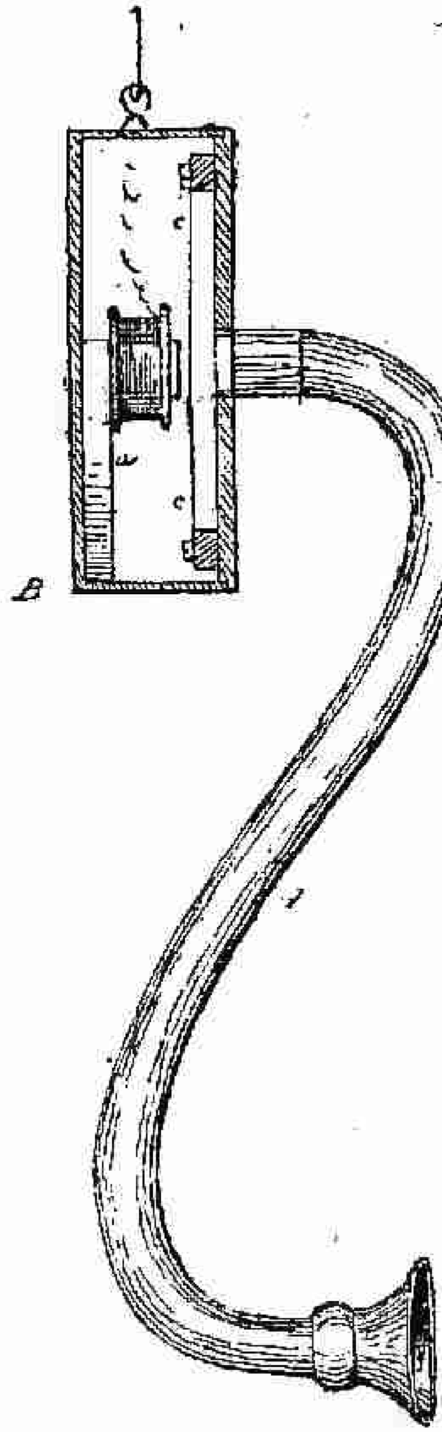


Fig. 9.



Gower Receiver.

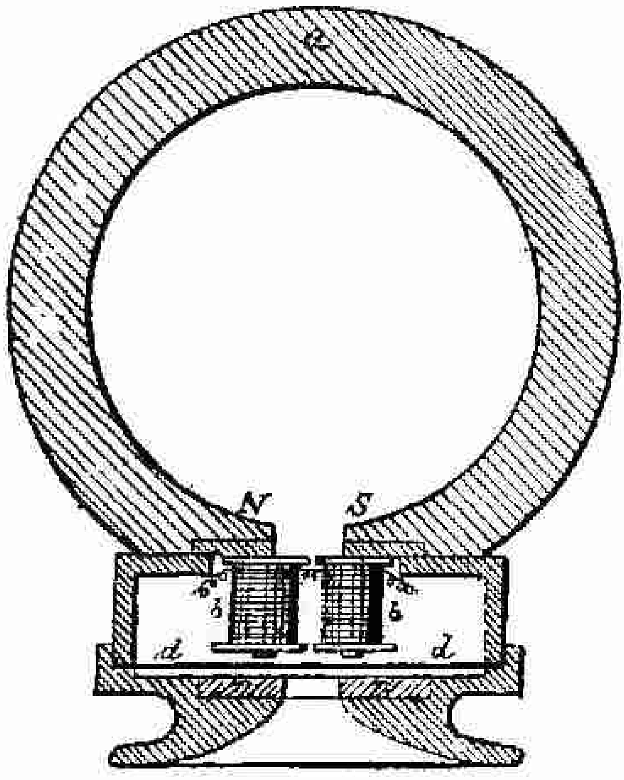
will be seen, is semicircular in form, and has at each pole two bobbins of wire, the soft iron cores of which form extensions of the two poles. The diaphragm *c*, which is generally of tinned iron, and somewhat larger than in the Bell, is carried by the front of the case, being fastened on to a brass ring by screws, as shown. In order to convey the sound from the diaphragm to the ear, a flexible tube *d* is provided of the form used for speaking tubes.

In the Gower-Bell combination the receiver is placed inside the switch-bell case, and the speech transmitted to the ears by two flexible tubes.

THE ADER RECEIVER.

Fig. 10 shows, partly in section and partly in elevation, the Ader receiver, which is the one employed by the Société Générale des Téléphones in France, and which is also largely used in Belgium and Austria. It is undoubtedly entitled to take rank as one of the most powerful and sensitive of receivers. It consists, like the Gower, of a semicircular magnet *a*, that

Fig. 10.

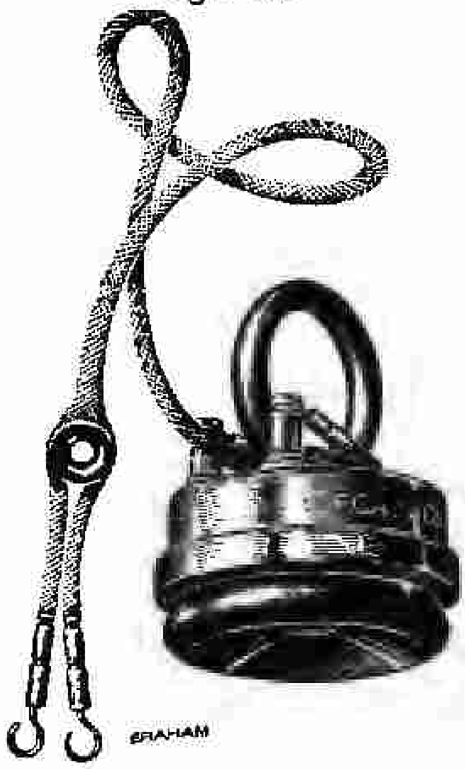


Ader Receiver.

carries at its polar extremities two iron cores, on which are fixed the two bobbins *b b*. The diaphragm *d*, which is of thin tinned iron, is clamped between the lid and body of the case, outside which case the magnet projects, thus serving also as a handle. The chief feature of the Ader receiver, however, is the soft iron ring *n n*, fixed in the front of the case, which intensifies the magnet field. This iron ring, which M. Ader calls the "sur-excitateur," concentrates the lines of force, causing the variations in the magnetism of the magnet to have a greater effect on the diaphragm, thus increasing the sensitiveness of the receiver.

In the smaller form of Ader receiver, which of late has been much used in this country, the magnet does not project through the back of the case, but is of small size and contained within it; this form is shown in Fig. 11. It is also

Fig. 11.



Ader Receiver.

to be obtained mounted as a Bell, as shown in Fig. 12, or as a spoon receiver, as shown in Fig. 13. The containing case of the Ader receiver is usually of metal, and the mouthpiece of ebonite, all external metal parts being plated.

The D'Arsonval Receiver.

In the receiver designed by M. D'Arsonval, and of which Fig. 14 is a section, the permanent magnet is bent into such a shape that one pole fastens to the iron core of the bobbin, and the other to an iron tube that surrounds the bobbin. In the figure *a* is the permanent magnet, *b* the iron core of the coil of wire, and *c* the iron tube surrounding it. The iron core has a threaded part at the top, which part screws through the one pole, the other pole being attached to the iron tube by the screw shown. The diaphragm *d*, which is of thin ferro-

Fig. 12.

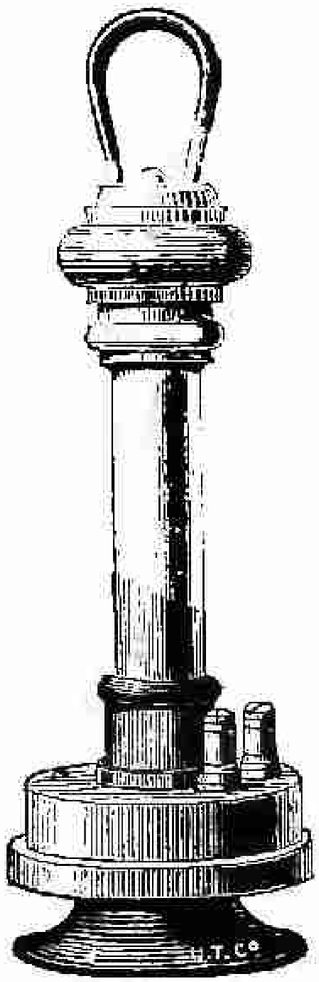
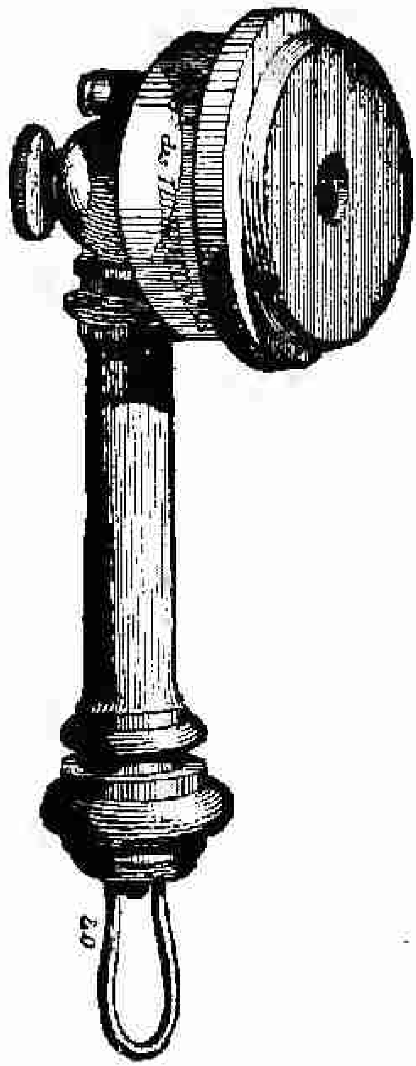


Fig. 13.



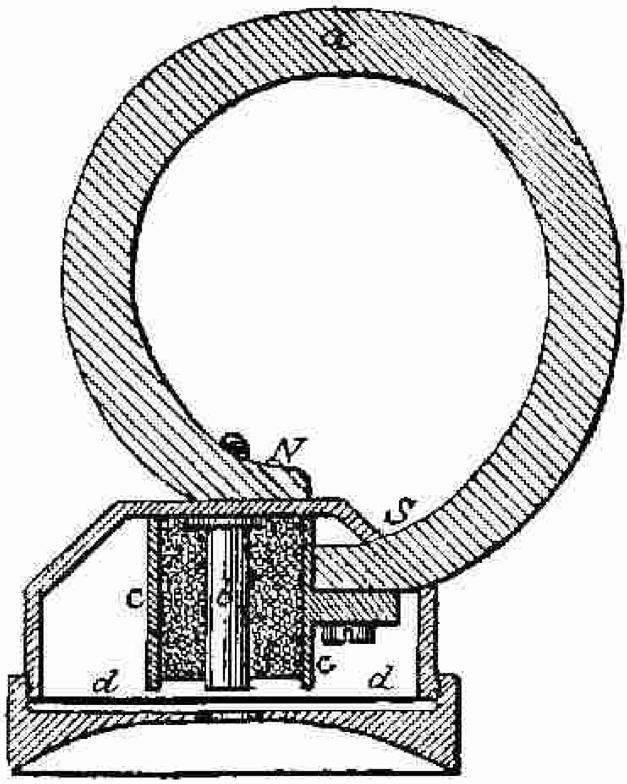
Bell-pattern Ader Receivers.

type iron, is clamped between the lid and body of the containing case, as in the Ader. The novel feature of the D'Arsonval receiver is that the two poles of the magnet are exposed to the diaphragm, using only one coil instead of two, as in the previously described forms of receivers having a horseshoe magnet. Thus there is no waste wire in the coil, the whole of it being subjected to induction. This receiver certainly gives very good results, and is, moreover, of comparatively light weight.

THE HICKLEY RECEIVER.

Fig. 15 shows in section the Hickley receiver. This receiver, it will be seen, consists of the permanent magnet *a*, with one pole in the centre (which may be either N or S), and three other poles *b*, of different polarity to the centre one. On the

Fig. 14.



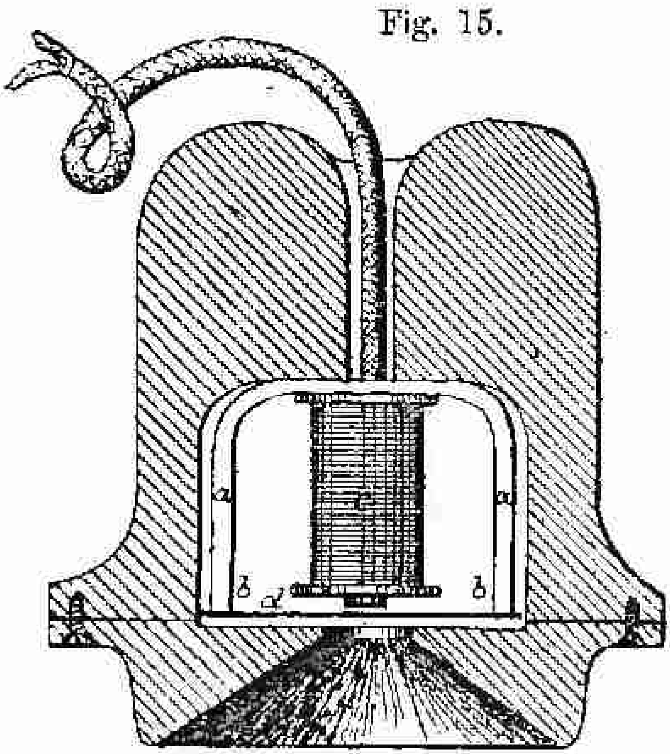
D'Arsonval Receiver.

centre pole is fixed the coil *c*, the two ends of which are connected to the flexible cord shown. The diaphragm *d*, which is of thin ferrotype iron, rests at its circumference on the outer poles, and by this means the resistance of the magnetic circuit is considerably reduced. Receivers made on this principle are capable of giving very excellent results.

THE SIEMENS RECEIVER.

The receiver designed by Messrs. Siemens and Halske resembles internally the double-pole Bell shown in Fig. 2, and consists like the Bell, of a horseshoe magnet, having two oval-shaped bobbins on its soft iron polar extensions. It is contained in a cylindrical case, the body of which is sheet iron, and the mouthpiece of polished hard wood, having the opening lined with brass. The regulation is effected by a small screw at the bottom of the telephone, by means of which the distance of the magnet off the diaphragm can be varied. Fig. 16 is an external view of this receiver.

Fig. 15.



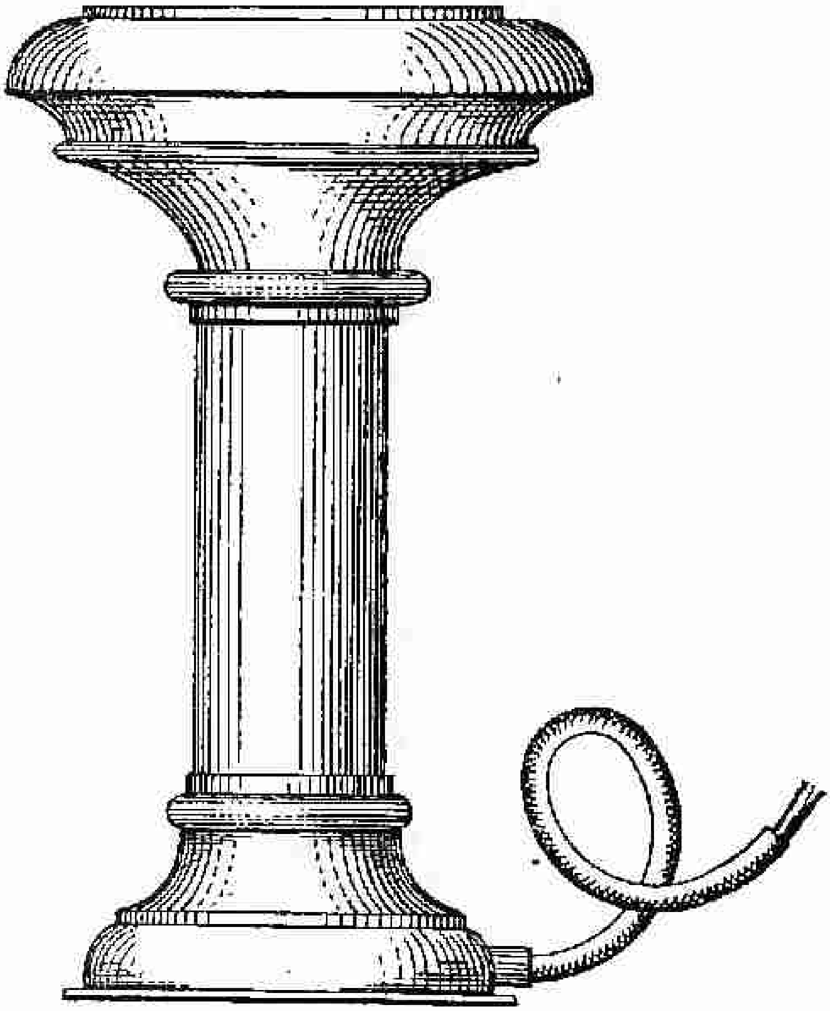
Hickley Receiver.

Spoon-shape and Double Receivers.

Another very convenient form of receiver is that known as the "spoon," a form of which is illustrated in Fig. 17. In the form shown it consists of a Watch receiver mounted on a convenient handle, but in another common form the diaphragm and mouthpiece are applied sideways to the magnet, which is made to form the handle. The magnet is a permanent one of the horseshoe form, and the soft iron cores of the two oval-shaped bobbins are fastened on to the side of the poles. The body of the magnet is wound with leather or faced with wood, forming a convenient handle, and the connecting cord enters at the bottom, while at the top is the loop by which it is hung on the switch-hook of the telephone.

In order to obviate the necessity of using two hands, the one to hold the transmitter and the other the receiver, what is known as a "double receiver" is often employed, a form of

Fig. 16.



Siemens Receiver.

which is shown in Fig. 18. It consists of two receivers fastened to one handle and fixed in such a position, the one to the other, that the act of holding the receiver to the ear places the transmitter in the proper position for the mouth, thus leaving one hand free. The watch form and the Ader are the receivers that lend themselves more readily for adaptation as double receivers.

The Collier Receiver.

This receiver, which has only recently been introduced, was devised by Mr. A. T. Collier, of Sydney, New South Wales. It has several new features, and when well made constitutes a most powerful receiver. Its construction and action will be best understood by referring to Fig. 19, which is a section of the

Fig. 17.

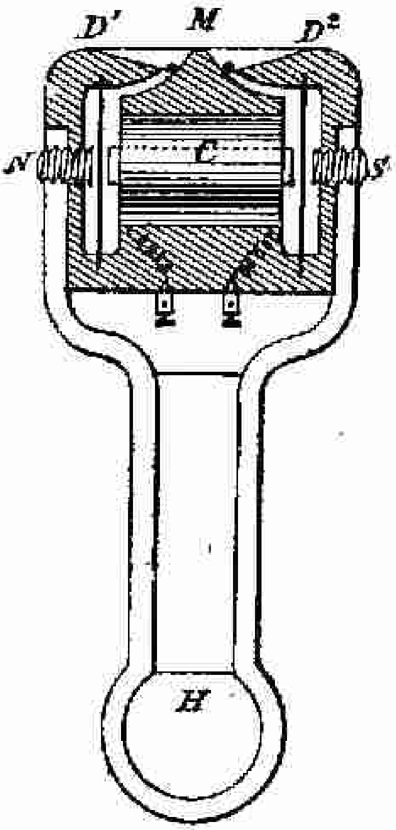
Spoon-shape Receiver.

Fig. 18.

Double Receiver.

complete receiver. In the figure H is the horseshoe magnet, of which N and S are the two poles. Between the ends of this magnet is fixed the coil C, the ends of the iron core of which come opposite the magnet poles. There are two diaphragms, D^1 and D^2, which are fixed one in front of each pole of the magnet. The mouthpiece M is not opposite the diaphragms, but immediately over them, and the diaphragms being completely cased in the only exit for the sound waves, which are taken from the inner sides of the diaphragms, is through this common mouthpiece at the top. The coil is wound to a resistance of about 250 ohms. It will be seen that the two diaphragms are in a very intense magnetic field and that their combined vibrations are projected through a specially shaped mouthpiece. In some tests made with the object of comparing the efficiency of this instrument with that of the double-pole Bell and Ader, it was found to give considerably better results, both as regards loudness and clear articulation, though it is perhaps only fair to state that the Collier had a very large number of turns on the magnet as compared with the Bell and Ader, the resistance of the bobbins of the former being about 300 ohms as compared to 75 ohms of the two latter.

Fig. 19.



Collier Receiver.

CHAPTER II.

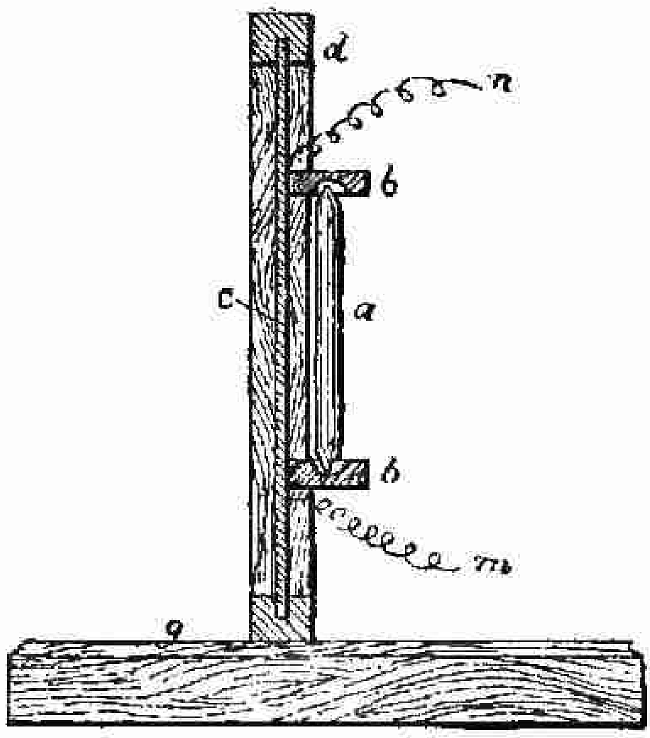
TRANSMITTERS.

ANY of the forms of receivers described in the last chapter can be used also as a transmitter, and such a combination, as was before stated, is sometimes to be preferred to a microphone for short distances, on account of their greater cheapness and simplicity. For long distances, however, the results obtained, from a pair of receivers, one of which is used as a transmitter, are in no way to be compared to those produced by using a microphone; and it was the very poor results obtained from Bell's telephone, when used as a transmitter and receiver, that induced the different inventors to turn their attention to devising a more efficient form of transmitter; though it was not until the discovery, by Prof. Hughes in 1878, of the microphone, that the telephone became an efficient, long-distance instrument. Some months previous to this Edison had, it is true, brought out his carbon transmitter, an instrument that acts from a somewhat different principle to the microphone, though it could scarcely be called an efficient transmitter, or at any rate one that was likely to have stood the test of everyday use. In as much, however, as Edison in his specification made mention of variable contacts and lamp-black (soft carbon), it was held that he had anticipated the discoveries of Hughes, and thus Edison's patent became the master patent for carbon transmitters.

Hughes's Microphone.

In Fig. 20 is shown, partly in section and partly in elevation, Prof. Hughes's microphone, which forms the basis on which all the modern carbon transmitters are constructed. As all receivers are more or less modifications or copies of the original Bell instrument, so are all the modern carbon transmitters modifications or rearrangements of Prof. Hughes's microphone. The instrument consists, as will be seen from

Fig. 20.



Hughes Microphone.

the figure, of an upright pointed carbon pencil *a*, the points of which rest loosely in the two supports *b b*. These supports *b b* are fastened to the thin sounding board *c*, which is fixed at the circumference by the wooden frame *d*. The whole apparatus is fixed on a suitable stand *g*. The apparatus is easily made, and the reader is advised to construct one, as a good idea of the action of carbon transmitters will readily be obtained by a little experimenting with it. For the carbon pencil *a*, a piece of carbon rod, such as is used for arc lamps, $\frac{1}{4}$ in. in diameter and 2 in. in length, should be procured, and the ends sharpened, as shown in Fig. 20. The two supports *b b* can be made out of a piece of old carbon battery plate, being filed to the shape shown, and drilled at the ends for the points of the carbon. A piece of $\frac{1}{8}$ board, about 6 in. by 4 in., is next procured, and mounted on a stand, as shown. To the centre of this board is supported the carbon pencil by means of the supports, as in Fig. 20, the carbon pencil being a *loose* fit in the holes in the carbon blocks. The carbon blocks are affixed to the board *c* by some elastic glue, or better still, by screwing, for which purpose the carbon blocks should be provided with a foot. Two pieces of thin silk-covered copper wire should be attached one to each carbon support, for the purpose of connections.

If now we connect up this microphone to any of the forms of receivers just described, interposing in the circuit one or two smallest size Leclanché cells, we find that any words spoken to this carbon pencil will be faithfully reproduced in the receiver. If a watch is laid on the stand of the microphone, the ticking is distinctly heard in the receiver, being very loud and pronounced. The slightest touching of the stand or pencil is made manifest in the receiver by a loud sound, and if the microphone is in good order, the walking of a fly on the pencil can be readily detected.

The action of the microphone is based on the principle that a loose contact, formed between two non-oxidisable substances, set into vibration, is subjected to great variations in resistance when traversed by an electric current, and that the greater or lesser intimacy of contact between these two surfaces is accompanied by a corresponding decrease or increase in its resistance. Thus, when words are spoken to the microphone described above, the carbon pencil partakes of the vibrations communicated to the air by the voice, and vibrates in unison with them. This causes the pencil to vary its pressure and intimacy of contact with the supporting blocks, which thus vary the resistance of the circuit, giving rise to undulations in the current which are faithfully reproduced in the receiver. When it is understood that these variations amount at times to about 400,000 a minute, during which time the circuit is never once broken, the extreme beauty of the instrument will be appreciated.

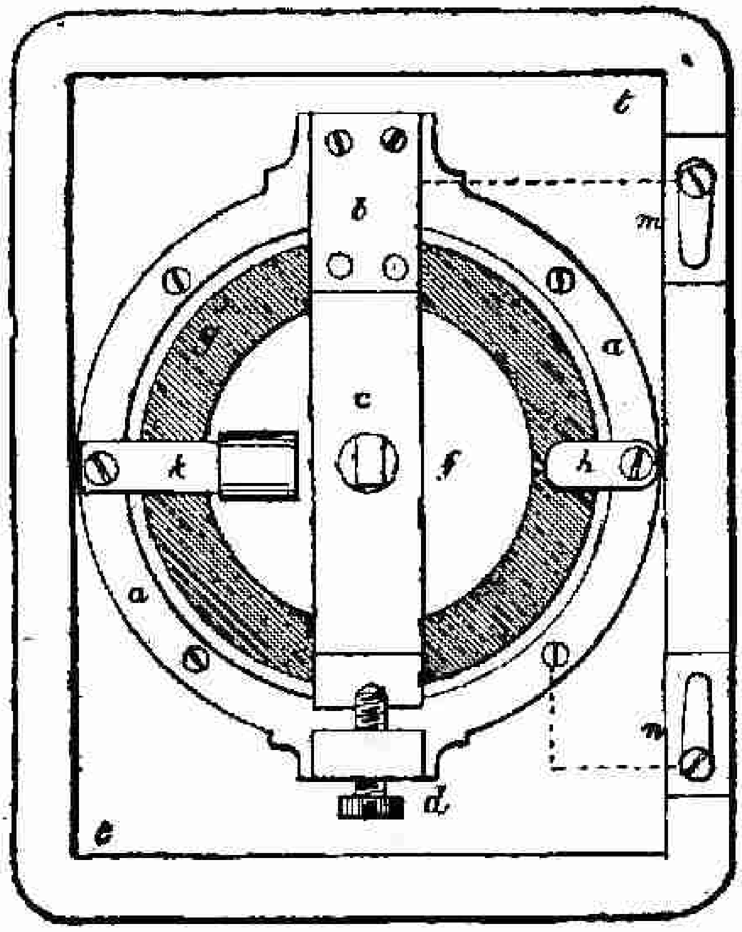
Microphone transmitters can be classed under three distinct headings, viz., the "platinum and carbon," the "carbon pencil," and the "granulated carbon" form. The first of these undoubtedly gives the most perfect and natural articulation, the second are the best for simple, reliable and all-round transmitters, whilst the third are capable of giving the most powerful results. The most important, and in fact the only one at present worthy of any note coming under heading No. 1, is the Blake, which will now be described.

The Blake Transmitter.

It was in May 1878, that Prof. Hughes first introduced his microphone to the public, and it was as early as August in the same year that Mr. Francis Blake, assisted by several experts of the American Bell Telephone Company, produced the first practical microphone transmitter. This instrument, which is known as the "Blake" transmitter, is the most widely used of any, there being over 100,000 in use at the present day. This is not due, as might be supposed, to any great superiority over other forms; for, as a matter of fact, for long distances it is inferior to some, but chiefly owing to its being the first satisfactory one produced and having fallen into powerful hands.

Figs. 21 and 22 show the form of Blake transmitter now in use, Fig. 21 being a plan, and Fig. 22 a section. It consists, as will be seen, of the circular iron frame *a*, with an upright post at the top and bottom. To the top post is screwed the spring *b*, to which is fixed the iron lever *c* that is adjustable by the screw *d* in the bottom post. At the top of the lever *c* is fixed the insulating block *x*, to which is fastened the thin spring *s*, carrying at its lower end the platinum point *j*. Against this platinum point presses the hard carbon button *o*, fastened to the brass carbon holder at the back, the carbon holder being carried by the spring *p*, which is fixed to the top part of the

Fig. 21.



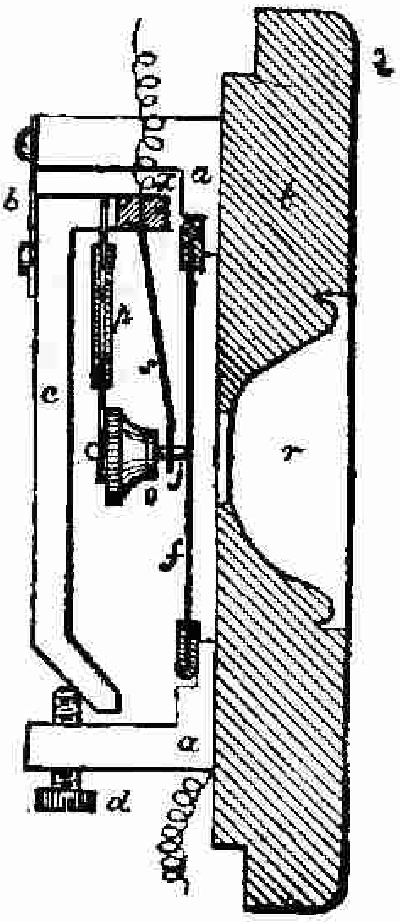
Blake Transmitter.

lever *c*. The thin sheet-iron diaphragm *f*, is insulated from the iron frame *a* by the rubber ring *g*, and the vibrations of the diaphragm are damped by the steel spring *k*, the end of which is insulated by a rubber glove. The whole of the apparatus is contained in the polished walnut wood case *t*, into the front of which is cut the mouth-piece *r*. The spring *s* carrying the platinum point is called the "normal pressure" spring, and the one (*p*) which supports the carbon button the "carbon" spring. The circuit through the transmitter is as follows:

The current entering, let us say, by the top wire, passes from there to the spring *s* and platinum point *j*, thence to the carbon button *o*, which presses lightly against it, then to the carbon holder, spring *p*, lever *c*, spring *b*, frame *a*, and leaving by the lower wire.

The following is the action of the instrument:—The sound-waves striking the diaphragm *f* cause it to vibrate in unison with them. The vibrations of the diaphragm cause the platinum point *j* to vary its pressure on the carbon button *o*, these variations in pressure causing changes in the resistance of the circuit, which give rise to undulations in the current.

Fig. 22.



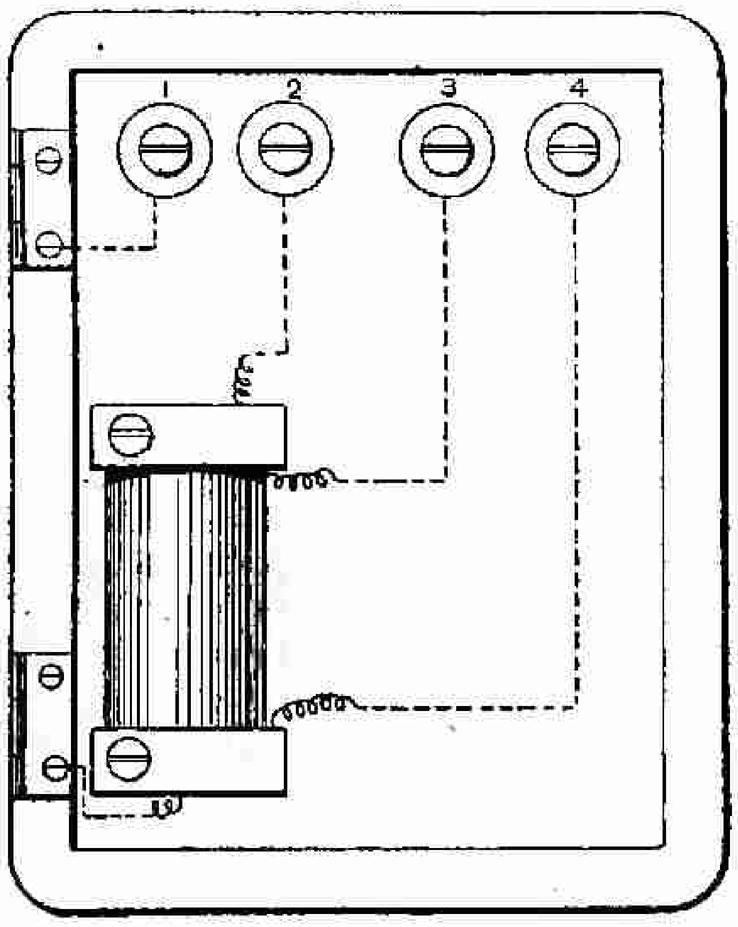
Blake Transmitter.

In adjusting a Blake transmitter, first, if the instrument is a new one, see that the paper padding is removed from between the carbon block and the frame. Next slack-back the adjusting-screw *d*, till the platinum point is just clear of the diaphragm, then turn upwards two full turns. This will usually bring the instrument to the right adjustment. Place the telephone to your ear, however, and tap the diaphragm of the transmitter, when, if all is connected up properly, a sound will be heard in the telephone. If the sound is dull and short, slacken back the screw *d*; but if it is inclined to be prolonged or make a humming noise, the screw must be tightened up a bit. When properly adjusted a clear musical sound should be heard, but leaving off sharp. Never at any time turn the screw more than a quarter of a turn at a time, as the best position is easily passed. If the carbon button be pulled back the platinum point should follow it nearly ½ in.

In adjusting a transmitter some allowance should always be made for the voice of the person who will usually use the instrument ; but the adjustment should never be left too loose or it will jar, and probably commence humming in an hour or two, as a newly set up battery becomes more active as the solution becomes saturated. In a well-adjusted Blake transmitter breathing against the diaphragm should be distinctly heard, and in a quiet place, persons talking some distance from the instrument should be heard at the other end of the line.

In Fig. 21 it will be seen only half the transmitter case is shown, and the microphone is connected up to the two nickelled

Fig. 23.



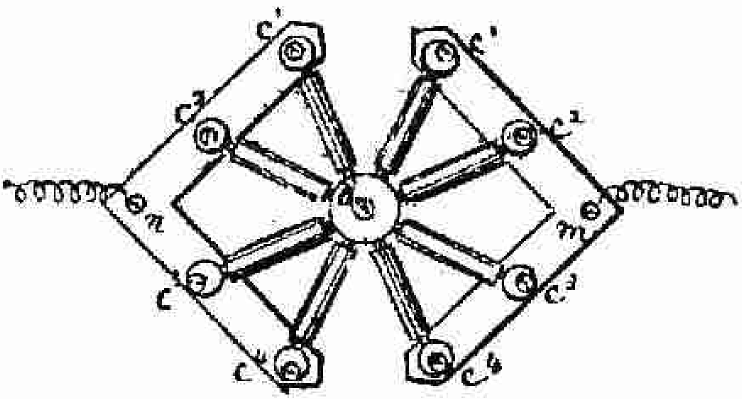
Case of Blake Transmitter.

springs on the hinges *m* and *n*, which make the connections across to the other half of the case (see Fig. 23) that contains the induction coil.

The induction coil, it will be seen, is at the bottom left-hand side of the case, and the ends of the two coils are connected up to the four terminals (1, 2, 3, 4) at the top. 1 and 2 are the ends of the primary, and 3 and 4 of the secondary, the lower end of the primary coil being connected to the hinge (n), and the circuit passes through the microphone before reaching terminal 1. The terminals 1, 2, 3, and 4 are connected up to similarly marked terminals in the switch-bell shown in Fig. 49.

We now come to microphone transmitters of the second kind, viz. "carbon pencil" transmitters, one of the most familiar of which is the Gower.

Fig. 24.

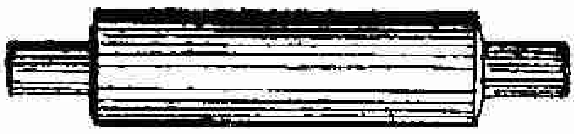


THE GOWER TRANSMITTER.

In Fig. 24 is shown Gower's transmitter, which is the form of transmitter adopted by the British Post Office. It consists, as will be seen from Fig. 24, which is a plan about quarter full size, of eight carbon pencils, connected together in two sets of four by means of the two copper strips m n. These carbon pencils are supported at one end by the separate carbon blocks c^1 c^2 c^3 c^4, the other ends being supported in the centre by the carbon block b, which is common to the lot. The carbon pencils are reduced at the ends, as in Fig. 25, which shows one of these pencils full size, and these thin ends fit loosely into holes drilled in the carbon supporting blocks.

These carbon pencils, with their supporting blocks, are attached to the under side of the diaphragm, which consists of a thin sheet of wood fixed at the top of the instrument, and inclined slightly from the horizontal position. The diaphragm is generally protected by a cover, in the front of which is fixed a mouthpiece, though in some instruments it is left exposed and ornamented with a painted design.

Fig. 25.



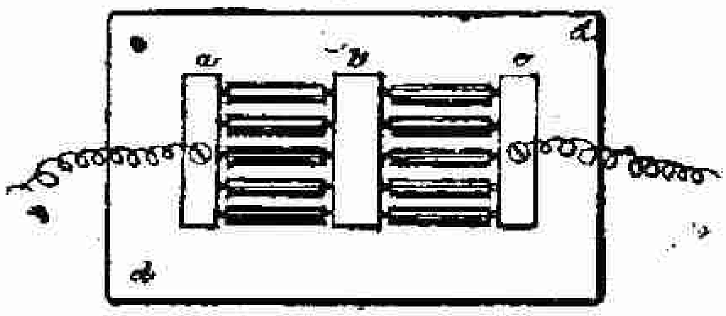
Carbon pencil of Microphone.

In the Hughes microphone described on p. 20, there are two loose contacts in the circuits, but in the Gower it will be seen there are no less than sixteen. The current entering, let us say, at the right-hand side wire, reaches the copper strip *m*; there it has four paths open to it, and so divides, a portion passing down each pencil and reuniting again at the centre block *b*. Dividing again between the second lot of four pencils, it reunites at the strip *n*, and leaves by the left-hand wire. When the sound-waves strike the diaphragm they set it in vibration, which causes the pencils to dance upon their supports, and so cause undulations in the current, as in the Hughes microphone; the Gower, however, owing to its eight pencils, being more sensitive.

THE ADER TRANSMITTER.

This transmitter somewhat resembles Gower's, only the carbon pencils are more numerous. It will be seen from

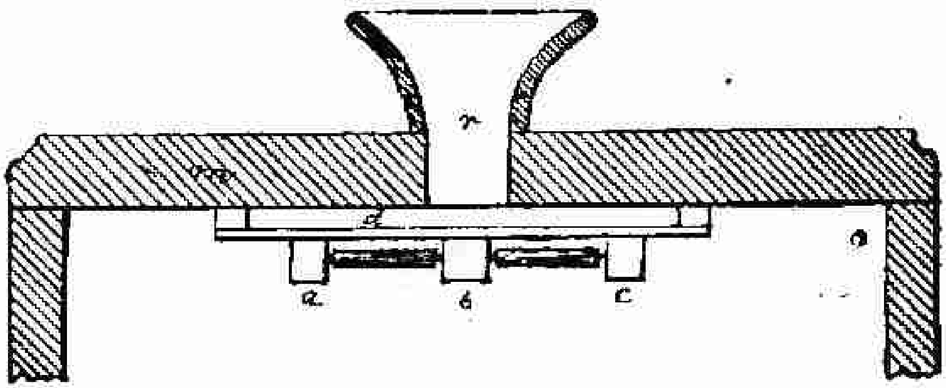
Fig. 26.



The Ader Transmitter.

Figs. 26 and 27, which represent this transmitter in plan and in section, that there are ten carbon pencils supported by the three carbon blocks *a*, *b*, *c*, mounted on the diaphragm *d*, which is a thin deal board. In Fig. 27, which represents the transmitter and top part of its case in section, it will be noticed

Fig. 27.



The Ader Transmitter.

that the diaphragm is fixed directly under the lid *m* of the case, in the centre of which is fastened the mouthpiece *r*, so that any sound-waves directed through the mouthpiece impinge directly on the diaphragm.

The Crossley Transmitter.

Fig. 28.

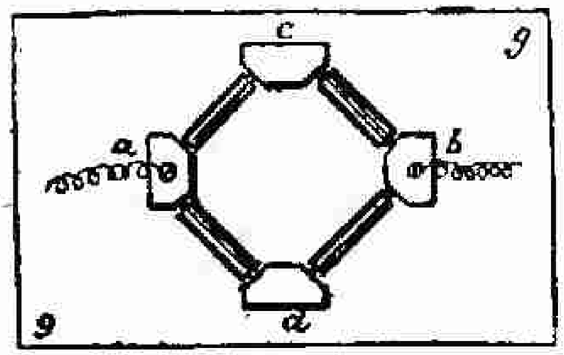
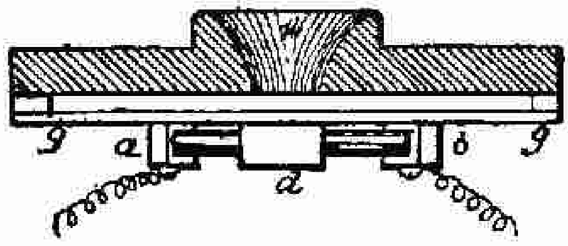


Fig. 29.

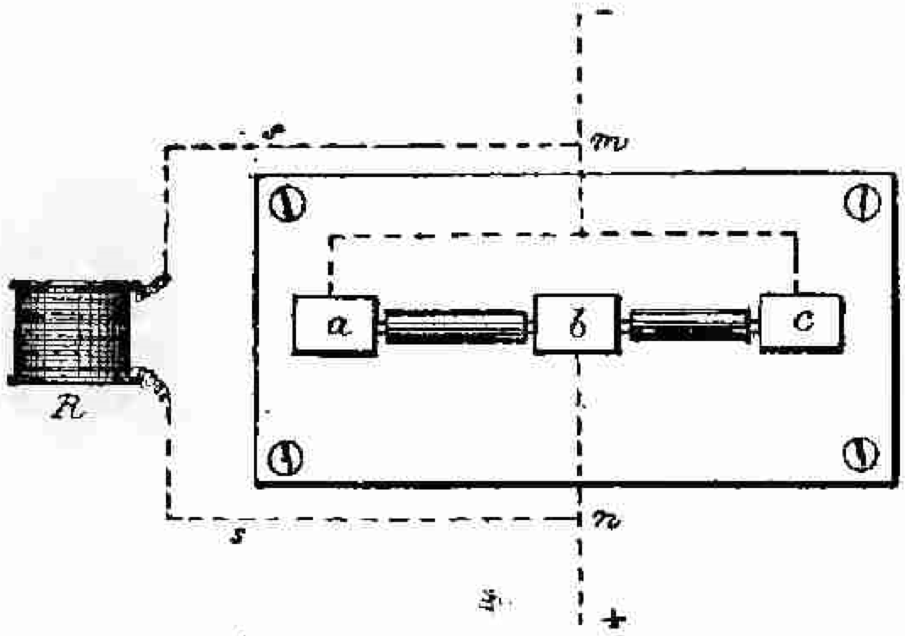


Figs. 28 and 29 show this transmitter in plan and in section. The diaphragm is a thin deal board *g*, as in the transmitter just described, on which are mounted the four carbon blocks *a*, *b*, *c*, *d*, these blocks being connected together by the carbon pencils shown. The connections are made to the blocks *a* and *b*, the current dividing, half passing by the carbon block *c*, and half by the block *d*. The diaphragm is supported off the bottom of the lid of the transmitter case by means of four cork pads, and in the lid of the case is cut the mouthpiece *r*.

The Johnson Transmitter.

This transmitter is shown in plan in Fig. 30. It consists of the three carbon blocks *a*, *b*, *c*, between which are freely suspended the two carbon pencils as shown. The diaphragm is a thin deal board, as in the previously described instruments.

Fig. 30.



The Johnson Transmitter.

The novel part of this transmitter, however, consists of the shunt *s*, in which is inserted a resistance coil R, the total resistance of the shunt being a little less than that of the microphone at rest. The object of this shunt resistance coil is to prevent the circuit being completely broken should the carbon pencils vibrate too far, and also to obviate excessive sparking at the microphone contacts should the current be too strong. It is important for the proper transmission of speech that the carbon pencils do not absolutely break contact with the carbon blocks while the pencils vibrate. This is got over in most microphones by having a number of pencils, as in the Gower and Ader, as it is not likely that all the pencils will break contact at the same moment. In the Johnson transmitter, however, only two carbon pencils are used, the circuit being as follows:—Starting from the lower wire, the current passes to the centre block *b*; here it divides, half passing by the right-hand pencil to the block *c*, and half by the left-hand pencil to block *a*, reuniting and leaving by the top wire. In addition to this there is the shunt circuit across the microphone, starting at the point *n*, thence through the resistance coil R, and joining the main circuit again at *m*.

The amount of current passing through the microphone and the shunt respectively is inversely proportional to their respective resistances. It follows, therefore, that slightly more than one-half passes through the shunt under ordinary circumstances, while the balance passes through the microphone. If, now, in consequence of the impact of sound-waves or from any other cause, the resistance of the microphone is varied, the proportion of current passing through the shunt will also be varied. Thus if the resistance of the microphone is reduced, the amount of current passing through the shunt is decreased. If, on the other hand, the resistance of the microphone is temporarily increased, or if its conductivity is broken, then the amount of current passing through the shunt is increased, or the whole of the current is diverted through it. It follows from this arrangement that the undulations of the current are very considerably modified, and that the extreme variations are altogether eliminated, the result being more distinct articulation in the telephone, and freedom from the defects of buzzing, humming, or rattling noises.

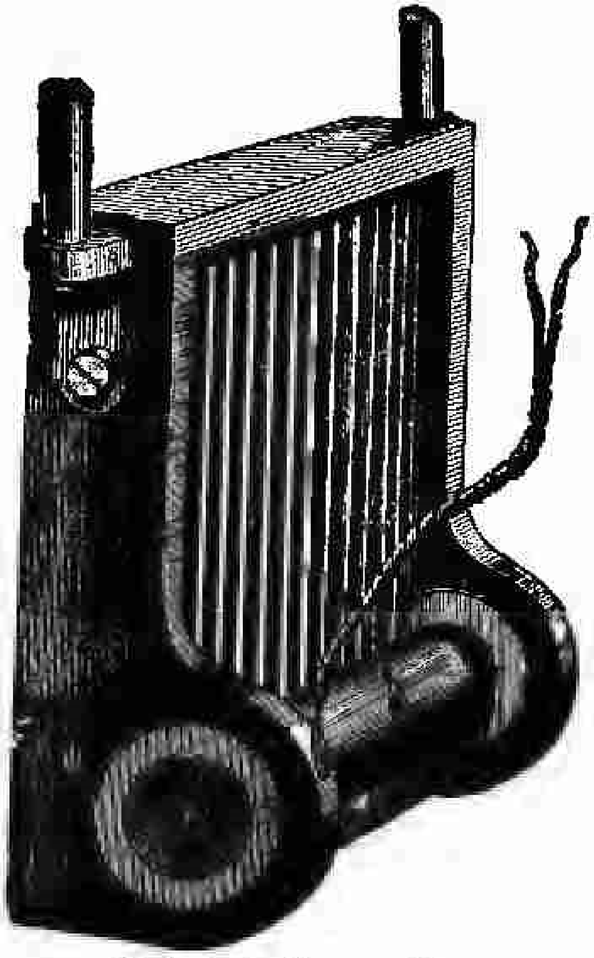
The microphone was arranged in a wooden case with mouth-piece, as in the Ader and Crossley transmitters, and in actual practice gave fair results. In the later forms of this microphone, however, the shunt has been discarded owing to its reducing the sensitiveness of the instrument too much.

Two forms of microphone transmitters (Swinton's and Sylvanus Thompson's), coming also under heading No. 2, will now be described, as they possess several features of interest although they are not now in use, being designed chiefly with a view to elude Edison's master patent, and for use while that patent was in force.

The Swinton Transmitter.

An ingenious transmitter is that devised by Mr. A. A. Campbell Swinton, of which a perspective view is shown in Fig. 31. It consists of a lead frame suspended in an adjustable manner by indiarubber pieces, so as to be unaffected by external vibrations. On a horizontal platinum wire stretched across the upper part of the frame are strung a number of vertical pendulous carbon pencils, which rest lightly at their lower extremities against an insulated horizontal carbon block fixed across the back of the frame, the whole forming a very powerful multiple microphone. The amount of pressure normally existing between the vertical carbon pencils and the horizontal block can be readily adjusted to a great degree of nicety by simply varying the inclination, and *vice versâ*. The transmitter is adjusted by varying the inclination of the frame supporting the microphone. This is done by slackening the two screws by which the frame is suspended, and moving the pieces backwards or forwards as required. When the adjustment is completed, the screws must be tightened up again. If the adjustment is too coarse, i.e. if the frame is too much inclined, or the pressure normally existing between the vertical and horizontal contact pieces is consequently too great, the articulation will be faint unless the speaker talks loudly very near the instrument. If, on the other hand, the adjustment is too fine, owing to the frame being too vertical, the vertical contact-pieces will be liable to break contact altogether with

Fig. 31.



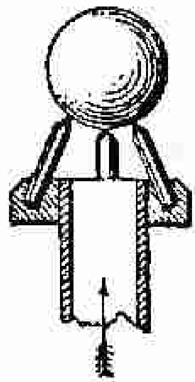
Swinton's Transmitter.

loud or near speaking, and burring sounds, coupled with indistinct articulation, will result. With proper adjustment, the best effect is obtained by speaking in an ordinary tone at a distance of 4 in. from the transmitter, the voice being directed on to the carbon pencils. It will be seen that, strictly speaking, the microphone had no diaphragm, and to design an instrument without one was the chief aim of the inventor.

The Thompson Transmitter.

This transmitter, devised by Prof. Sylvanus Thompson, is generally known as the "valve" microphone. It consists, as will be seen from Fig. 32, of three carbon pencils fixed at the top of a bent tube, the lower end of which is fitted with a mouthpiece. On the points of these pencils rests a carbon ball, against which the sound-waves impinge when directed in the mouthpiece. This transmitter gave very good results, and as with the Swinton transmitter, was thought that, owing to its having no diaphragm, it would elude the Edison patent.

Fig. 32.



Valve Microphone.

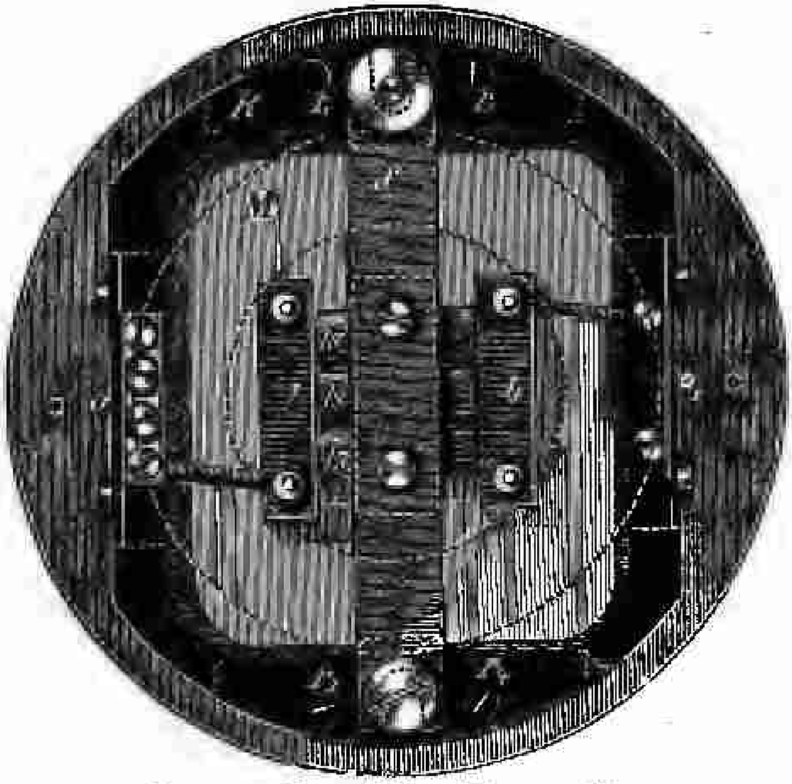
Both inventors, however, or rather the companies working their patents, were restrained from using these instruments by the National Telephone Company, who obtained an injunction against them.

Various were the attempts to get over the Edison patent; but, owing to the very wide meaning applied to the word "diaphragm," none met with any success.

The German Post Office Transmitter.

In Figs. 33 and 34 is shown the microphone transmitter employed by the German Post Office. The chief feature of this instrument is the spring arrangement *f*, by means of which a steady pressure against the diaphragm by the carbon pencils is secured, while the vertical position of the transmitter is retained. The diaphragm M consists of a thin pine-wood board, and is secured in position by the two clamps *a a*. The three carbon pencils *k k k* fit loosely in their bore-holes in the carbon blocks *b b*, and against the back of the carbon pencils presses the spring *f* by means of the brass plate *m*, the face of which is padded with the felt or cotton wool *d*. The whole of the apparatus is carried by the iron ring R, to the front of which is screwed the mouthpiece T. The circuit through the microphone is from one of the carbon blocks *b b* to the other by means of the pencils *k k k*, the pressure of

Fig. 33.



German Post Office Transmitter.

which against the front of their bore-holes can be varied by the adjusting nuts *s* and s_1. The object of the spring *f* is to insure the carbon pencils resting against the front of the bore-holes, and the damping effect of the slight pressure effectually does away with the rasping noises so often noticeable in pencil microphones having a vertical diaphragm. In the later forms of this instrument, fine bristles have been substituted for the cotton wool.

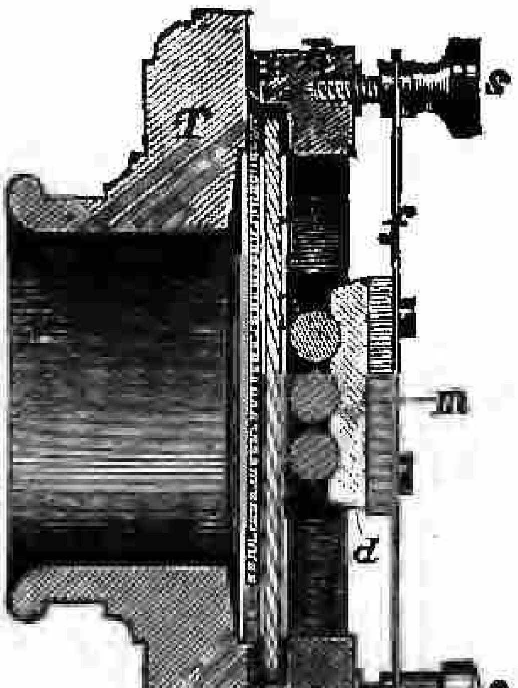
Granulated Carbon Transmitters.

Of microphone transmitters of the third kind the Hunnings was the first produced, and in its most modern form is one of the most efficient.

The Hunnings Transmitter.

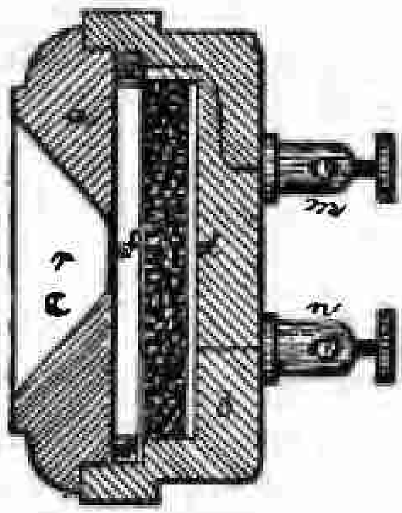
Fig. 35 shows in section Hunnings' transmitter, which consists, as will be seen from the figure, of a wooden case *b*, fitted with a lid *a*, that screws on and off, and in the front of which is cut the mouthpiece *r*. In the back of the inside of the case is fastened the platinum or carbon plate *d*, and in the front (clamped between the lid and the body of the case) is the diaphragm *f*, made of thin sheet platinum. The space between the diaphragm *f* and back plate *d* is loosely filled with

Fig. 34.



German Post Office Transmitter.

Fig. 35.



Hunnings Transmitter.

granulated carbon. At the back of the case are the two terminals *m* and *n*, the top one *m* being connected to the diaphragm *f*, and the bottom one to the back plate *d*. A ring of metal *o* is inserted between the lid of the case and the diaphragm.

The action of the transmitter is as follows :—The sound-waves striking the diaphragm *f*, set it in vibration, which squeezes the carbon granules closer together as the diaphragm moves towards the back plate, and loosens them as it recedes from it. As the carbon granules are squeezed closer together, so the resistance between the diaphragm and back plate is decreased, and as they are loosened, so the resistance increases, thus giving rise to undulations in the current.

Several modifications of the Hunnings transmitter have been introduced and are extensively used both in this and other countries. The most prominent of these are the Western Electric pattern, the Berthon, Berliners Universal, and the "cone" Hunnings.

The Western Electric Hunnings.

This instrument, which is used on a good many long distance lines, differs but slightly from the original Hunnings except that it is put into a more reliable shape. The containing case is all of metal, and the thin metal diaphragm is gold plated on both sides to resist the action of any gases or acids that might be precipitated on it during use. The carbon granules are contained in a rubber tube, the one face of which is open to the diaphragm and the other filled up by a carbon block. The carbon block is one end of the circuit and the diaphragm the other, the interval being bridged across by the carbon granules. The instrument has a very piercing tone and is capable of the most delicate adjustment.

The Berthon Transmitter.

This transmitter, which is much used in France, consists of two thin carbon plates A and B, the front one of which A, forms the diaphragm. To the back carbon plate B is attached a small carbon cup, which is three-quarters full of minute carbon balls, each of these balls having been moulded separately. The two carbon plates are kept apart by a rubber ring, and the distance between the plates can be varied by screwing up the brass ring G, which causes the plates to come closer together owing to the rubber ring compressing. The vibration of the diaphragm A causes the carbon balls to be more or less compressed, thus producing undulations in the current, and by leaving the holes H, in the back of the case it has been found a freer movement of the diaphragm is obtained, since by this means the otherwise confined air can escape. This transmitter, owing to the round form of the carbon granules, has not the least tendency to "cake."

Fig. 36.

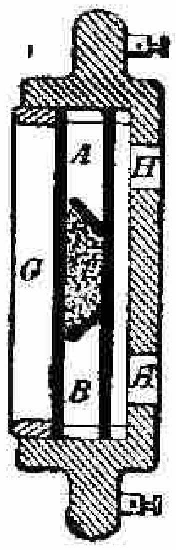


Fig. 37.

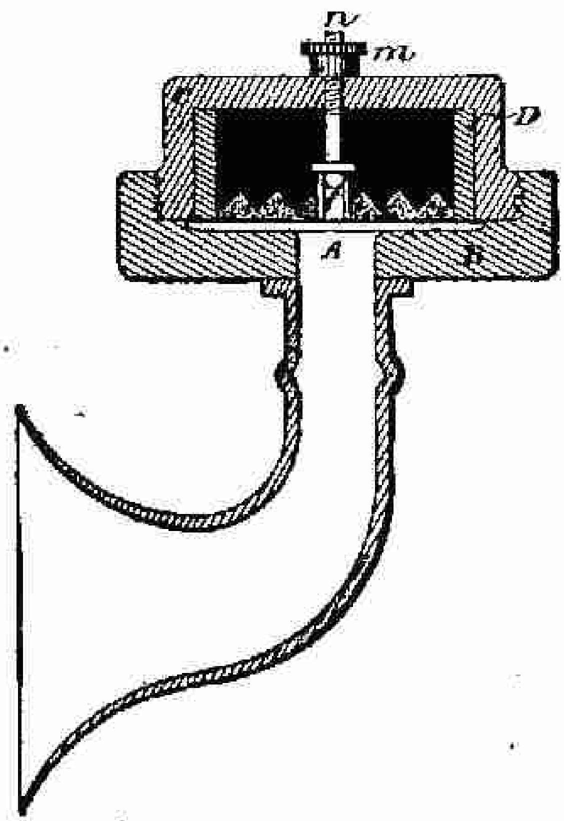
Berthon Transmitter.

This transmitter is shown in section in Fig. 36, and in perspective mounted on backboard in Fig. 37.

Berliner's Universal Transmitter.

One of the most powerful of transmitters is the Berliner, which differs from both of the preceeding forms in that its diaphragm is fixed in a horizontal position. The instrument is shown in section in Fig. 38, and consists of the thin carbon diaphragm A, above which are the carbon granules. The diaphragm is held in position by being clamped between the cover B and the body of the case C, and above the carbon granules is the carbon block D, the lower face of which is cut with concentric grooves, and which maintains a light pressure on the top of the granules. This carbon block is adjusted by

Fig. 38.



Berliner Transmitter.

turning the milled nut *m*, which raises or lowers the pin *n* according to direction, so that the pressure of the carbon block on the granules can be adjusted to a nicety. A special trumpet-shape mouthpiece is used as shown to direct the sound-waves on to the diaphragm.

The Cone Hunnings.

This transmitter, so called from the peculiar shape of the surface of the back carbon block, has recently been introduced. Its chief novelty consists in the special way in which the diaphragm is "damped" and the carbon granules kept in place, so that the instrument can be used with the diaphragm in a vertical position. The diaphragm is a thin carbon plate, and the back contact for the granules is a carbon block, the face towards the diaphragm of which is cut across with numerous grooves, which thus form the surface into a number of little cones or pyramids. From each of these cones arise little tufts of silk which reach out and press lightly on the diaphragm. This effects two objects, it damps the extreme vibrations of the diaphragm and also prevents the carbon granules which are between the tufts of silk from settling down towards the bottom of the case. The containing case is of polished ebonite and is fitted with a conical mouthpiece.

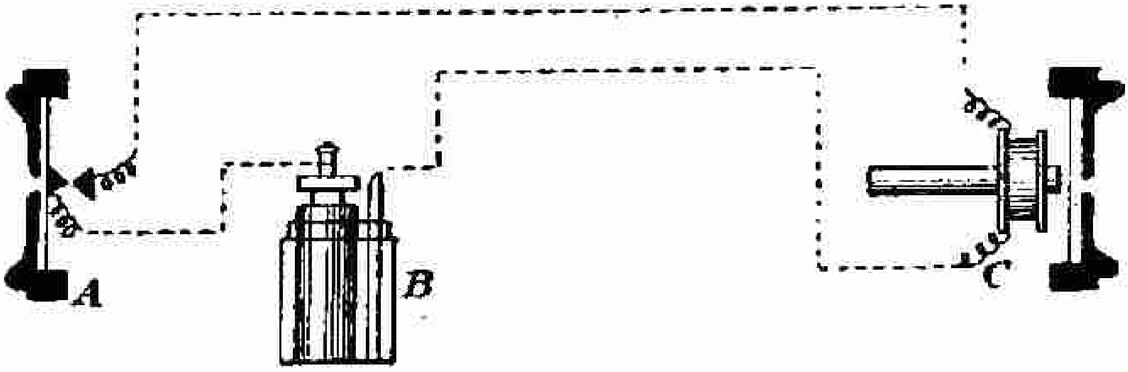
Transmitter Induction Coils.

An induction coil is used in a transmitter because the range of variation of resistance of the microphonic contact would be small compared to the total resistance of a long line, and, therefore, would give rise to but small undulations in the current, yet the same variation produces very great changes in the low-resistance primary circuit of the induction coil, and, therefore, great variations in the current. These variations are still more magnified in the secondary windings of the induction coil, the current generated in the secondary having, moreover, a high E.M.F., which has thus power to overcome a very high line resistance.

In Fig. 39 are shown the connections of a microphone with a receiver connected direct *without* an induction coil, and in Fig. 40 are shown the connections for the same combination *with* an induction coil interposed in the circuit. In Fig. 40 *a* is the transmitter, *d* the receiver, *c* the induction coil, *b* the battery, *p p* the ends of the primary, and *s s* the ends of the secondary winding.

In Fig. 39 there is, it will be seen, only one circuit comprising the microphone A, local battery B, and receiver C, and any variation of the current by the transmitter acts directly

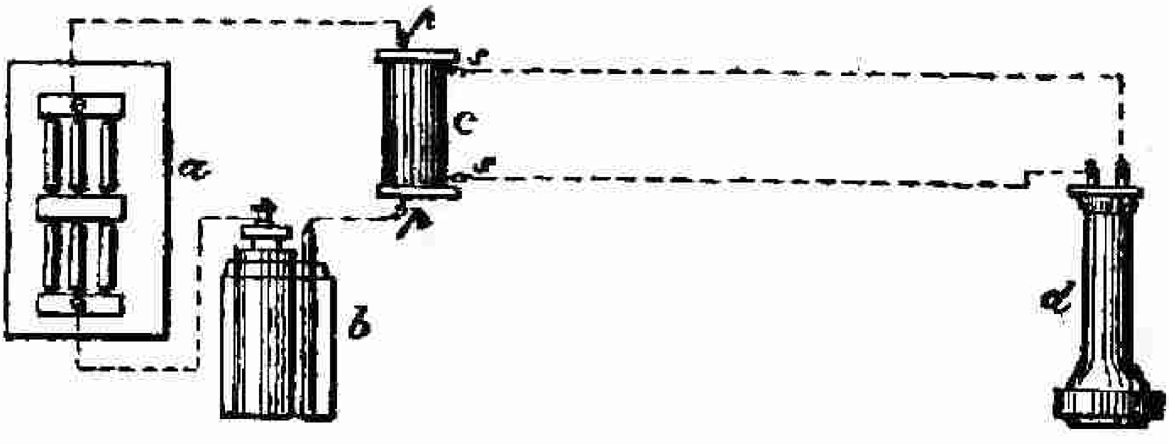
Fig. 39.



Microphone without Induction Coil.

on the receiver, while in Fig. 40 there are two separate circuits, the one called the "local circuit," consisting of the microphone *a*, battery *b*, and primary layers of the induction coil; and the

Fig. 40.

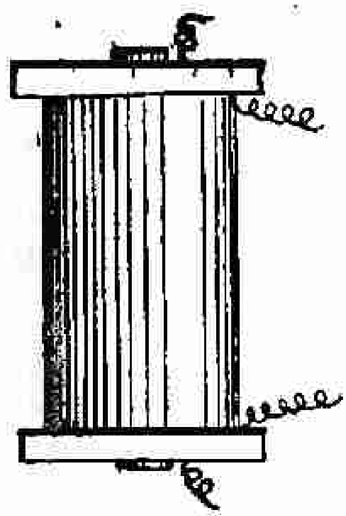


Microphone with Induction Coil.

other, called the "main circuit," consisting of the receiver's line wire between the two instruments, and the secondary layers of the induction coil. When the sound-waves strike the diaphragm they set the carbon pencils in vibration, causing them to vary the resistance of the local circuit, thus sending undulatory currents through the primary of the induction coil. These currents by induction give rise to similar undulatory currents, but more magnified, and of greater E.M.F. in the secondary windings of the coil, which currents, in passing through the bobbin in the receiver, faithfully reproduce the vibrations of the transmitter diaphragm.

The induction coil generally used is a square-ended one, as shown in Fig. 41, about 2 in. long by $1\frac{1}{4}$ in. broad, and with a core consisting of a bundle of soft iron wires. The question as to the respective resistances of the primary and secondary coils is in a great measure influenced by the construction of the microphone and the length of the line on which it is required to work. Theory dictates that the resistance of the secondary coil should be about equal to that of the "line" or external circuit; but from actual experiments, conducted with a view to ascertain the best resistances, practice appears somewhat at variance with theory. In the induction coil generally used by the various telephone companies, the primary has a resistance of ·5 ohm, and the secondary ·250 ohm, and as an all-round coil these resistances are hardly to be improved upon. Where the induction coil is for use on a long line the number of turns in the secondary is generally increased in preference to increasing the battery power in the primary circuit. One No. 2 agglomerate block Leclanché is the battery power used with the Blake transmitter, and this is mostly sufficient for all transmitters having an induction coil.

Fig. 41.

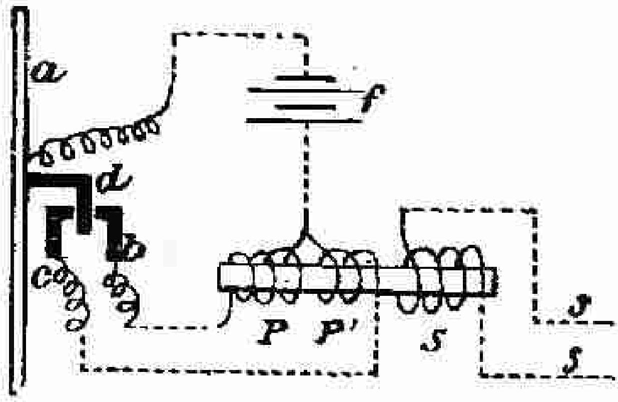


Microphone Induction Coil.

For short distances an induction coil can frequently be dispensed with, the battery power being increased to three or four cells, but on long lines an induction coil is indispensable, even on short lines will be found to wonderfully increase the intensity and clearness of the speech.

Another form of the transmitter induction coil is used by the Société Générale des Téléphones, in Paris, in some forms of their instruments, and has two primary coils wound in opposite directions, and one secondary. This form of coil is shown diagramatically in Fig. 42, and although the figure does not show the actual form of the microphone, yet it sufficiently illustrates the principle on which it acts.

Fig. 42.



Microphone Coil with two Primaries.

The diaphragm *a*, has affixed to it the carbon arm *d*, against which presses on one side the carbon block *b*, and on the other a similar block *c*. P is one primary coil and P^1 the other wound in an opposite direction. S is the secondary coil wound over the two primary ones, and *f* the two cells connected in circuit as shown. When the diaphragm vibrates so as to cause *d* to press against *b*, the curren tin coil P is increased and that in coil P^1 diminished, both of which actions have the same effect on the secondary coil S. When the diaphragm vibrates so as to cause *d* to press against *c*, the reverse action takes place with the coils P and P^1 to that just described. This form of coil is a very excellent one, and the transmitter with which it is used is capable of giving very powerful speech.

The Microphone Transmitter Patents.

Before closing this chapter a few remarks on the position of the various microphone patents may not be without interest. The Edison patent has expired, releasing all the different parts necessary for the construction of an efficient microphone transmitter, and though there are one or two patents still in force to which importance is usually attached, viz. the Blake, Hunnings, and Crossley, yet all these have reference almost wholly to special forms of, or methods of mounting, certain parts.

Edison's Specification (No. 2909), July 30th, 1877.

The most important points liberated by the expiration of this patent are contained in the second claim, which runs as follows :—" In an instrument for transmitting electric impulses by sound, the combination with a diaphragm or tympan of an electric tension regulator for varying the resistance in a closed circuit substantially as set forth." The term " electric tension regulator " the inventor tells us he applies to "the small bunches, tufts, or discs of semi-conducting elastic fibre and an intermediate conducting or semi-conducting material, which is more or less compressed by the vibrations of the diaphagm, and the electric current rises in tension as it is compressed or lessens as the fibre expands." The inventor further adds that " the fibre is rendered semi-conducting by being rubbed with plumbago, soft metal, or similar material." It was this claim for the combination with a diaphragm of electric tension regulators that made it impossible to devise a battery transmitter free from infringements while this patent was in force, since this is the very essence of the instrument, and with the very wide definition of a diaphragm, practically covered the whole field. In the specification various forms of the tension regulator are shown, some being mounted on rigid back-stops, and others on adjustable springs. Reference is made to the importance of the circuit not being broken to get satisfactory results, for, on page 5, the inventor says: "I find it is not practicable to open and close the line circuit in instruments for transmitting the human voice; the circuit to line must be always closed, and the transmission be produced by a rise and fall of electric tension resulting from more or less resistance in the line." In cases where an induction coil is used, of course the words local circuit must be substituted for "circuit to line."

Speaking of the construction of the diaphragm, Edison mentions that he uses many materials, such as metals, horn, vellum, celluloid, ivory, &c., but gives the preference to mica, in that it is almost entirely free from any resonant action, and will respond, "when secured at its edges," with the greatest accuracy to the sound vibrations. This, therefore, frees all forms of diaphragms fixed at their edges.

The Edison specification contains numerous illustrations, but perhaps the most important one is Fig. 10, which shows a transmitter with a diaphragm coated with platina foil, against which presses a spring, the point of which is faced with compressed plumbago, the spring being fitted with an adjusting screw. One connection is made to the diaphragm, and the other to the spring with the plumbago point. When the diaphragm vibrates, says the inventor, it causes a greater or lesser pressure on the plumbago point, and "as the tension regulator of plumbago decreases and increases its resistance enormously under slight changes of pressure, it follows that the strength of the electric waves will be in proportion as the speaker's voice is strong or weak." Two springs are shown in the figure in conjunction with a special way of connecting the battery; but take away the second superfluous spring, and we have a combination very much resembling the Blake microphone.

Fig. 24 of the specification shows the method of connecting up the transmitter with an induction coil, the transmitter being in the primary and receiver in the secondary windings after the manner now almost universally employed.

At the foot of p. 5 reference is made to a multiplicity of contacts, for, says Mr. Edison, "if there are several electrodes opposite to each other, and insulated except at their ends, and the circuit be led from one to the other, so that the current passes through all the electrodes in succession, the rise and fall of electric tension will be promoted because the smallest vibration of one set of electrodes is multiplied by the number of places at which the metallic circuit is interrupted or varied." Here we have substantially the "compound" or Crossley microphone.

It is interesting to note that on p. 4 Edison makes mention of the well-known difficulty in getting a satisfactory reproduction of the sibilants, and suggests as the cause that hissing sounds are projected downwards after leaving the mouth, and thus, by escaping the mouthpiece, fail to take full effect on the diaphragm. As a remedy he proposes a special form of mouthpiece, in the bottom lip of which is a hole against the edges of which the downward sound-waves are directed. It seems more probable to the writer, however, that the bad transmission of the sibilants is due more to the complexity and rapidity of their vibrations, seeing that the microphone of to-day fails to satisfactorily transmit them.

To sum up, then, the various parts of the battery transmitter set free by the expiration of Edison's patent may be recapitulated as follows :—

1. The ordinary microphone diaphragm, whether of metal, wood, &c., so long as it is secured at its *edges.*

2. The use of a variable resistance, acting by the variation of pressure between two contact surfaces, either conducting or semi-conducting, one contact of which is mounted on the diaphragm, and the other attached to an adjustable back-stop, or, better still, mounted on the end of a spring the pressure of which can be adjusted by a set-screw.

3. The combination of microphone, battery, and induction coil, the one circuit consisting of the microphone, battery, and primary windings, and the other of the receivers, line, and secondary windings.

Prof. Hughes's Discoveries.

In May 1878, some ten months after the filing of Edison's patent, Prof. Hughes made public certain facts which were the means of bringing about a vast improvement in telephone transmitters. These were the discovery of the microphonic principle and the excellent results to be obtained by the use of *hard* carbon. It was considered, however, that Edison in his patent had anticipated the discoveries of Hughes, seeing that mention was made in his specification of variable contacts and lampblack, or soft carbon. Thus by the expiration of Edison's patent, all the discoveries made by Hughes (and from his various papers it would appear that he had experimented with the microphone in innumerable forms) are thrown open free for public use. Although the action of Hughes's microphone is commonly held to be somewhat different from that of Edison's carbon transmitter, yet at first sight it is exceedingly difficult to see where the one begins and the other ends, the two instruments having so much in common. The microphone is a loose contact in a circuit which is subjected to great variation in resistance when set into vibration; but what is Edison's transmitter but a loose or imperfect contact? True, in the Edison specification the variation of the resistance of the tension regulator is pointed out as being due more to the compression of the semi-conductive substance, but nevertheless it is at the point of contact that the greatest variation takes place. As we have seen, Edison was fully alive to the necessity of the circuit not being broken while speech is being transmitted, and this is also of vital importance in respect to the microphone. In both instruments the transmission of speech to be satisfactory must be produced by a rise and fall of electric tension brought about by more or less resistance in the circuit resulting from greater or lesser intimacy of contact.

Hughes, in his papers, makes mention of a "multiplication of transmitting contacts both in series or parallel"—a fact that cannot but have a serious bearing on the validity of all patents for a multiple contact microphone.

By Prof. Hughes's disclosures, then, we have thrown open for public use (in addition to the points released by the Edison patent) his discoveries with regard to the microphone and the use of hard carbon and multiple transmitting contacts in parallel, and one is, of course, at liberty to combine and interchange Hughes's and Edison's ideas. This gives ample material for the construction of an efficient microphone transmitter that will not infringe the three patents (owned by the National Telephone Co.) still in force—viz., the Blake, Hunnings, and Crossley, and which patents we will now proceed to investigate.

Hunnings' Specification (No. 3647), Sept. 16th, 1878.

This patent, the first in order to expire, has not nearly so voluminous a specification as the Edison. The inventor first proceeds to describe in detail, with reference to a very clear illustration, his well-known form of microphone, consisting of powdered carbon between two thin metal diaphragms. After drawing attention to the fact that he wishes it to be understood that he lays no claim to carbon in the solid or consolidated form, "as exemplified in the well-known Hughes microphone or Edison carbon telephone," he concludes by indicating the new features of his invention, which are summed up in two claims, as follows:—

1. "The use of finely-powdered carbon or like conductor (preferably oven-made coke prepared as described) in a loose and free state (not compressed or consolidated in any way or combined with foreign material) as a means of varying the

resistance of a telephonic circuit by the vibrations of a thin metallic or metal-covered diaphragm inclosing it, controlled by the sound-waves impinging upon it."

Fig. 2. "A telephone transmitter consisting of a layer of finely divided carbon or similar conducting material, preferably oven-made engine coke placed in a loose and free state between the thin metallic or metal-covered diaphragms in a suitable case as, and for, the purposes described."

After a careful perusal there appears very little reason to doubt that the Hunnings microphone in its most efficient form is effectually covered by this patent and that the matter is good subject for a patent.

What strikes one most on first glancing at Hunnings' illustration, is that the shape he has given his transmitter scarcely accords with that which in actual practice has been found to give the best results. He shows a large diaphragm with but ittle depth of powdered carbon whereas a smaller diaphragm and considerable thickness of powdered carbon will be found more effectual. Carbon in the form of small balls with highly polished surfaces has also been found to be the best material to use between the diaphragms, the mixture described by Hunnings having a tendency to "cake."

BLAKE (No. 229), JAN. 20th, 1879.

The Blake transmitter is protected in this country in the name of William Robert Lake, it being a communication from abroad, and although the instrument gives evidence of much originality, yet a combination of Edisons's ideas with Hughes's discoveries is clearly traceable; in fact, on close investigation it bears, it will be seen, a remarkable resemblance to Edison's, Fig. 10. Its novel points are the supporting of the diaphragm by spring pressure, the affixing of the second electrode—not as Edison does on the diaphragm, but to a small independent spring—and a special form of adjusting lever. A fourth claim is made for supporting the back electrode, or carbon button, on a spring; but in the face of Edison's specification it is difficult to see how such a claim could be substantiated.

Commencing with a statement as regards his method of supporting the diaphragm, the inventor passes on to the transmitting contacts, and remarks: "As heretofore constructed, one of the electrodes is held in a fixed position, while the other, being free to move to some extent, is pressed against it with greater or less force by the vibrations of the diaphragm to which it is connected." Such a state of things, the inventor avers, is not conducive to obtaining the best results, for the instrument must be adjusted with great care and delicacy, and when so adjusted is liable to lose its adjustment on the first abnormal vibration of the diaphragm. This statement, although true in regard to some forms shown in Edison's specification, does not apply to Fig. 10, where the back contact is supported on a spring. Continuing, the inventor proceeds to describe his well-known microphone with reference to three illustrations which, as indicating that the instrument must have been pretty well perfected before being patented, differ but slightly from the Blake transmitter of to-day. The method of supporting the diaphragm is explained, it being kept in position merely by the pressure of two "gloved" springs from the back. Passing on to the mounting of the first electrode or platinum contact, the inventor says that this may be attached directly to the diaphragm, but that he prefers to support it independently on a light spring, "for it not unfrequently happens, when the intermediate electrode is attached directly to the diaphragm, that a too rapid vibration of the diaphragm or some other disturbance in its vibrations will throw the outer electrode out of contact with the intermediate electrode, and thus break the circuit; but in my construction such irregular vibrations of the diaphragm will separate the diaphragm from the intermediate electrode rather than separate the two electrodes from each other, and the circuit would not be broken." The supporting of the carbon electrode is next described, which, we are told, is weighted for the purpose of resisting by its inertia the vibrations of the diaphragm. This second electrode, the inventor says, may be of metal, but better results are obtained from hard-pressed carbon, such as is used for electric lighting.

After describing the special form of adjustment, the specification concludes with the following claims:—

1. "The method herein described for holding the diaphragm of a telephone by means of springs pressing against one of its surfaces."

2. "A spring forming or carrying one electrode of the circuit of a telephone, and constantly pressing against the other electrode and diaphragm to maintain the required initial pressure between the electrodes, and yield to the movements of the diaphragm substantially as described."

3. "The adjusting lever for regulating the tension of the spring which carries one of the electrodes, and the initial pressure between the two electrodes and against the diaphragm substantially as described."

4. "The combination of the two electrodes by means of springs acting against each other substantially as described, to maintain the electrodes in contact when forced away from the diaphragm."

5. "The yielding weight connected with the movable electrode to resist the movement of the diaphragm, and modify by its inertia the variation of pressure between the two electrodes substantially as described."

As regards the first of these claims, this, of course, covers the mounting of the diaphragm by springs; but since diaphragms fixed at their edges are just as efficient, it is of no consequence. The second is apparently intended to cover the form of microphone with one electrode on a spring and the other attached to the diaphragm; but this form is released by the expiration of Edison's patent. So far as this claim relates to the second electrode being also on a spring, it is undoubtedly new. The third is for the special form of adjusting lever, which is certainly novel and efficacious. Nevertheless, the mechanic who could not devise a dozen others equally as good may reasonably be adjudged to have mistaken his vocation. Claim 4, for the combination of the two electrodes on springs, Blake is undoubtedly entitled to, this being one of the main features of his invention. In the 5th claim, however, exception must be taken, for although Edison does not make mention of specially weighting his spring carrying the plumbago button, nevertheless it follows, as a matter of course, for the simple reason that it would be impossible to construct such a button without weight. Edison makes no limit as to the size of the button, and the bigger the button the more weight it must necessarily have, and it does not require a a button of very large size to give the requisite weight to get satisfactory results.

Crossley (No. 412), Feb. 1st, 1879.

Crossley's claim is for a "compound" microphone, which he defines as one having three, four, or more carbon pencils with six, eight, or more points of contact, as differing from the ordinary microphone with only one pencil and two points of contact, to which he lays no claim.

In the body of the specification he describes the construction with reference to several figures, of his well-known and excellent four-pencil microphone, and concludes with two claims. The second of these is for "the arrangement, construction, and employment of compound microphones" . . . . "substantially as described with reference to the accompanying drawing," a claim to which no one can take exception, and to which the inventor is justly entitled. Claim No 1, however, is of a very wholesale character, and covers all forms of compound microphones "having three, four, or *more* carbon pencils, with six, eight, or *more* surfaces touching each other," and also compound microphones with thin metal plates instead of carbon pencils, and whether mounted on parchment, wood, or any other suitable substance." In the face of what Edison has shown in his specification and Hughes makes mention of in his papers with regard to multiple contacts, it is somewhat surprising that such a claim should have been made. A very weak point in the specification, and one that is glaringly obvious to all who take it up, is that matter is introduced into the final specification that is not even foreshadowed in the provisional—a fact which alone is liable to invalidiate the patent. To quote Crossley's own words, he says, "I employ an ordinary microphone," and throughout the entire provisional not one word is mentioned about compound microphones, nor so much as a hint let drop that he employs anything but an ordinary microphone. The "ordinary" microphone had been devised by Edison and by Hughes a year or two before. It is only in the complete or final specification that any light is thrown on the matter, when the inventor substitutes the word "compound" for "ordinary." He then proceeds to define a compound microphone and also an ordinary one, to which latter he repudiates claim, which, to say the least of it, is somewhat contradictory.

Taking into consideration, therefore, this extraordinary want of sympathy between the provisional and complete specifications, with the fact that a multiplication of transmitting contacts had been previously mentioned by both Edison and Hughes, it is extremely doubtful if the Crossley specification would "hold water." Even were this not so, however, all claim to a two-pencil microphone is repudiated, and with two carbon pencils a microphone transmitter can be constructed of the speaking capabilities of which no one need be ashamed.

The different parts or methods of mounting such parts that one is not at present entitled to use may be briefly recapitulated as follows:—

1st. Blake's method of holding the diaphragm by *special* spring pressure.

2nd. Blake's method of mounting the second or platinum electrode on a spring.

3rd. Blake's combination of the two electrodes on springs.

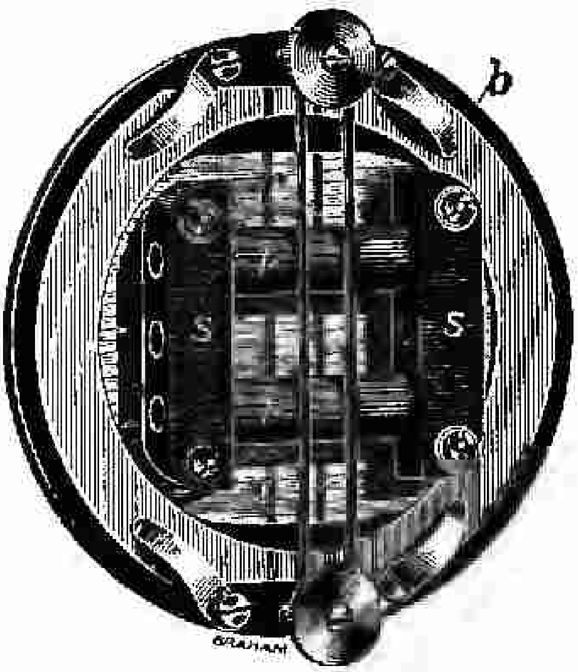
4th. Blake's special form of adjusting lever.

5th. Crossley's microphone or any pencil microphone with more than two pencils.

6th. Hunnings' microphone or any microphone consisting of granulated carbon between thin metallic or metal-covered diaphragms.

The 1st, 2nd, 3rd, and 4th of these may not be used till after Jan. 20th, 1893, the 5th till Feb. 1st, 1893, and the 6th till after Sept. 16th, 1892.

Fig. 43.



Two-pencil Microphone.

A form of the two-pencil microphone that gives excellent results, and which can be used without fear of infringing any of the above-mentioned patents, is shown in Fig. 43.

It consists of a pine-wood diaphragm *a*, specially treated to prevent its warping by the moisture from the breath and clamped into a metal frame *b*, by the four metal clips shown. The two pencils fit loosely into the two carbon supports *s* and *s*, and a constant pressure of pencils against the sides of the holes is maintained by a rubber band *r*, stretched across two adjusting screws seen, one at the top and the other at the bottom of the metal frame *b*. The pressure of the band can be adjusted by turning the screws, and this allows the vertical position of the diaphragm to be retained without giving rise to the disagreeable rasping noises that would otherwise arise. Connection is made with the one wire to the right-hand block *s*, and with the other to the left-hand one.

A further improvement can be effected in this microphone by specially shaping the holes, whereby the necessity for an indiarubber band or any spring pressure whatever is done away with. The way in which this is effected is shown in Fig. 44, the two carbon pencils and the two carbon supports only being shown. The holes in carbon supporting blocks are cut diagonal shape, as shown, instead of round, as is usually done. This causes the carbon pencils to roll forward against the front face of the holes, which action can

Fig. 44.

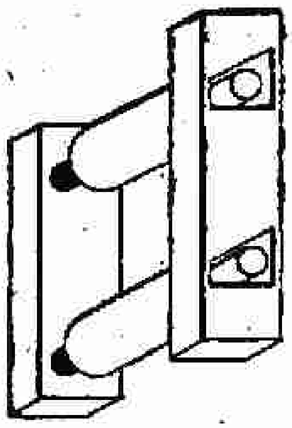
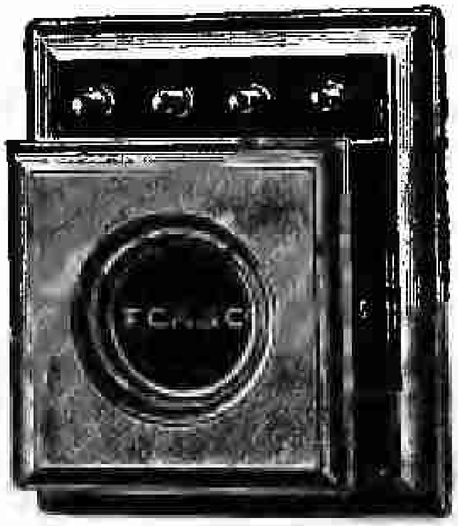


Fig. 45.



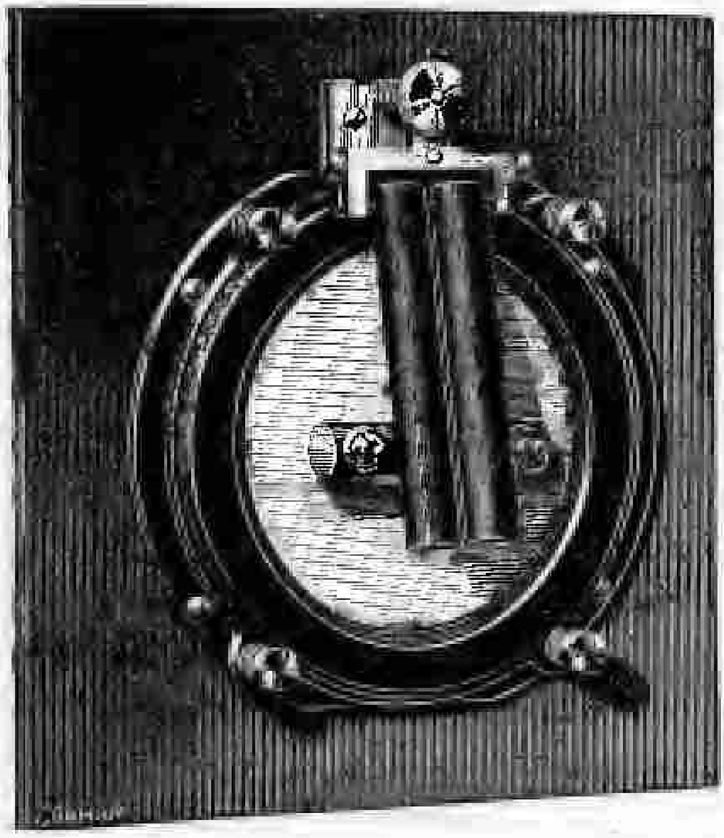
Two-pencil Microphone.

be further assisted if necessary by weighting each carbon with a thin lead ring. This method does away with all necessity of spring pressure, and makes an efficient microphone that cannot get out of order. Fig. 45 shows the external appearance of this microphone complete.

The necessity for spring pressure or for specially shaping the bore-holes arises from the fact that a certain amount of pressure is necessary to obtain good results, and this pressure must be either towards or from the diaphragm. If no spring pressure is employed the pencils only roll in the holes, giving rise to but poor speech, which is almost overpowered by a disagreeable rasping noise caused by this rolling. In all forms of microphones having a horizontal or inclined diaphragm, such as the Crossley, Ader, and Gower Bell, there is, of course, no necessity for spring pressure, as the weight of the carbons is downwards in the direction in which the diaphragm vibrates, and they do not thus roll.

A form of two-pencil microphone devised by the writer is shown in Fig. 46. It consists of a thin pine-wood diaphragm faced both sides with mica, and clamped in a circular brass frame. To the centre of the diaphragm is bolted a horizontal carbon block, against which rest two pivoted carbon pencils, the pressure of the pencils against the carbon block being varied by turning the milled nut A, thus throwing the pencils more or less out of the perpendicular. When the milled nut A is turned, it forces the brass arm, carrying the two pencils forward against the pressure of a spiral spring so that the frame remains perfectly rigid in all positions. One wire is connected to the frame carrying the pencils, and the other to the carbon block. The illustration show a back view of the microphone mounted on the lid of the transmitter case, which is of similar form to Fig. 45. Only one cell is required for this microphone, which is very sensitive, and which can be adjusted so that it will take up speech directed towards it 40 feet distant.

Fig. 46.



Two-pencil Microphone.

CHAPTER III.

SWITCH-BELLS.

IT is evident that unless some means were provided of readily calling attention at the distant end when it is desired to speak that a telephone, however good its speaking capabilities, would be practically useless. This is done by means of an electric bell, which may be either a battery or magneto one, and the containing case, with its bell and switching apparatus, is known as the "switch-bell." It is necessary also that some means should be provided of cutting out the transmitter and receiver, and putting the bell into circuit when it is desired to ring, and cutting out the bell while conversation is being carried on. In the early days of telephony, this was done by means of a two-way switch fixed near the telephone which was moved from "ringing" to "speaking" by hand. This, naturally, was a very unsatisfactory method, as the speaker, after using the instrument, often forgot to return the switch to the "ringing" position, and if this was the case, the person at the other end was unable to "call" him until a messenger had been sent round to explain the state of affairs.

Soon, however, the idea occurred to some one that the weight of the receiver might be utilised to actuate the switch, and this is the method almost universally now employed. When the receiver is hanging on a hook at the side or bottom of the case, the transmitter and receiver are cut out and the bell is in circuit; but when the receiver is removed, the hook, impelled by a spring, moves up, cutting the bell out of the circuit, and inserting the transmitter and receiver. This form answered all that was required until the advent of the battery transmitter, when another requirement arose: it became necessary, in order to prevent running down the local transmitter cell, to break the local circuit when the instrument was not in use, and another make-and-break was introduced into the switch-bell.

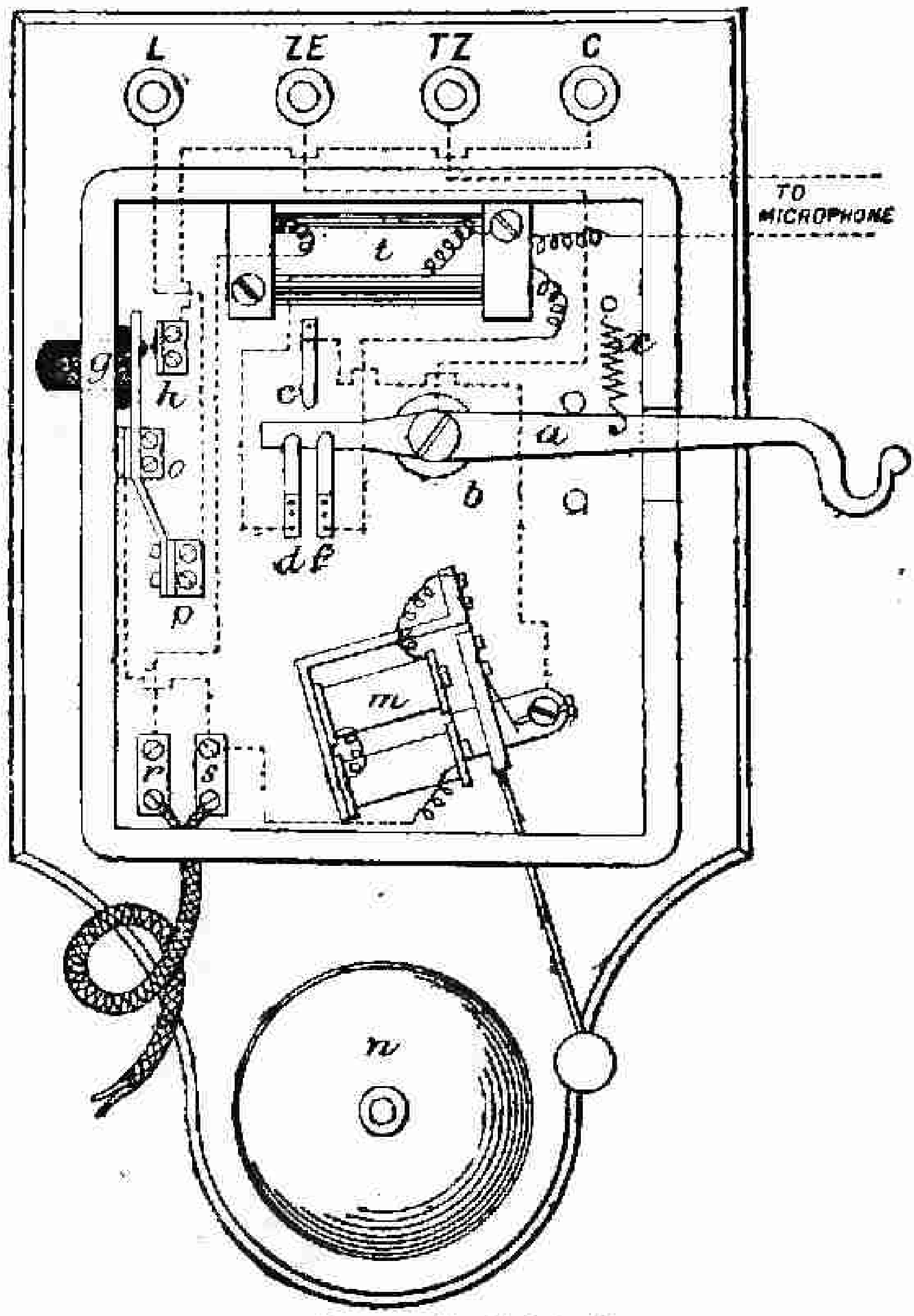
It would be superfluous to describe in detail the switch-bells used in all the different instruments, since the similarity is so great, the only difference being a slight rearrangement of parts; so we shall illustrate and describe at some length one or two forms, the other forms being shown in the illustrations of the complete instruments as well as in the diagrams of connections.

Switch-bells are of two kinds, either "battery" or "magneto." The first require a battery to effect the ringing, while in the second it is done by a magneto generator and bell.

Battery Switch-bells.

Fig. 47 shows a form of battery switch-bell now very widely used. It is shown in the figure with the front removed, thus disclosing the interior construction and connection. It consists of polished walnut-wood case mounted on a backboard, at the bottom of which is the bell gong, the movement *m* being inside, and the hammer working through a hole in the woodwork. On the right-hand side is the automatic switch-hook *a*, working on the pivot *b*, and engaging, when down, with contact spring *c*, but when up with the two springs *d* and *f*. On the left-hand side is the ringing key, the button of which is marked *g*, the spring *p*, the back contact *o*, and the front one *h*. The induction coil *t* is at the top of the case, and the two connecting plates *r* and *s* at the bottom are for the ends of the receiver cord. The four terminals at the top are—"Line" (L), "zinc and earth" (Z E), "transmitter zinc" (T Z), and "copper or carbon" (C). When the receiver is off the hook, the lever, impelled by the spring *x*, moves up into the position shown,

Fig. 47.



Battery Switch-bell.

but when actuated by the weight of the receiver it falls and the back end makes contact with the spring *c*.

The circuit, ringing from the other end, is as follows:— Terminal L, spring *p* of ringing key, back contact *o*, plate *s*, oell movement *m*, spring *c*, switch-hook *a*, pivot *b*, terminal Z E, "earth," and thence back to the other instrument.

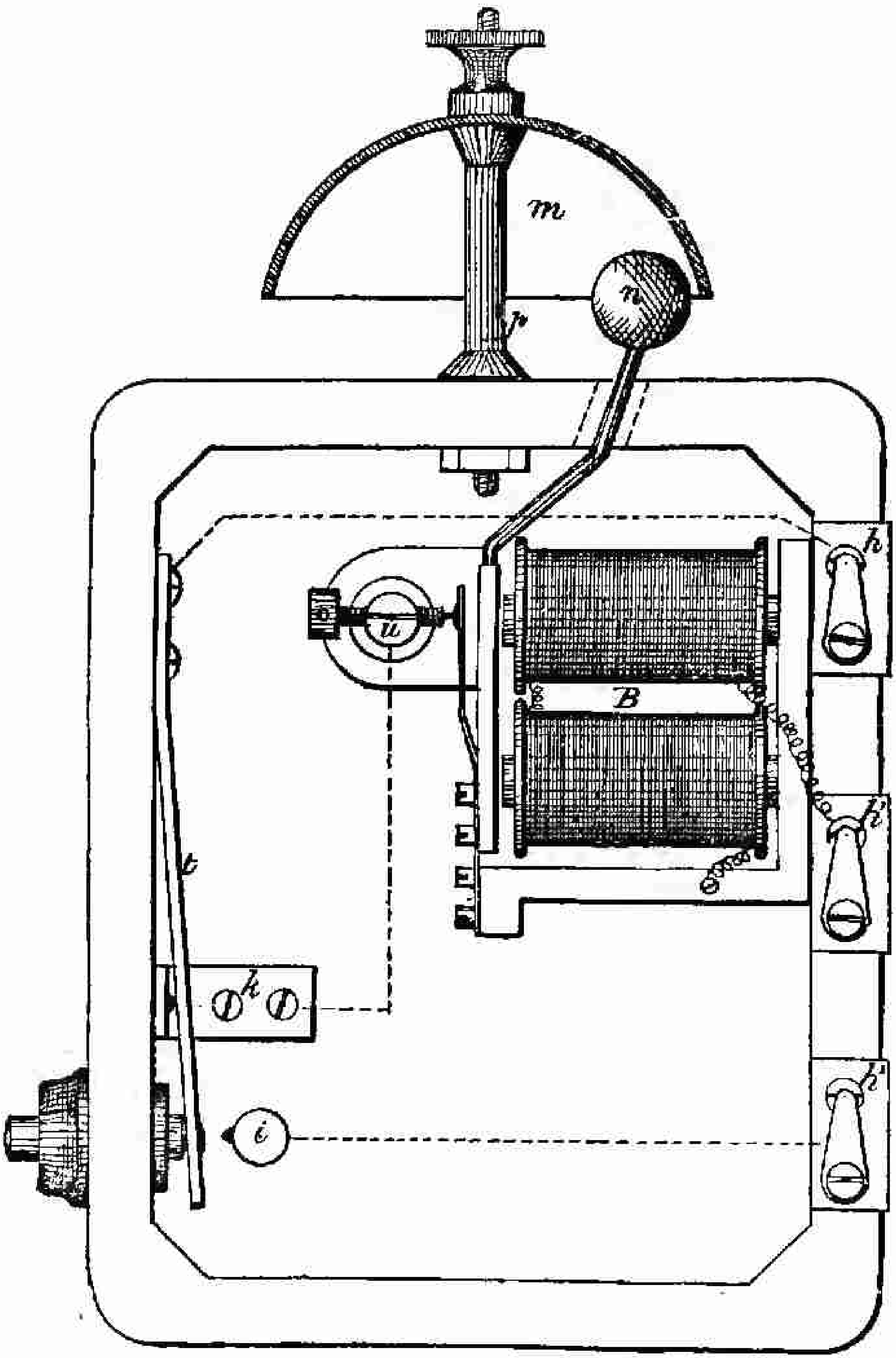
Ringing from this end the circuit is as follows:—Terminal C, front contact *h* of ringing key, spring *p*, terminal L, "line" wire, other instrument, and thence to battery and terminal C.

The speaking circuit is as follows:—First microphone or local circuit runs from terminal T Z to microphone, primary of induction coil *t*, spring *f*, switch-hook *a*, pivot *b*, and thence to terminal Z E. The secondary circuit runs from secondary windings of induction coil, spring *d*, switch-hook *a*, pivot *b*, terminal Z E, "earth," other instrument, "line" wire, terminal L, spring *p*, back contact *o*, plate *s*, receiver, plate *r*, and back to secondary windings of induction coil. The external appearance of this switch-bell is shown in Fig. 64, and the external connections in Fig. 168.

Figs. 48 and 49 show the switch-bell used by the United Telephone Company (now the National Telephone Company) and its subsidiary companies. The United, when they first started, used almost exclusively this type of bell; but as their exchange system developed the difficulty of keeping so many batteries in order induced them to adopt the magneto switch-bell, which, for exchange work, has many advantages, so that these are gradually being substituted for the battery switch-bells.

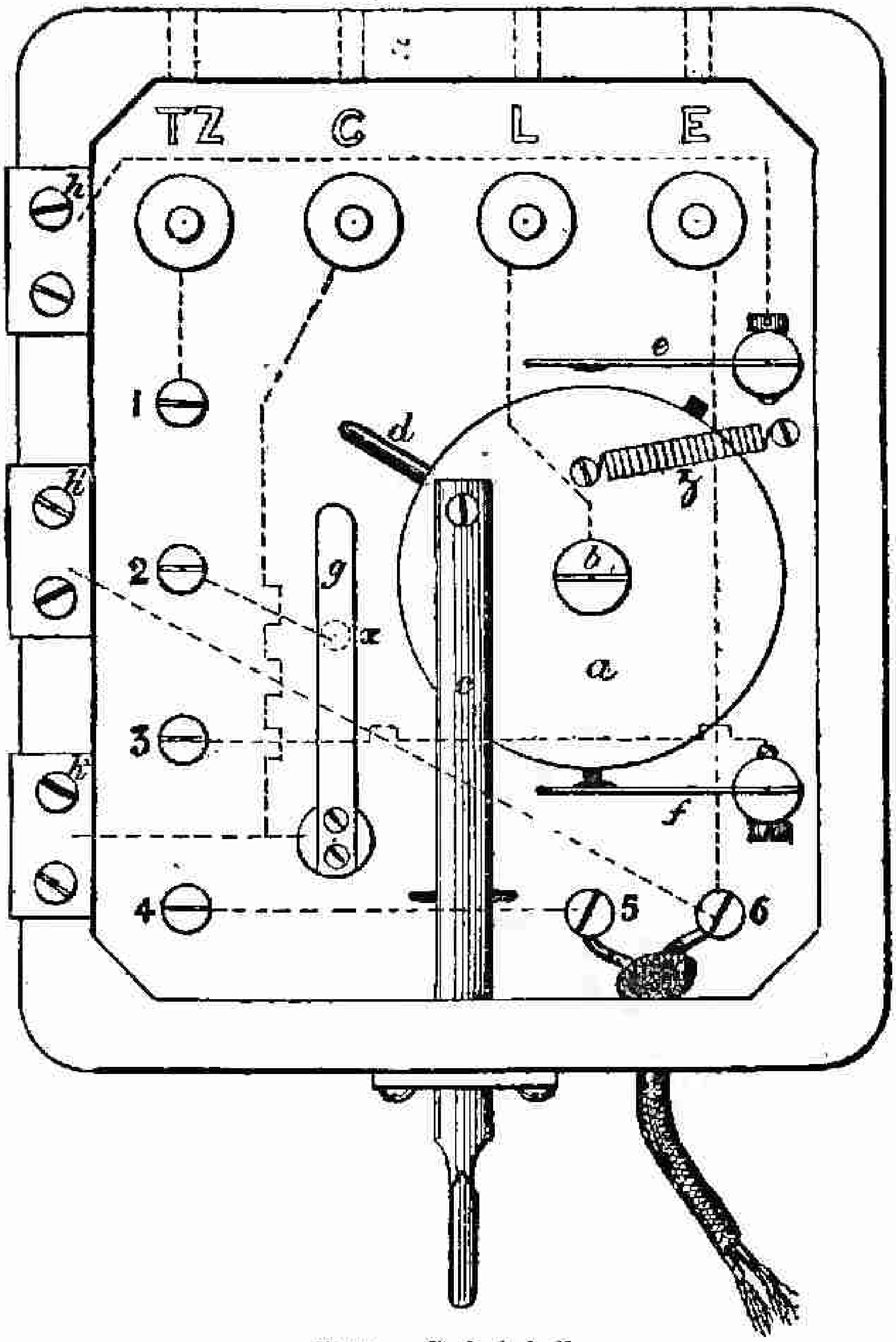
In Figs. 48 and 49 the switch-bell consists, it will be seen, of a containing case (made of walnut-wood), the case being made in two halves and hinged together by the three hinges h, h^1, h^2. These hinges also serve to make three connections from one half of the case to the other. In the left-hand side of the case is the bell B with the hammer *n*, which strikes on the inside of the gong *m*, fixed to the top of the case by the post *p*. In the same half of the case is also the ringing key, consisting of the ivory button *o*, brass spring *t*, back contact *k*, and front contact *i*. In its normal position the brass spring *t* makes contact with the back contact *k*; but when the button *o*

Fig. 48.



Battery Switch-bell.

Fig. 49.



Battery Switch-bell.

is pressed it breaks with the back contact, and makes with the front contact *i*. In the right half of the case is the automatic switch, consisting of the brass disc *a*, turning in its centre on the screw *b*. On the left-hand side of this disc is pivoted the brass rod *c*, the lower end of which is bent into the shape of a hook, and on which is hung the receiver when not in use. Two platinum-pointed springs *e* and *f* are fixed one below and one above the brass disc, the one *e* being in the "ringing" and the other *f* in the "speaking" circuit. In the position shown in the figure the receiver is off the hook, and, impelled by the spiral spring *z*, the disc is pulled round, breaking the "ringing" and making the "speaking" circuit. When the receiver is placed on the hook its weight draws down the rod *c* against the pull of the spring *z*, causing the brass disc to make contact with the spring *e*, and break with the spring *f*. At the same time the ivory pin *d* in the edge of the brass disc engages with the thin brass spring *g*, causing it to ride up on the pin, and thus break contact with the contact-post *x* underneath. This breaks the local circuit of the transmitter. The four terminals at the top of the case are those to which connection is made when connecting up the instrument, and are labelled respectively "earth," "line," "copper," and "transmitter zinc." The four smaller terminals, marked 1, 2, 3, 4, are connected to similar terminals in the transmitter case, both the transmitter case and the switch-bell case being fastened on to a common backboard. Terminals 1 and 2 are the local circuit, consisting of the microphone, primary of the induction coil, and one cell of the battery; while terminals 3 and 4 are the circuit through the secondary of the coil. Terminals 5 and 6 are those to which the ends of the flexible twin wire connected to the receiver are attached.

When the receiver is off the hook the circuits are as follows:—The local circuit through the transmitter is from carbon of battery to terminal C, spring *g*, contact post *x* (now closed), terminal 2, and from there outside the case to primary of induction coil, microphone (see p. 25) to terminal 1, terminal T Z and zinc of the battery.

The "speaking" circuit is:—Line wire from other instrument to terminal L, screw *b*, disc *a*, spring *f* (now closed), terminal 3, secondary of induction coil, terminal 4, terminal 5, flexible cord, receiver, terminal 6, terminal E, and thence to "earth."

When the receiver is on the hook the circuits are:—Ringing from the other end of the line the current enters at terminal L, from "line" to screw *b*, disc *a*, spring *e* (now closed, spring *f* being open), hinge *h*, spring *t*, back-contact *k*, contact-post *u*, bell-coils, hinge h^1, terminal 6, terminal E, and thence to earth.

Ringing from this end of the line, the circuit, when the button *o* is pressed, is:—Carbon pole of battery, terminal C, hinge h^2, contact-post *i*, spring *t*, hinge *h*, spring *e*, disc *a*, screw *b*, terminal L, and thence to "line."

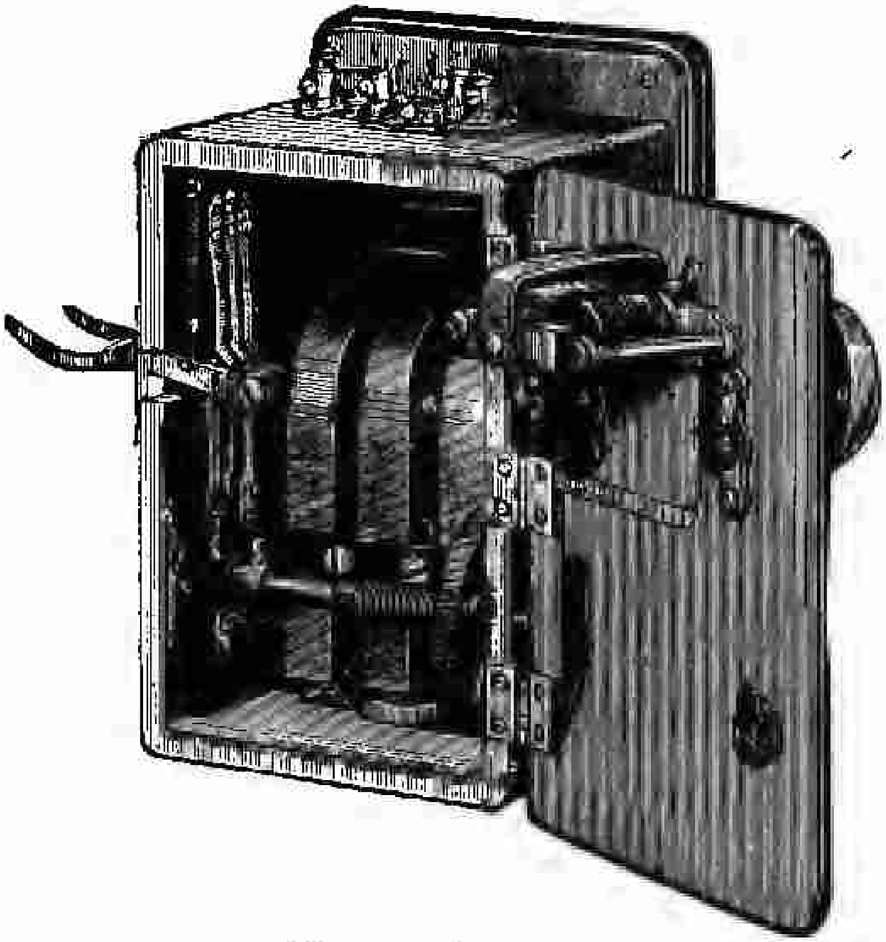
In some of these switch-bells an improvement in the arrangement for closing the local circuit has been adopted, which has a rubbing contact, the one shown in the figure having a dotting one, which is more liable to derangement.

In the Gower switch-bell two hooks are used, as there are two listening tubes. One of the hooks makes the change from "ringing" to "speaking," and the other breaks and makes the local circuit through the microphone. The majority of the switch-bells, such as the Ader, Crossley, Johnson, &c., have only one hook, which is made to do the two operations, as in the one just described.

Magneto Switch-bells.

These are rapidly coming into favour in preference to the battery switch-bells, their chief advantages being that they require less attention to keep in order, and they are also capable of signalling to a much greater distance. The form used by the telephone companies consists (see Fig. 50) of a walnut-wood box, in which is placed a magneto generator, a full description of which will be found in Chapter V) and a magneto bell, the gongs of the bell and handle of the generator projecting through to the outside of the case. On the left-hand side of the case is a hook, on which the receiver is hung when not in use, and which hook, by moving up and down, makes the necessary change of connections from "speaking" to "ringing," as in the battery bell just described.

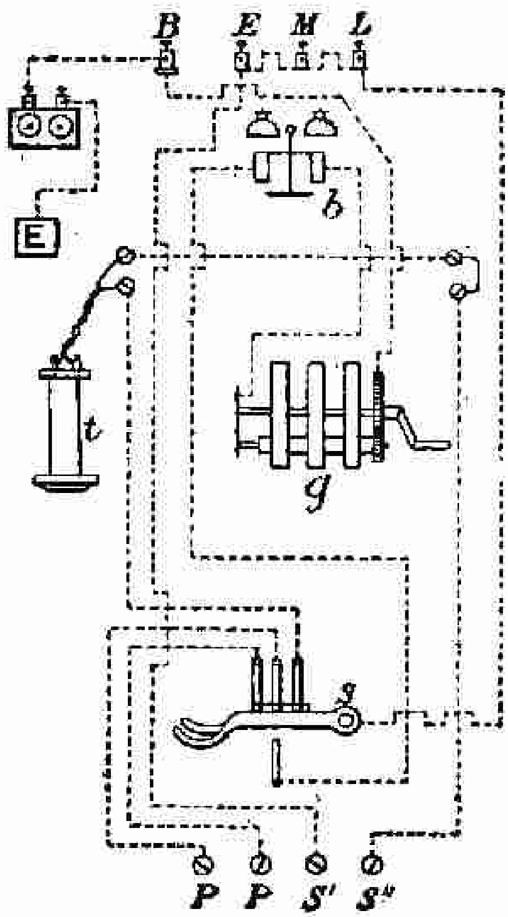
Fig. 50.



Magneto Switch-bell.

The connections of the instrument are shown in Fig. 51, the external circuits, including the microphone and induction coil, not being shown. In the figure, *b* is the bell, *g* the generator, and *t* the receiver. The switch-hook is marked *s*, while *p*, *p'*, are the primary and *s' s''* the secondary terminals. It will be noticed there are four terminals at the top of the case, marked B, E, M, and L respectively. E and L are the "earth" and "line" terminals, M is an extra "earth" terminal for use where the instrument is the intermediate station of three or more, and B is for an extension bell if such is used. By having this extra terminal for the extension bell it saves speaking through the bell, which would have a prejudicial effect upon the speech. If no extension bell is used, terminals B and E must be joined with a piece of wire, as shown in Fig. 50. If the instrument is a terminal station, terminals E and M should also be connected. The lightning-arrester is fixed between the terminals E, M, and L. Only one receiver is shown in Fig. 51, but terminals are to be found on the right-hand side for a second if such is required; if not, these two terminals must be joined with a piece of wire. The switch-hook S is shown in the position into which it moves when the receiver is off the hook.

Fig. 51.

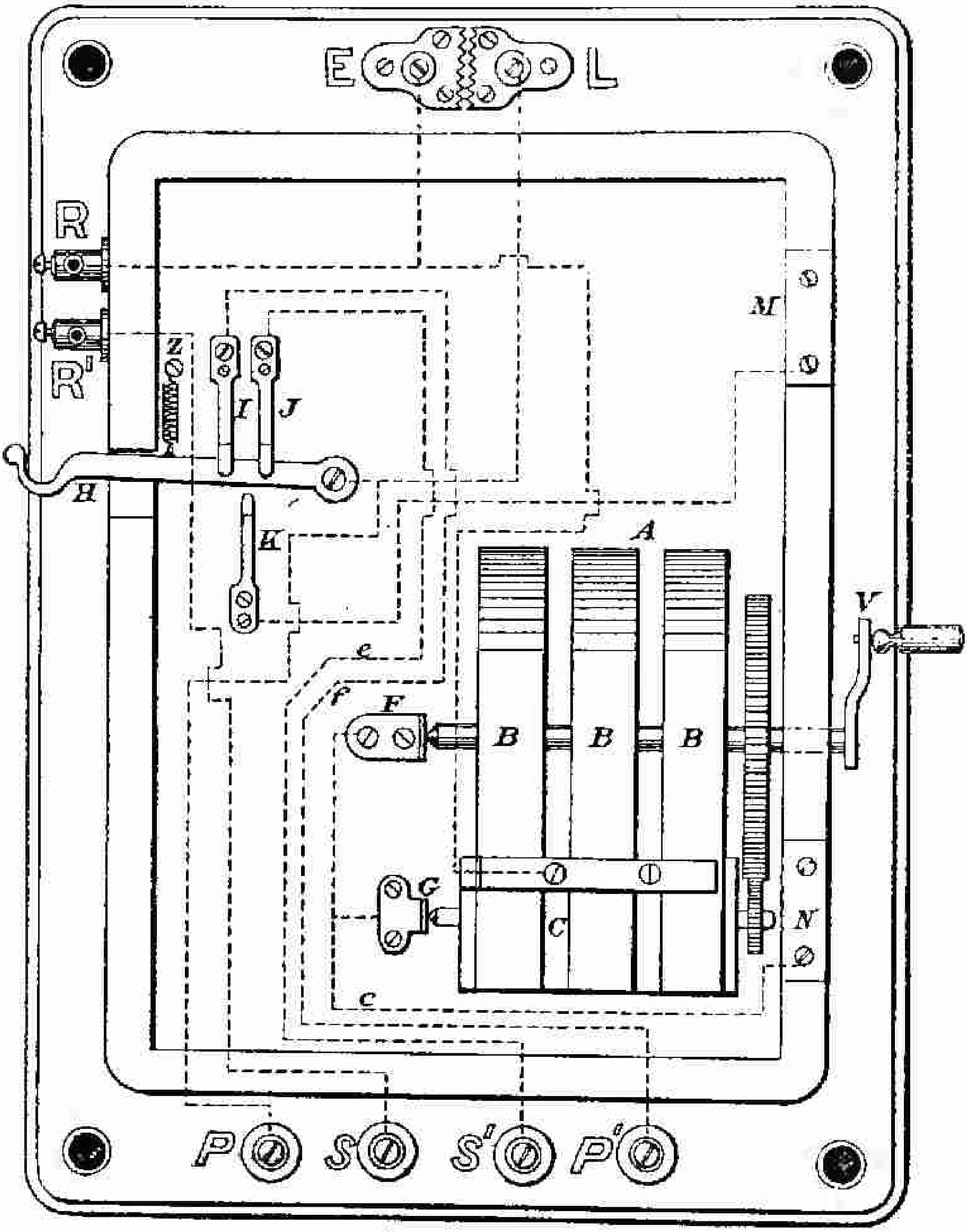


Connections of Magneto Switch-bell.

A simpler form of magneto switch-bell, and one very much used, is shown in Figs. 52 and 53, which also show the arrangement of the circuits. Two other different forms of the automatic switch are shown in Figs. 54 and 55.

In the Figs. 51 and 52 A is the generator, B B B the permanent magnets belonging to it, C the armature; F is the back stop of the automatic cut-out, and G the contact spring that makes connection with the insulated pin in the armature spindle. H is the automatic switch-hook, on the top of which are the springs I and J and below the contact spring K. When the arm H is up it makes contact with the two springs I and J, and when down with K. The arm is kept down by the weight of the receiver against the pull of the spiral spring Z. M and N are the two hinges that make connection across the

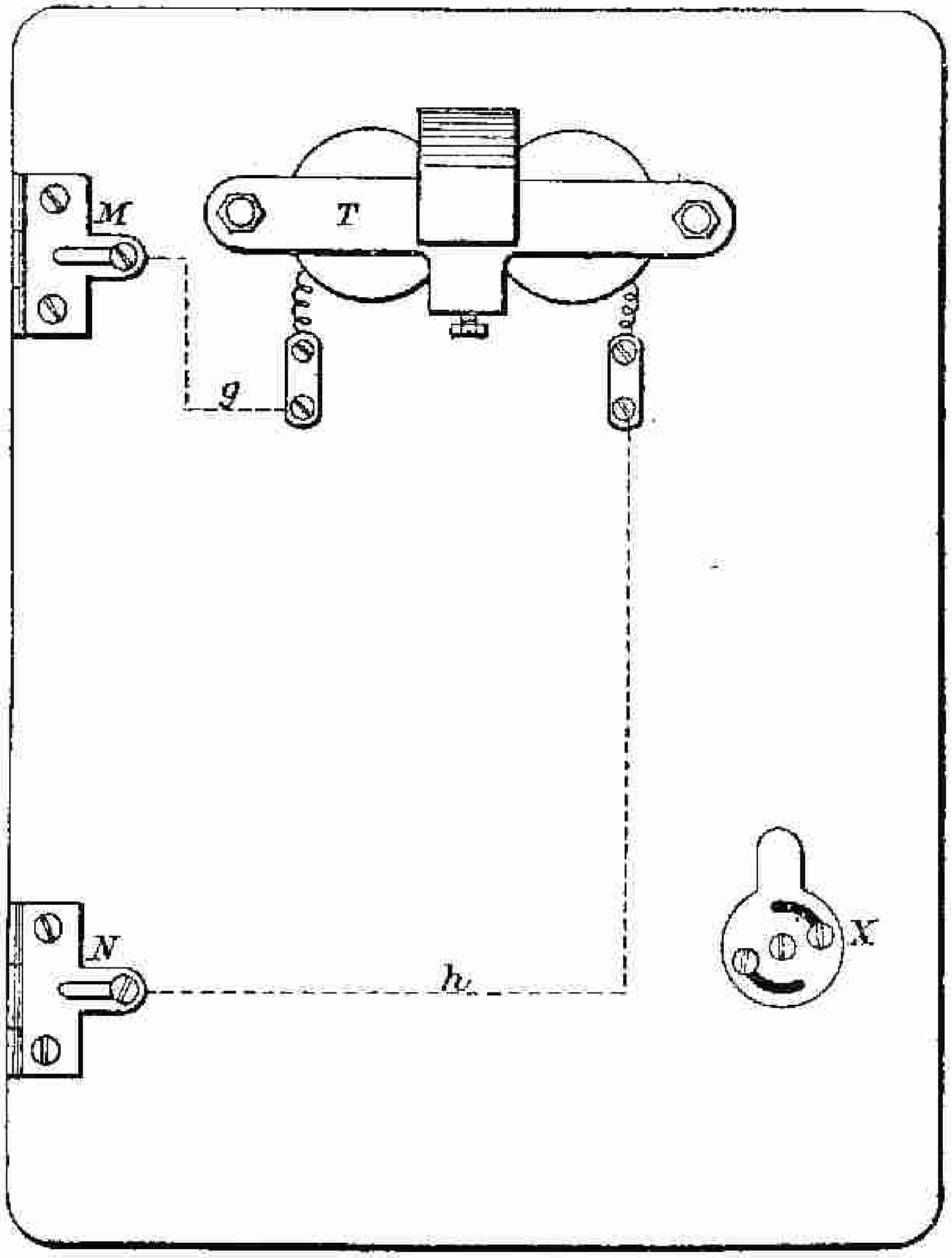
Fig. 52.



Magneto Switch-bell.

lid to the bell T; L and E are the "line" and "earth" terminals, and R and R^1 those for the receiver. P and P^1 are the terminals for the primary circuit of the microphone, and

Fig. 53.



Magneto Switch-bell.

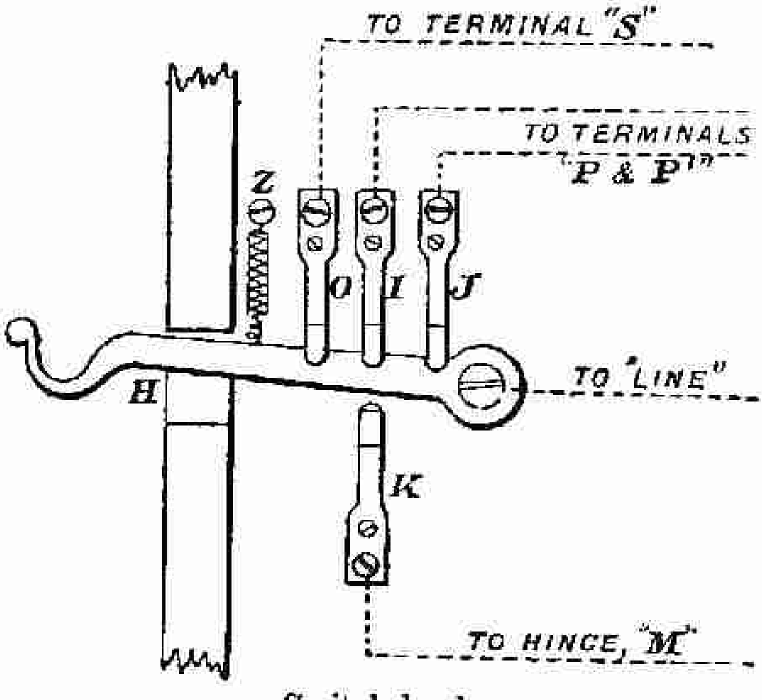
S and S^1 those for the secondary. The lightning-arrester at the top under the L and E terminals.

The "ringing circuit consists of (when the receiver is on the hook), starting from the armature C:—Armature C, contact spring G, hinge N, wire *h*, bell T, hinge M, spring K, switch-hook H, terminal L, "line" wire, other instrument, "earth," terminal E, frame of generator, and back to armature C.

Ringing from the other end the circuit is just the same, except that when the current arrives at the frame of generator it passes through to the hinge N by means of the low resistance circuit formed by the armature cut-out (see p. 103).

When the receiver is off the hook the "speaking" circuit is, starting from the secondary of the induction coil:—Secondary of induction coil, terminal S, terminal R[1], receiver, terminal R, terminal E, "earth," other instrument, terminal L, switch-hook, spring J, wire *e*, terminal S[1], and back to secondary of coil.

Fig. 54.



Switch-hook.

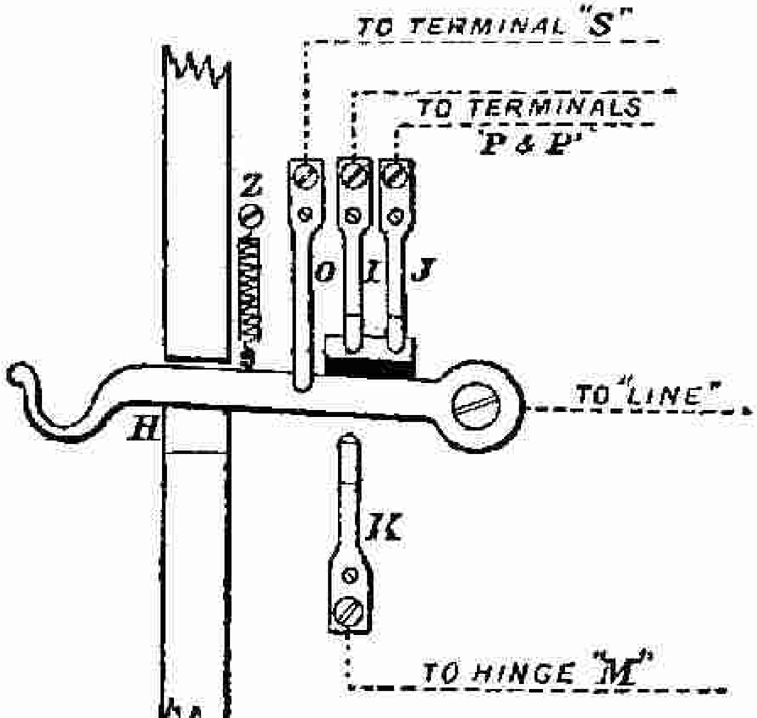
The "local" circuit runs from the microphone to primary of induction coil, local battery, terminal P, switch-hook, spring I, wire *f*, terminal P[1], and back to the microphone.

The two other methods of connecting up the switch-hook are shown in Figs. 54 and 55. The same letters are used to denote the different parts as employed in Figs. 52 and 53.

In Fig. 54, it will be seen, there is but little difference between this and the method shown in Fig. 52, an extra spring *o* only being employed so as to have a separate spring for the secondary circuit.

In Fig. 55 we have substantially the same arrangement as in Fig. 54, only that the two microphone springs are connected across by a metal piece that is insulated from the switch-hook, thus preventing the secondary and primary circuits of the induction coil being in connection at the switch-hook, which,

Fig. 55.



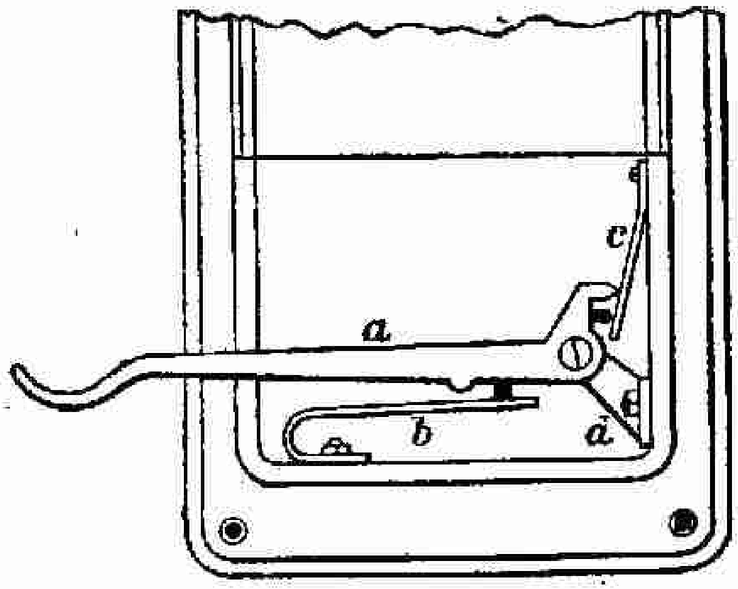
Switch-hook.

it will be seen, is the case in Figs. 52 and 54. The method shown in Fig. 55 is perhaps the best, though Fig. 52 is much used on account of its being the simpler.

A special form of switch-hook, now much used, is shown in Fig. 56. In this form of switch-hook, which is of a very solid character and has an excellent rubbing action in the contacts, the bottom spring *b*, is arranged so as to supply the pressure necessary to keep the hook up when the receiver is removed, as well as form one of the contacts.

The different parts consist of the switch arm *a*, the three top springs *c* (only one of which is shown), and the bottom spring *b*. The switch arm is pivoted on the bracket *d*, and normally is weighted down by the receiver, causing it to make contact with the spring *b*. When released it flies up into the position shown, thus making contact with the springs *c*, the connections for the different springs being exactly the same as shown in Fig. 55. It will be seen from Fig. 56 that the switch arm

Fig. 56.



Switch-hook.

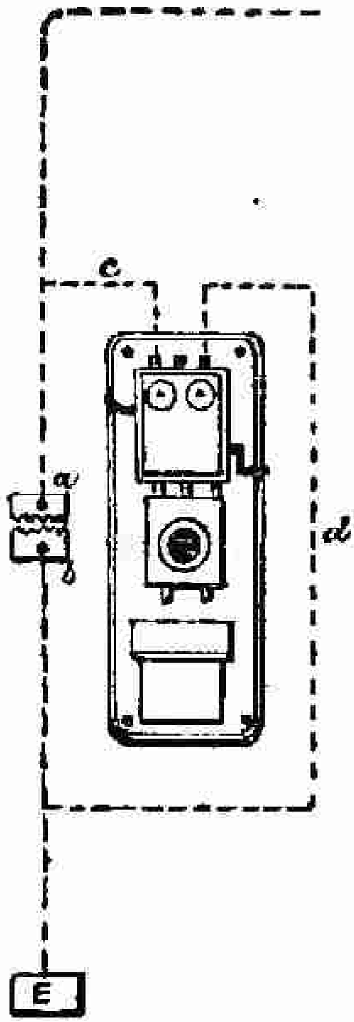
is fitted with insulating studs, on to which studs the springs slide as they break contact with the arm. Thus both the top and bottom springs *always* maintain a firm pressure on the switch-hook, that of the bottom one preponderating, so as to throw the arm up when the receiver is removed.

Lightning-Arresters.

The liability of overhead wires to be struck by lightning necessitates the employment of lightning-arresters in a telephone line where the wires are overhead, though the necessity for lightning-arresters is not so great in this country as abroad.

When a telephone line without an arrester is struck, the discharge passes to earth by means of one or both ends of the line, passing through and destroying the instrument, and might pass, if the conditions were favourable, to any person standing near the instrument, in all probability with unpleasant, if not fatal, results. The duty of a lightning-arrester is to intercept the discharge and pass it directly to earth, thus protecting the instrument and the person who might be using it. The manner in which this is done will readily be understood by referring to Fig. 57, which shows the connections at one end of a telephone line with the telephone and lightning-arrester in circuit. The arrester consists of the two brass plates *a* and *b*, fixed on an insulating base so as to be perfectly insulated from one another. The two sides of the brass plate, where they come close together, are cut to a saw-edge, as shown in the figure, and the plates are so fixed that the projecting points of the one plate come opposite those of the other plate, and as close as possible without touching. The telephone currents entering at line pass to the wire *c*, through the telephone instrument, to wire *d*, and thence to earth E. If the line, however, is struck by lightning, the discharge endeavours to pass to earth, and arriving at the plate *a*, jumps across to the plate *b*, in preference to going round through the telephone, and passes directly to earth, the jumping across the two plates being assisted by the serrated edges.

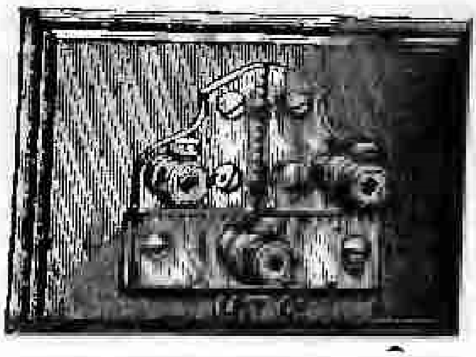
Fig. 57.



Lightning-arrester.

As is pointed out on page 163, it is important that the earth wire does not pass too close to any pipes in connection with the earth, or it might jump across to these in preference. Six inches is the least distance that should be allowed.

Fig. 58.



Lightning-arrester.

The arrester is usually combined with the switch-bell, being fixed by the "line" and "earth" terminals. Fig. 58 shows in detail a separate lightning-arrester for fixing at the point where the line wires enter the building, or for use in other places where it is not deemed advisable to have the arrester on the instrument. The two top plates are for the line wires, and the bottom one is connected to earth.

CHAPTER IV.

COMPLETE INSTRUMENTS.

THE recent expiration of the whole of the master patents of Bell and Edison effected a break down of the great monopoly that had existed in telephones for the last ten or twelve years. That the cessation of this monopoly will prove a great stimulus to the erection of short private telephone lines is quite certain, though it is not likely to much affect the large telephone companies, whose exchanges in the various towns have gained too firm a footing to fear the advent of any rival.

The patent rights in this country were originally acquired by the United Telephone Company, who worked the London and suburban districts and issued sub-licenses to various other companies, viz. the Western Counties, the Lancashire and Cheshire, and the South of England Telephone Company, for certain other districts. Subsequently, the majority of these companies amalgamated with the parent company, the combination being now known as the National Telephone Company. The instruments are let out to the public on a rental system which, although admirable for "exchange" lines, has not met with much favour in regard to "private" ones, where purchasing outright is undoubtedly more satisfactory.

The Bell patent expired on December the 9th, 1890, throwing open to the public the Bell receiver with its permanent magnet and metal diaphragm. Before the expiration of this patent, the form of telephone used by such persons as were not licensed by the United, was the "English Mechanic" receiver, with its membrane diaphragm and electro-magnets; and although satisfactory results were obtained by these under favourable conditions, yet they were in no way to be compared to any forms of the Bell.

The next patent to lapse was the Edison (No. 2909, 1877), which expired on July the 30th, 1891, throwing open to all the battery transmitter, by means of which only is long distance telephony practicable. It was on this patent, and not, as imagined by many, on that of the Blake transmitter, that the United Telephone Company took up their stand and held so successfully the sole right to use a battery transmitter in this country.

The different forms of complete instruments may be classed under four distinct heads, viz.:—1st, Those with battery switch-bells and magnetic transmitters and receivers; 2nd, Those with magneto switch-bells and magnetic transmitters and receivers; 3rd, Those with battery switch-bells, magnetic receiver, and microphone transmitter; and, 4th, Those with magneto switch-bells, magnetic receiver, and microphone transmitter.

Those of the 1st class are suitable for short lines, such as from room to room in large buildings, or for attaching telephones to existing electric bell circuits. The second class are suitable for somewhat longer lines, such as from house to stables, &c., or where it is desired to have no batteries. The 3rd class are suitable for all lines of moderate length, and are a favourite instrument. Those of the 4th are intended for very long lines, such as from 10 to 50 miles in length.

Battery Switch-bells with Magnetic Transmitters.

Two forms of this class of telephone instrument are shown in Figs. 59 and 60. The form shown in Fig. 59 consists of a Morse key-board, with two hooks at the bottom, these two hooks forming the automatic switch. A separate bell is required with the instrument, which can be fixed above or at any other convenient place. The receiver, which in this instrument is also the transmitter, hangs on the two hooks at the bottom, the metal suspension ring connecting them together, which thus short circuits the receiver and obviates the necessity of ringing through the high resistance of its coil. Any form of receiver can be used with the instrument, a "watch" being show in the figure. The ringing is effected by pressing

Fig. 59.

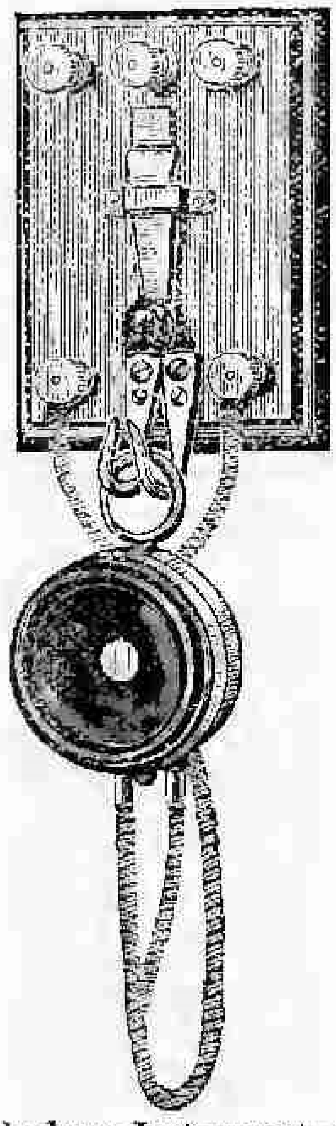
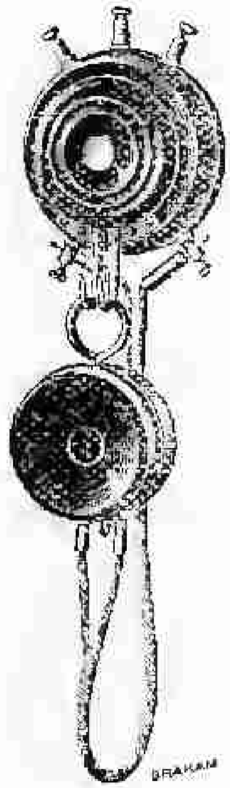


Fig. 60.



Telephone Instruments with Magnetic Transmitters.

the button of the key, and to speak the receiver is lifted off the hooks, thus throwing it into circuit. Another very convenient form is shown in Fig. 60, the working and connections of which are similar. The external connections of both these instruments are shown in the diagrams of connections at the end

Magneto Switch-bells with Magnetic Transmitters.

Figs. 61 and 62 show two forms of this class of telephone instrument, which is perhaps the simplest and easiest fixed of any.

The form shown in Fig. 61 has two double-pole Bell receivers, which hang on two hooks on the front of the generator case, the right-hand side hook being the automatic switch.

Fig. 61.

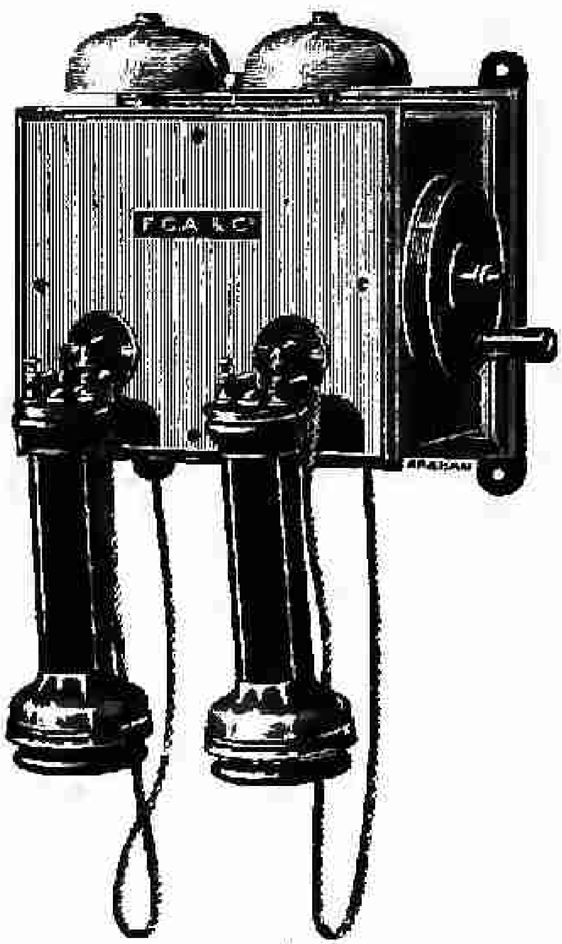
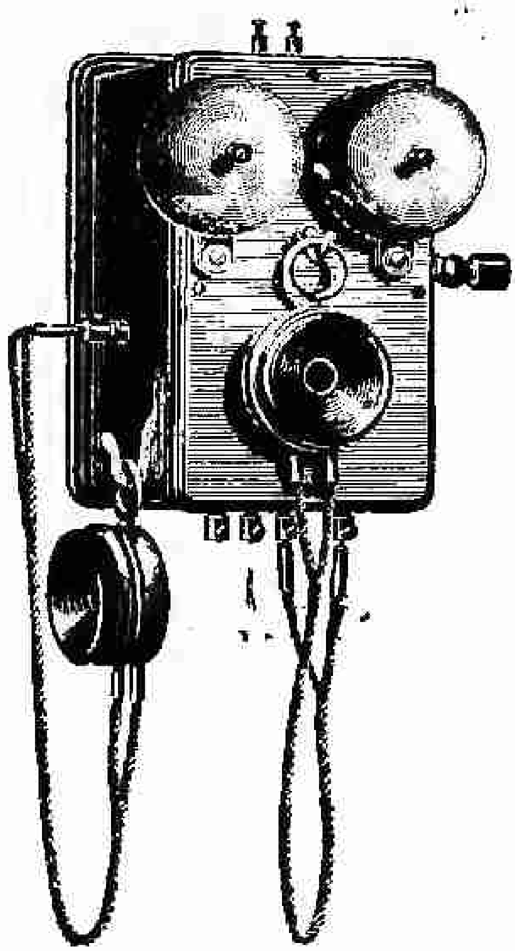


Fig. 62.

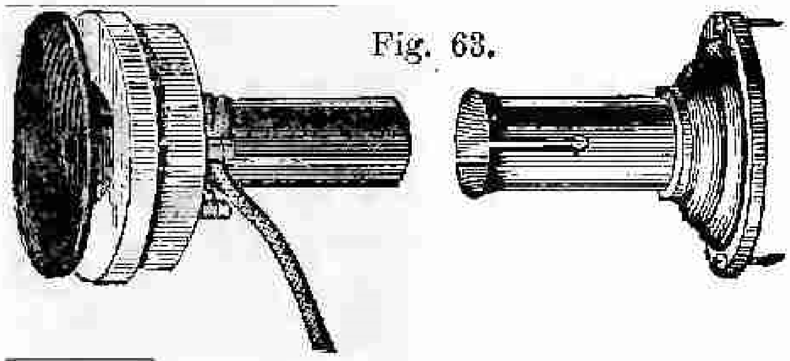


Telephones with Magnetic Transmitters.

To call attention, the handle on the right of the generator case is turned once or twice sharply, which causes both the bell at the other end of the line and also that at the sending end to ring. When the reply signal is received, the receivers are lifted off the hooks and held, the one firmly to the ear, and the other a convenient distance from the mouth, the speech being directed into the mouthpiece. The form of instrument shown in Fig. 62 is similar to that just described, except that it has two "watch" receivers instead of double-pole Bell, and the automatic switch is at the left-hand side of the generator case. The two terminals "line" and "earth" are at the top of the case.

As it is often desired to have the right hand free for the purpose of taking down messages, these instruments are frequently used with a fixed transmitter, a form of which is shown in Fig. 63. The "transmitter" in this case is an Ader receiver, to the back of which is fixed a wooden plug. This plug fits nicely into the metal tube seen to the right, and

Fig. 63.



Special Transmitter.

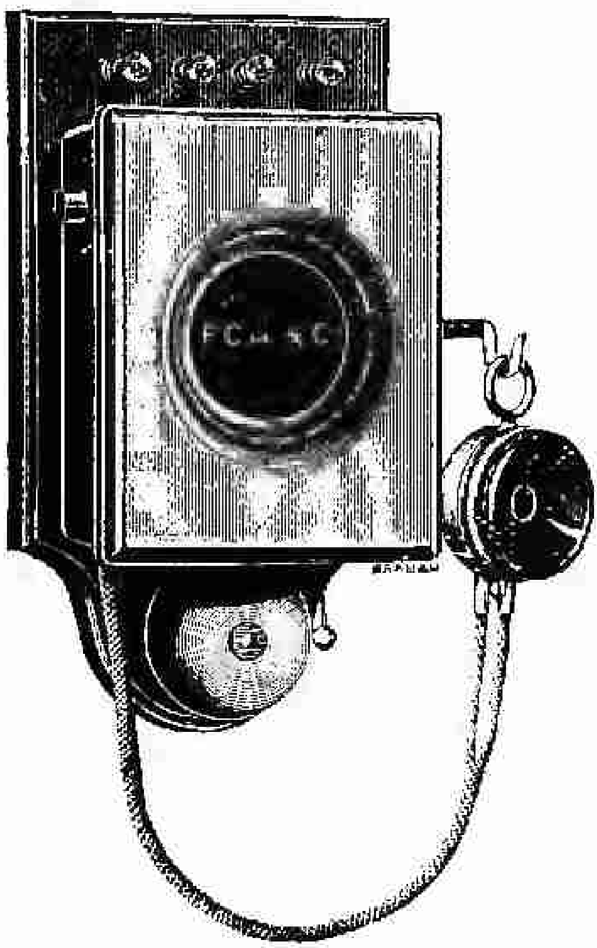
which is screwed on to the front of the generator case. Thus the receiver can be held in the hand while the speech is directed to the fixed transmitter on the front of the case. Few people were probably aware, until they came to try them, of the really excellent results capable of being obtained from Bell receivers, one of which is used as a transmitter. Nevertheless, for short distances the results obtained by using two double-pole Bell or Ader receivers are really very good, and from their simplicity they are in some instances to be preferred to a microphone, as being less likely to get out of order, besides being cheaper both in the first cost and the subsequent expense of maintenance.

It is necessary, however, to speak rather louder than when a microphone is used, and, moreover, the intonation of the voice is not so well reproduced. In using these magnetic receivers they should be held firmly to the ear when listening, while for speaking the receiver should be held with the mouthpiece about three inches off the lips, and the speech should be clear, fairly loud, and directed well into the mouthpiece. The Ader receiver is, perhaps, the most powerful for use without a microphone, but it has not the soft tone of the double-pole Bell.

Battery Switch-bells with Microphone.

A form of telephone instrument coming under the third heading, and made by the writer's firm, is shown in Fig. 64.

Fig. 64.



Telephone Instrument with Microphone.

It consists of a polished walnut-wood case, in the front of which is cut the circular aperture seen. Inside this lid is fixed the microphone (of the form shown in Fig. 46, p. 55), which is connected directly to the induction coil in the body of the case. On the right-hand side is the automatic switch-hook, which is of a very solid character. At the bottom of the case is the gong of the bell, the movement of which is inside the case, and the ringing button can be seen on the top

Fig. 65.

Telephone Instrument with Microphone.

left-hand side. The connections and interior construction of this instrument are shown in Fig. 47, the four terminals at the top being L, E Z, T Z, and C respectively, starting from the left-hand side. This class of telephone makes a very compact and loud-speaking instrument.

Another form of the battery switch-bell instrument with microphone transmitter is shown in Fig. 65. It differs somewhat from the preceding form, and is also fitted with a relay, being intended for long-distance working. The bell gong is at the top, the automatic switch on the left-hand side, and the ringing key in the front of the case. The induction coil is in the bottom half of the body of the case, and on its right-hand side is the relay. Two "watch" receivers are used with the instrument, and the microphone is of the form shown in Fig. 46. A lightning-arrester is provided, being fixed just below the bell gong.

Fig. 66.

Telephone Instrument with Microphone.

Magneto Switch-bells with Microphone.

A form of telephone instrument coming under the fourth heading is shown in Fig. 66. It consists of a polished wood backboard, on which are mounted a magneto switch-bell, a microphone transmitter and local cell for the microphone. The switch-bell is at the top, and has hanging on the automatic switch a double-pole Bell receiver. Below the switch-bell is the microphone, and below this a box containing the local cell. The top of this box is sloped for use as a writing-desk, should it be necessary to take down a message. The switch bell being very powerful, this instrument is eminently suited for long-distance working. Any other form of microphone can of course be substituted if desired. At the top are the three terminals, the right-hand side one the "line," on the left the "earth," and that in the middle is an extra one, for use where the instrument is not at a terminal station. If such is not the case, this terminal and the earth one must be joined with a piece of wire.

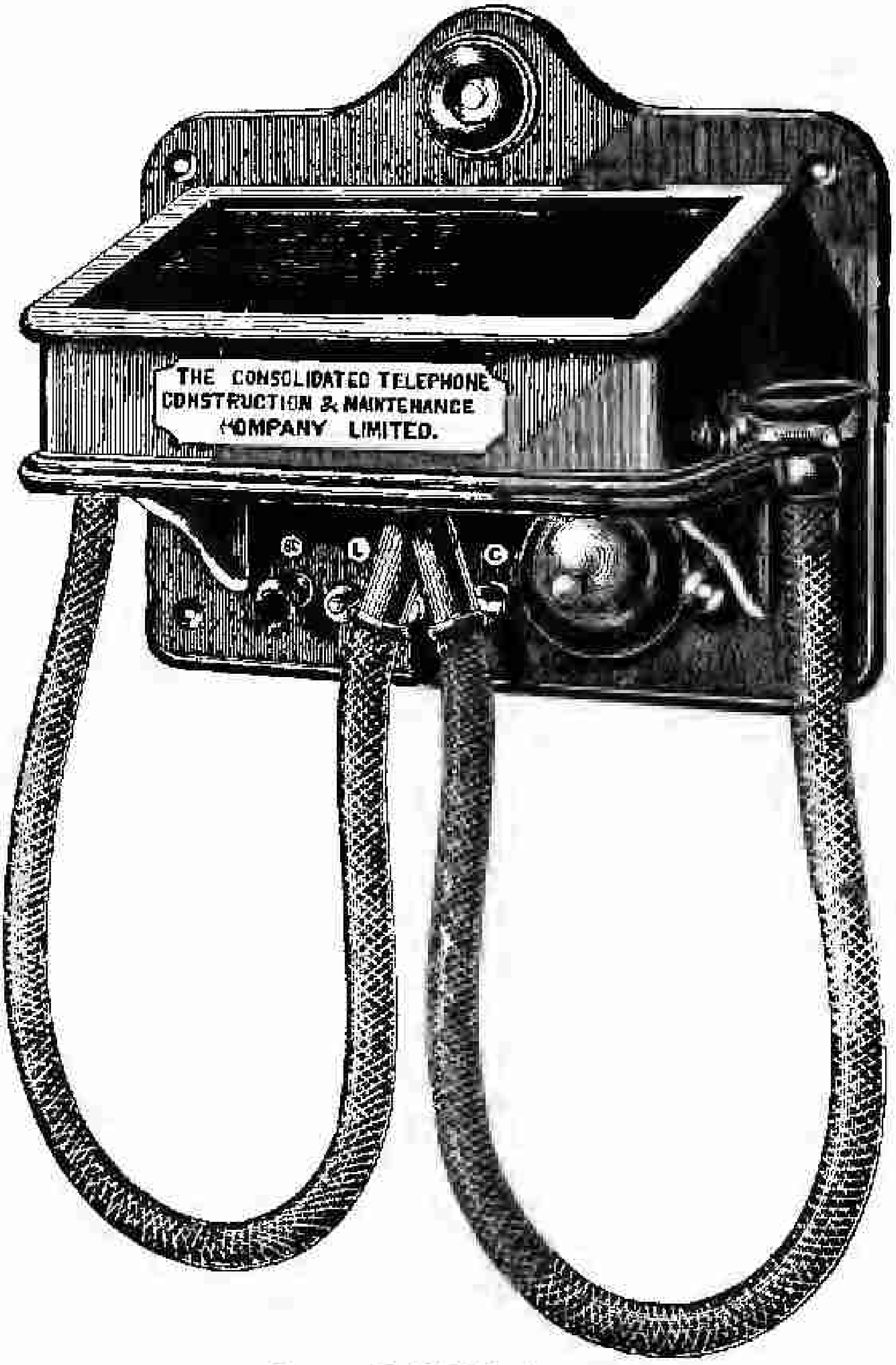
Having described the different types of complete instruments, we will now pass on to one or two special forms that are in use or have been devised in the last six or seven years.

One of the most prominent of these is the Gower-Bell, a very excellent instrument, and the one used by the British Post Office.

THE GOWER-BELL TELEPHONE.

Fig. 67 shows this instrument complete, it being a combination of the Gower microphone and the Gower-Bell receiver. The diaphragm, which is a thin pine board, is, it will be seen, exposed, and, in fact, forms the lid of the mahogany containing case. To the under side of the diaphragm is attached the Gower microphone, shown in Fig. 24, p. 26, connection being made to the body of the case by flexible wires. In the centre of the containing case is fixed the Gower receiver, the diaphragm being placed downwards, and the sound-waves produced are communicated to the ears by the two flexible speaking-tubes shown. On either side of the case are two movable supporting hooks, only one of which is visible, and on these hooks are hung the receiving tubes when the instrument is not in use. These hooks form the automatic switch, the weight of the tubes moving them down against the action of a spring. The one hook opens and closes the local circuit through the primary of induction coil and microphone, and the other hook makes the change of connections from "ringing" to "speaking." The induction coil is fixed at the back part of

Fig. 67.



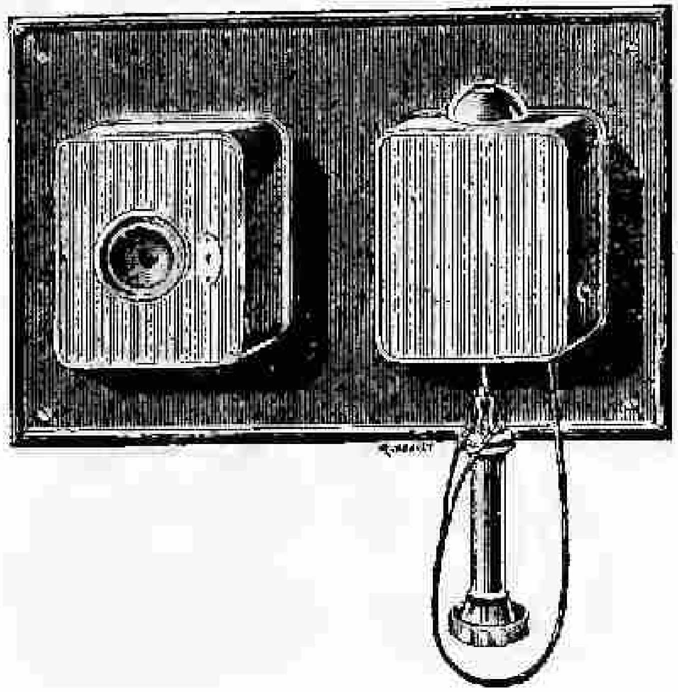
Gower-Bell Telephone.

the inside of the case on the left-hand side, and on the right-hand side is the movement of the bell, the hammer projecting through a hole in the bottom of the case, and striking against a gong fixed below. At the top of the back-board of the instrument is the ringing key, which is an ordinary Morse-key push, the spring of which is attached to line, and its normal position rests against a brass plate let into the back-board of the instrument. The instrument can be obtained with a covered-in diaphragm and mouthpiece, so that the diaphragm is protected from injury.

The Bell-Blake Telephone.

These instruments, which are, perhaps, better known as the National Telephone Company's instruments, are the most widely used of any in this country. They are met with in three forms—the battery-bell instrument, the desk, and the magneto switch-bell instrument.

Fig. 68.

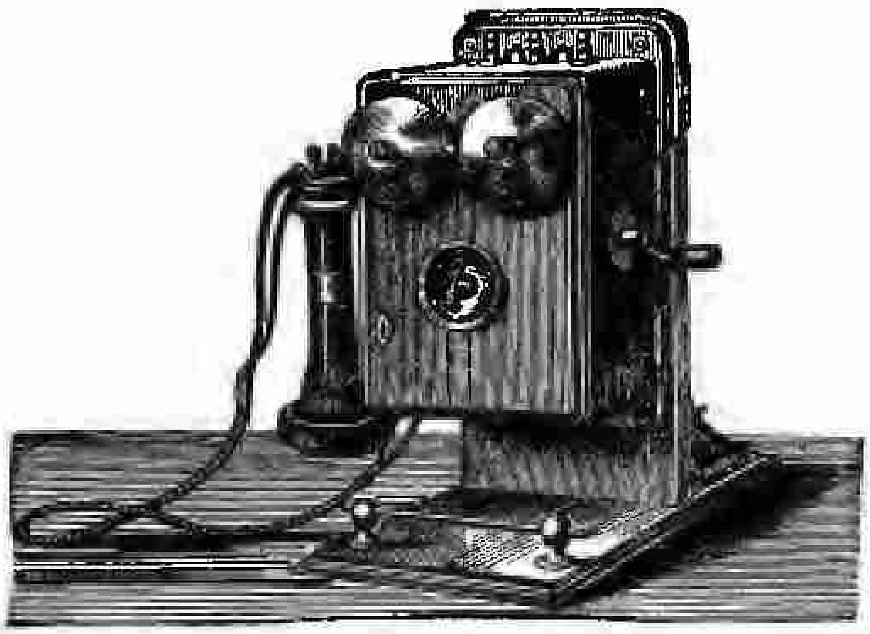


Bell-Blake Telephone.

Fig. 68 shows the battery switch-bell type, which is not so much used now, it having given way to the magneto switch-bell form. It consists of a stained wood back-board, the front being covered with green baize, on which are mounted two polished walnut-wood cases. The case on the left-hand side contains the Blake transmitter, the diaphragm of which is visible through the mouthpiece. The other case contains the switch-bell, which bell is shown in detail in Fig. 48, p. 60. The connections from the one case to the other are made at the back of the board.

A form of the portable or desk instrument is shown in Fig. 69. It consists of a magneto switch-bell mounted on a

Fig. 69.

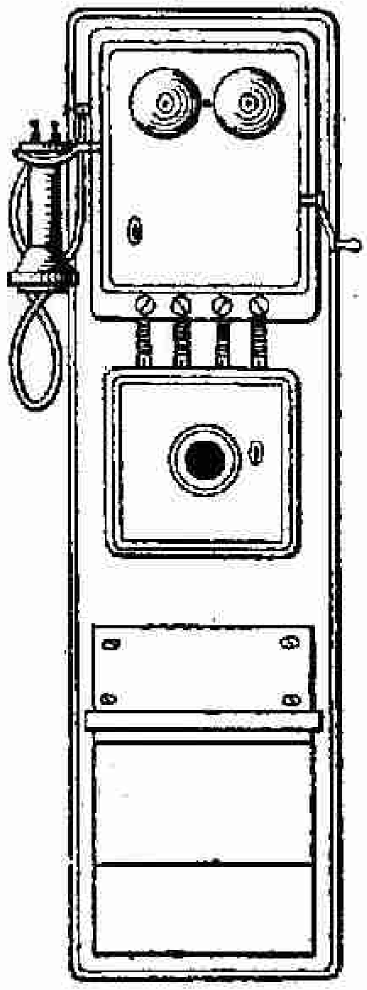


Bell-Blake Telephone.

special polished wood base so arranged that it will conveniently stand on the table. The transmitter, which is a special circular-form Blake, is contained within the switch-bell, the mouthpiece being visible in front of the case. The receiver, a single-pole Bell, is to be seen hanging on the left, and from the back of the case springs the flexible wire that connects the instrument with the line wires. This form of instrument is very convenient for office use, as it can be stood on the desk and moved from one part of the room to the other as desired.

The third form of the Bell-Blake combination, used by the National Telephone Company, has a magneto switch-bell, and a form of this instrument, now largely employed by them, is shown in Fig. 70. The switch-bell, Blake transmitter, and box containing the local cell, are mounted the one below the other on a long back-board of polished walnut-wood. The switch-bell is of the form shown in Fig. 50, and the receiver used is generally a single- or double-pole Bell. The Blake transmitter is placed directly beneath the switch-bell, and is frequently supported by rubber bands, so as to prevent vibration being transmitted to it through the medium of the back-board.

Fig. 70.



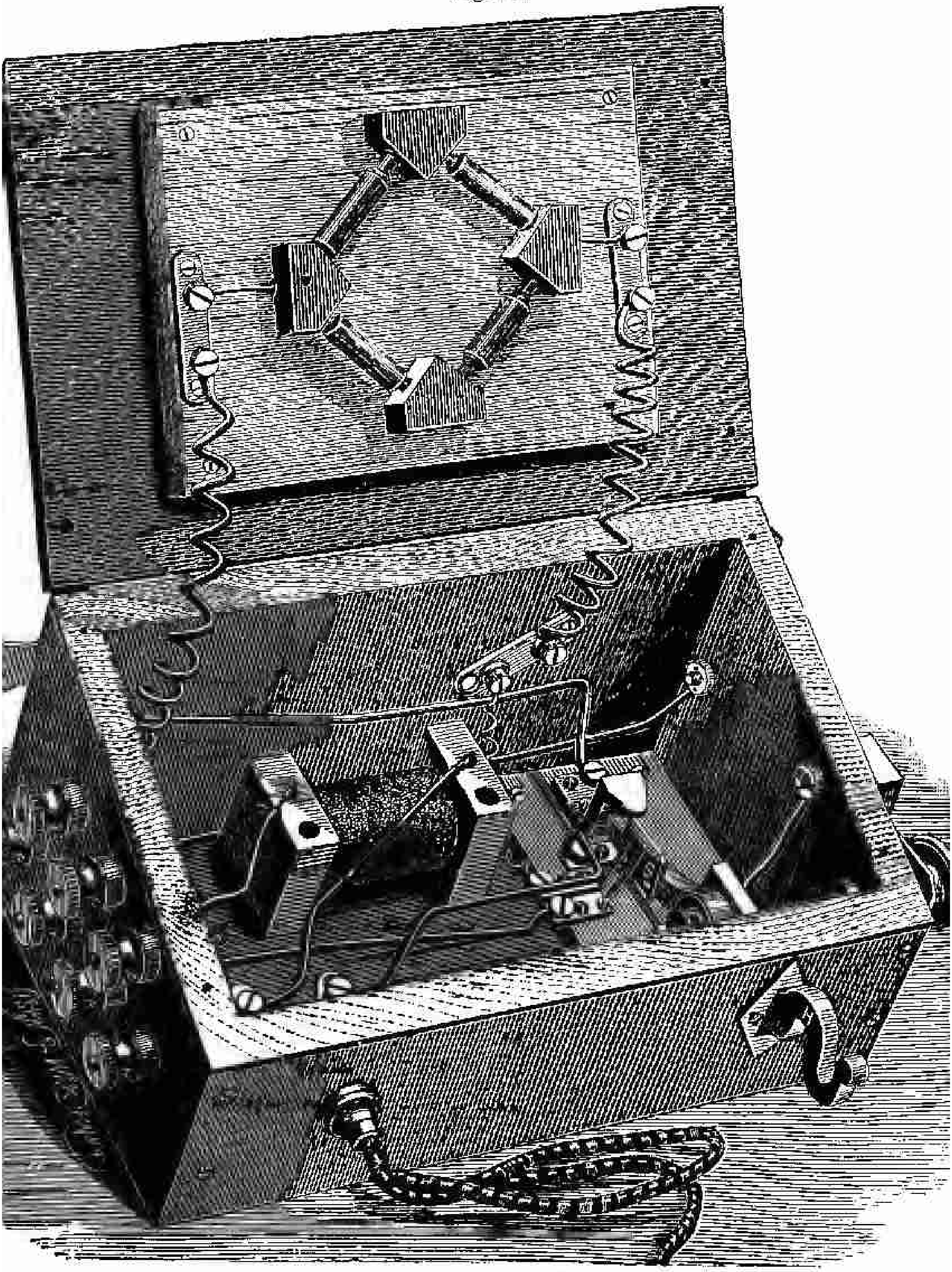
Bell-Blake Telephone.

The battery for working the microphone (a No. 2 agglomerate Leclanché) is placed inside the case at the bottom. The lid of this case is sloped so as to form a writing-desk, which lid, together with the front, is hinged, so that it can be let down when it is desired to inspect the battery. The internal connections of the switch-bell of this instrument are shown in Fig. 51.

THE CROSSLEY TELEPHONE.

Fig. 71 shows the Crossley complete instrument, the lid of the case being open, thus showing the interior construction and the switching apparatus. As in the Gower-Bell telephone, the diaphragm consists, it will be seen, of a thin pine board, to the under side of which is fixed the Crossley microphone, described and illustrated on p. 28. The diaphragm is supported off the lid of the case for $\frac{1}{4}$ in. by cork pads, and the sound-waves are directed on to it by a mouthpiece fitted in the front of the lid. On the left-hand side are the terminals of the instrument, and

Fig. 71.



Crossley Telephone.

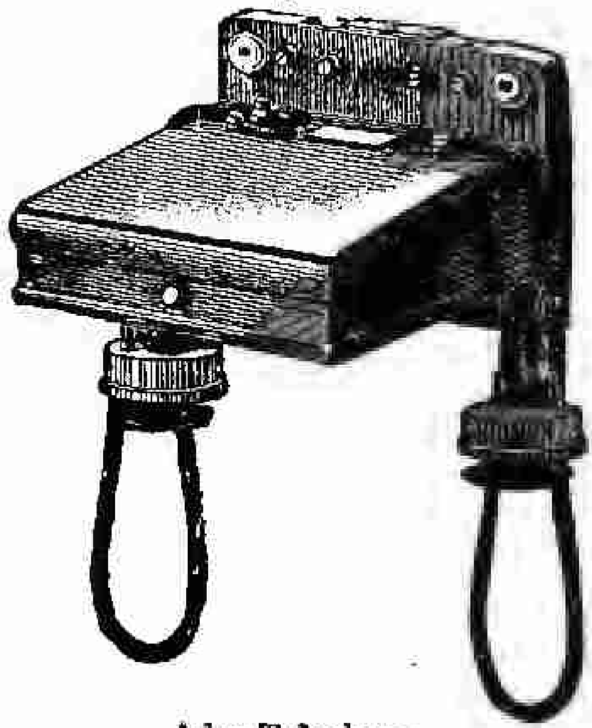
on the right is the ringing key, consisting of a stout brass spring working between a front and back contact. Inside the case on the right-hand side is the switching apparatus, which consists of the brass hook H working on a pivot inside the case and kept in the position shown by a steel spring. In this position the back part of the arm H is resting against the bottom contact, and the "speaking" circuit is closed. When, however, the receiver is hung on the hook H, the hook moves down, and the back end of the arm moves up, making connection with the top contact and closing the "ringing" circuit. On the left-hand side of the brass arm H is the ebonite block S, at the top of which is a brass plate, and when the arm is down, as is the case when the receiver is off the hook, and conversation is being carried on, this plate connects across the two thin German silver springs shown, thus closing the local circuit of the transmitter. When the receiver is hung on the hook the arm moves up, and the springs slide from the brass plate to the ebonite block which opens the local circuit. At the bottom of the inside of the case is the induction coil, and outside, on the front of the case, the cord to the end of which the receiver is attached.

The lid is fastened to the body of the case by screws, and connection is made to the microphone by two flexible wires. The instrument is fixed with its back to the wall by means of the two brass brackets (one of which only is visible), thus leaving the diaphragm in a position slightly inclined from the horizontal.

The Ader Telephone.

The Ader complete instrument is shown in Fig. 72. The form shown has a battery switch-bell, microphone transmitter, and a pair of receivers. In general outline it will be seen it somewhat resembles the Gower-Bell instrument, though in the Ader there is only one switch-hook, and the ringing key is usually on the body of the case. The diaphragm is a thin pine board, which also forms the lid of the containing case, the lid being slightly inclined from the horizontal position. A separate bell is usually employed with this instrument, though if desired a circular bell can conveniently be mounted on the under side of the case.

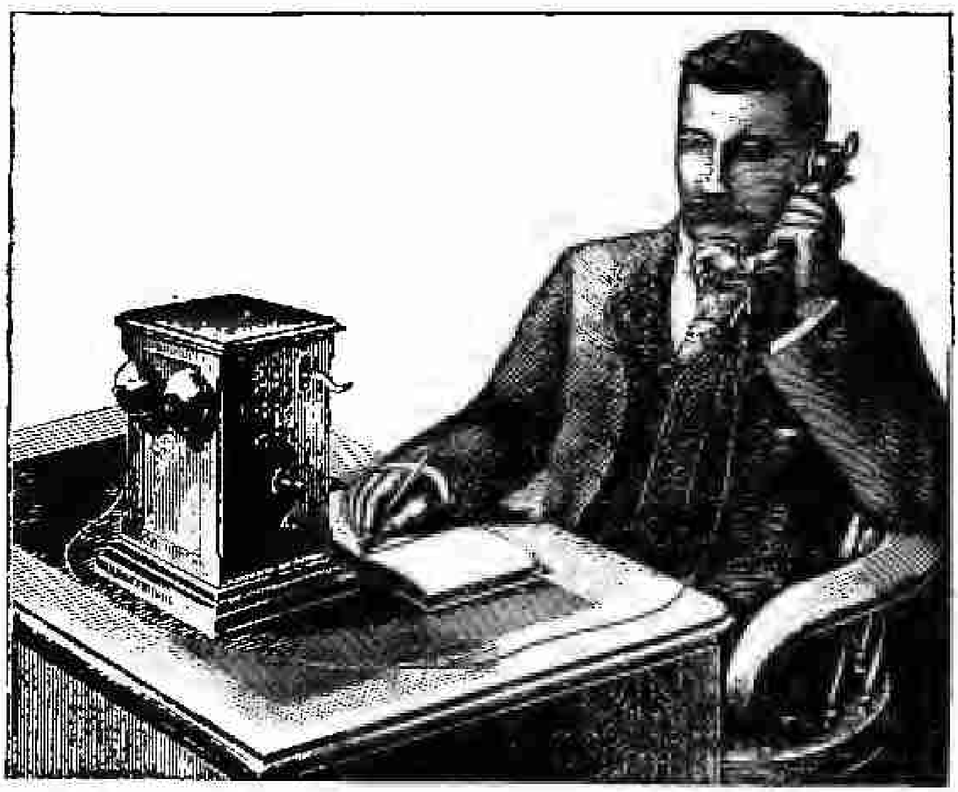
Fig. 72.



Ader Telephone.

Another combination of the Ader telephone is shown in Fig. 73. It is intended for desk use, or for use in other places where a portable instrument is desirable. The switch-bell is a magneto one, and arranged in a case that will conveniently stand on

Fig. 73.



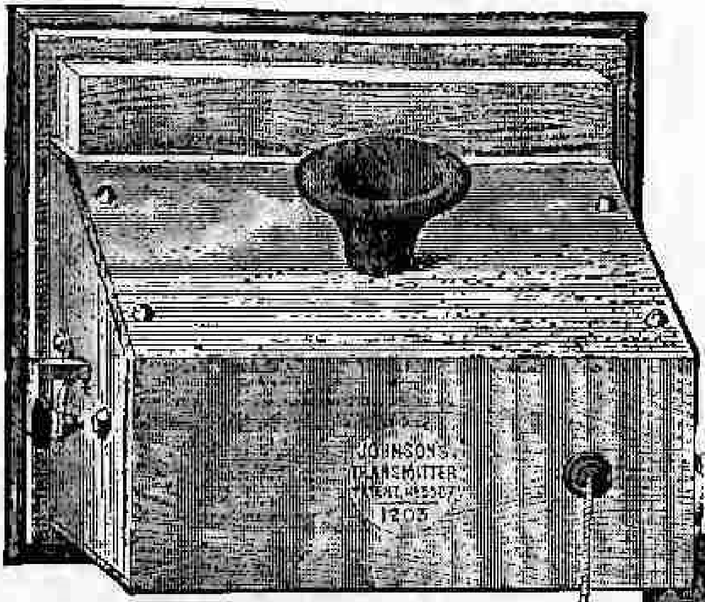
Ader Double Telephone.

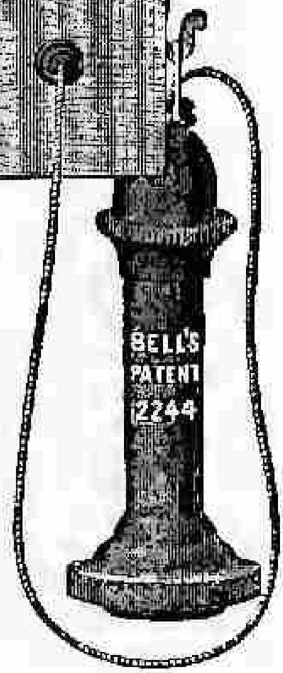
the table, as shown in Fig. 73. To this the combined receiver and transmitter (which is of the form shown in Fig. 18) is attached by a long flexible cord. On the left-hand side of the switch bell is the handle of the generator, above which is the automatic switch-hook on which the telephone is hung when not in use.

The Johnson Telephone.

The Johnson instrument, complete with Bell receiver, is shown in Fig. 74. Externally this instrument very much resembles the Crossley, but differs with regard to the microphone and switching apparatus. The microphone (which

Fig. 74.

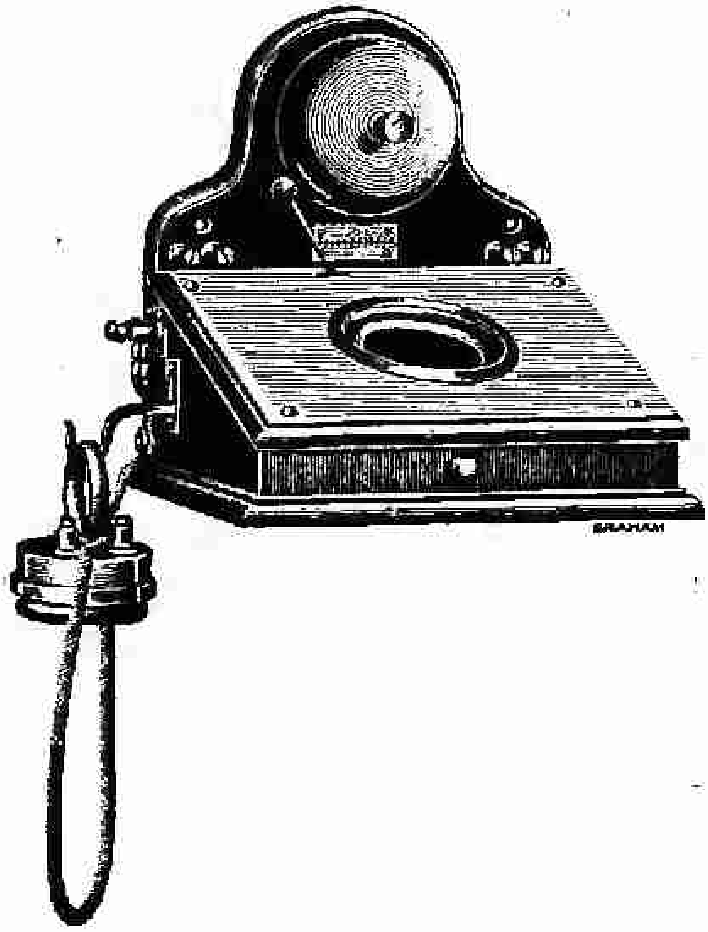




was described and illustrated on p. 29) is provided with a shunt, and is fixed underneath a diaphragm of thin pine wood, supported after the manner of that shown in the Crossley instrument. The automatic hook switch is placed at the side, and performs the same functions as the other automatic switches just described, though the various parts are somewhat differently arranged. Only one receiver is shown, which is sufficient for all ordinary purposes; but two can, of course, be employed with this or any other instrument, and two are to be preferred if the instrument is fixed in a noisy position.

Since the expiration of the microphone patents another form of the Johnson telephone has been introduced, which form is shown in Fig. 75. As it will be seen from the figure, the

Fig. 75.



Johnson Telephone.

external appearance is somewhat different, the bell gong being above the body of the instrument and a wider mouthpiece being employed. The ringing button is in the centre of the case, and the switch-hook, on which is hanging an Ader receiver, is on the left. The resistance coil, used as a shunt to the microphone in the former instrument, has been discarded in the one shown above, because in actual practice it has been found to reduce the sensitiveness of the instrument.

Special Applications of the Telephone.

There are various special uses to which the telephone is put, and in which it proves of great service. In the army it is rapidly finding favour, and there is no doubt that in future

Fig. 76.

Outlying Picket with Telephone.

warfare it is likely to be extensively used. As a ready means of signalling between the camp and outposts it is eminently suited, since by its use the commanding officer in the camp can be placed in direct communication with the outlying picket.

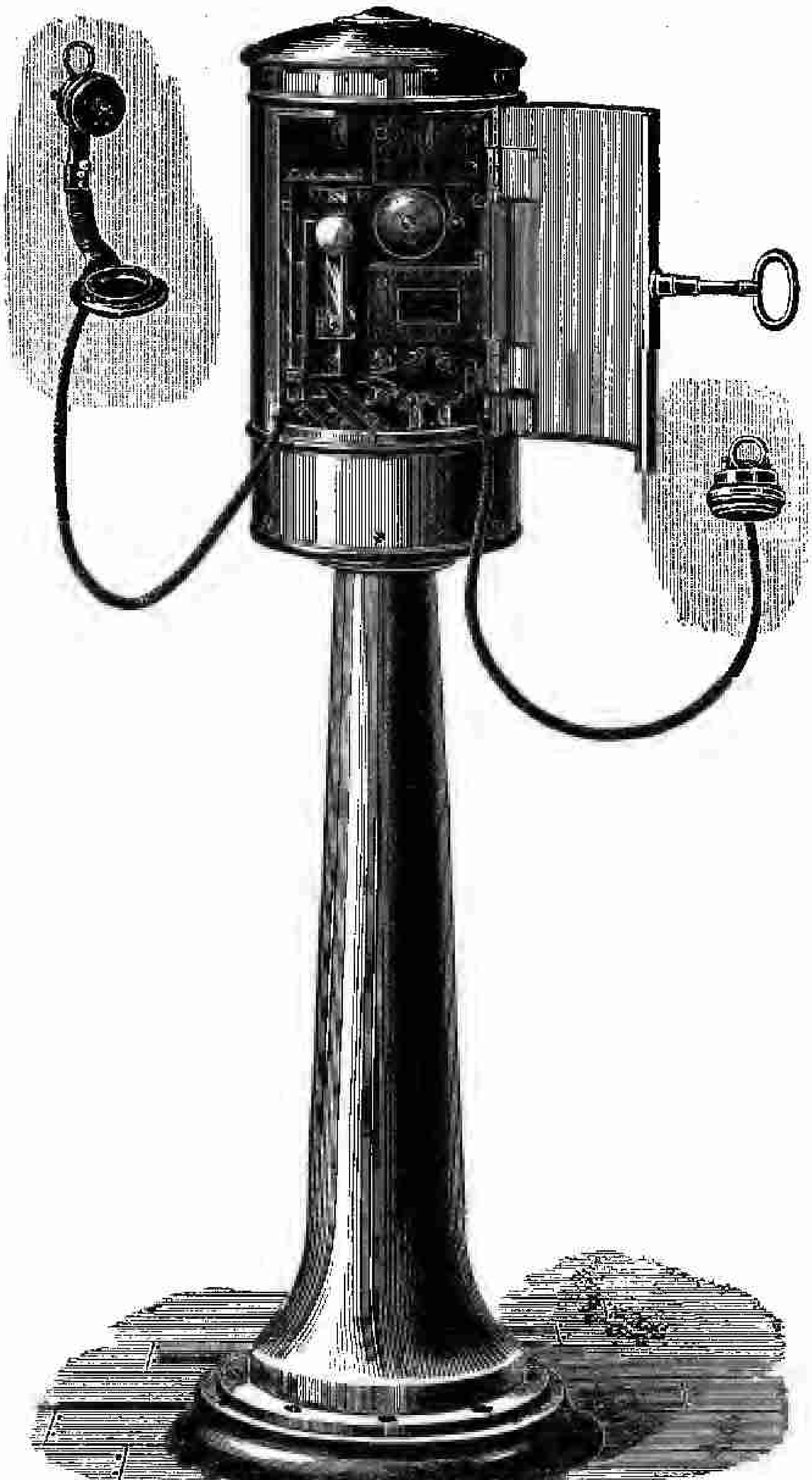
For reconnaissances, or when watching the movements of the enemy, it is likely to be of great service, as by its means the advanced or prospecting party can keep in touch with the main body of the army, and this for the distances of even five or six miles. It has numerous advantages over flag signalling, which is so slow that much valuable time might be lost, and which also is likely to attract the attention of the enemy. Where captive balloons are used to observe the movements of the enemy or survey the surrounding country, it forms an excellent means of communicating results to those below.

The form of instrument generally used, and the method of operating it, is shown in Fig. 76. The telephone used is of some such form as shown in Fig. 18, with either two magnetic receivers, or, what is better, a receiver and Hunnings transmitter combined on one handle. The case containing the switch-bell (which is a magneto one) is slung by a strap over the shoulders, the handle of the generator projecting through a hole in the side of the case. Within the case, also, are two dry cells for working the microphone. The cable used is a specially flexible double wire, well insulated and strongly braided. This is best employed in lengths of about 500 yards, or even less, with special clip ends, so that one section can be rapidly connected or disconnected from the other. Thus lengths can be added as the party proceeds, or when necessary to retreat each man can be told off to disconnect and roll up his section as it is reached.

Ship Telephones.

As a means of establishing communication from one portion of a ship to another, the telephone is extensively employed. On men-of-war it forms an excellent method of communicating orders from the captain's quarters (where the officers may be assembled directing the attack) and the engine room, turrets, and torpedo room. On the first trials of telephones for this purpose it was found that the instruments required certain

Fig. 77.



Ship Telephone.

modifications before they would be likely to be a success The firing of the heavy guns, if it did not break the carbon pencils of the microphone, so severely shook them as to render them utterly useless. The sea air also rapidly attacked all exposed and delicate metal work, necessitating very solid and specially treated parts. These difficulties were soon overcome, by using a magnetic transmitter as well as a receiver, making the different parts very solid, and soldering all connections.

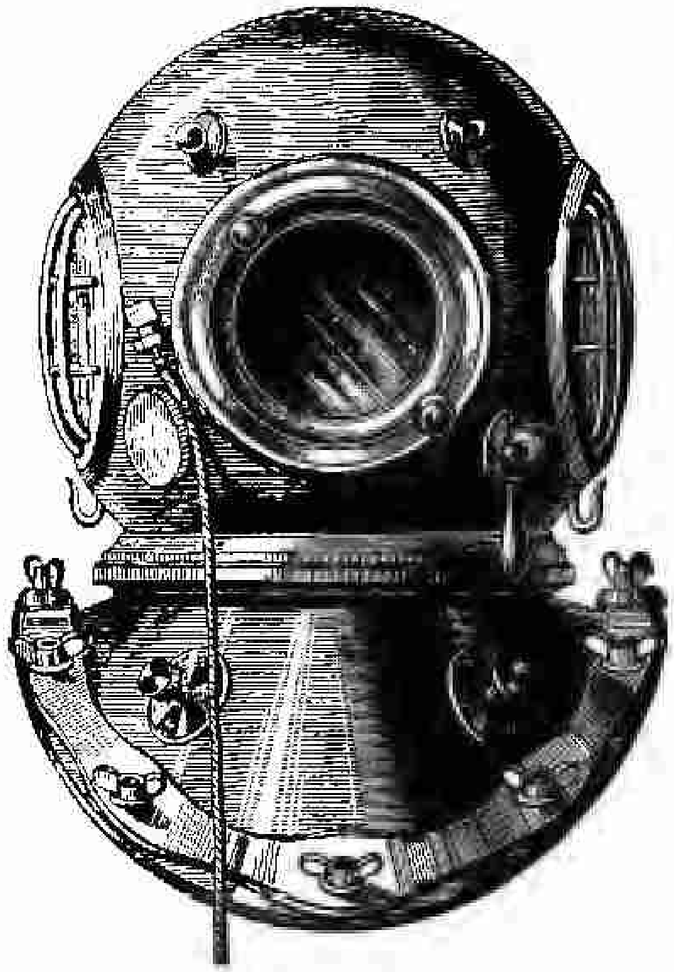
In the merchant service danger of damage to the microphone from firing of guns does not exist, and all we have to provide against is corrosion by the sea air. Fig. 77 shows a form of telephone instrument for use on board ship, the one shown being intended for use on deck. It consists of a circular metal case mounted on a pedestal in order to bring it to a convenient height. Inside this is the battery switch-bell, ringing key, &c., all of which are of an extremely solid character, with large surfaces of contact. The bell movement is entirely cased with metal, and above this bell will be seen the two hooks on which hang the receiver and transmitter. The transmitter is of the Berthon or Hunnings type, and is combined on the same handle as the receiver, there being also an additional receiver on the right hand which can be used in rough weather to keep out external noises. The case of the instrument has a tight-fitting lid to prevent wet penetrating in rough weather.

Telephones for Mines and Diving Purposes.

In mines, also, the telephone proves a great convenience, enabling more definite information to be conveyed than is possible with the ordinary electric bell signals. It can be used in conjunction with existing bell systems or separately by specially arranging the instruments. As the instruments are necessarily subjected to much rough usage, and are, moreover, frequently situated in very damp places, they must be constructed with a view to meet these requirements. The whole instrument must be contained in a metal case, and all connections should be made with brass strip, the joints being well soldered. The form of transmitter and receiver used also must be such as are not likely to get out of order by rough handling, or to be in any way affected by damp or gases.

An individual to whom the telephone must certainly prove a great boon is the diver, forming as it does an excellent means of readily communicating his wishes to his assistants

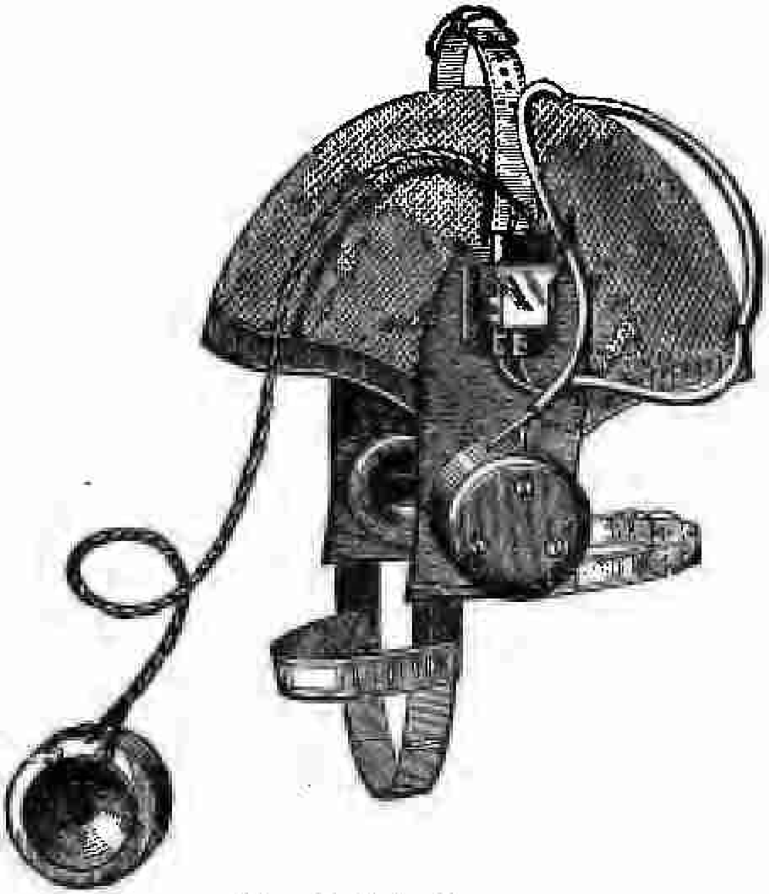
Fig. 78.



Diver's Telephone.

above. A small wire being the only connection necessary, the telephone adapts itself readily for diving purposes. A form of instrument designed by the Consolidated Telephone Company for the use of divers is shown in Figs. 78 and 79, Fig. 78 being an external and Fig. 79 an internal view of the apparatus. The transmitter and receiver are so fixed that the one comes conveniently to the mouth and the other to the ear, being fixed to a cap which the diver puts on his head previous to putting on the helmet.

Fig. 79.



Diver's Telephone.

Telephones for Fire Brigades.

Another use to which the telephone has been put with the most encouraging results is that of establishing a means of communicating from one portion of a fire brigade to another, thus allowing the central fire station to keep in touch with the different brigades who may be away at a fire. The fire stations can in this way be kept duly advised of the progress of the fire, more help can be readily summoned if required, and by being able to state definitely what is wanted much valuable time is saved.

Quite recently the Glasgow Fire Brigade have been fitted throughout with telephones, the ordinary fire alarm circuits being utilised Each brigade when it turns out carries on the engine a portable telephone, which on arrival at the fire is immediately plugged on to the fire-alarm box nearest to the scene of operations. Thus should a second alarm arrive at any of the fire-stations, intimation can at once be sent to the brigade at the first fire, from whence men could, if necessary, be sent direct to the second fire. Moreover, in case of need, these portable telephones can be tapped by the firemen on to any of the overhead wires that may be near for the purpose of communicating with the central exchange or private individuals.

LONG-DISTANCE TELEPHONY.

The distance to which the telephonic transmission of speech can be carried is rapidly increasing, and talking is now successfully carried on between places that a few years ago were deemed much too far apart. Paris and Brussels have for some time been in communication, while in this country London and Brighton, London and Manchester, London and Birmingham, and numerous other towns are connected. One of the most recent and satisfactory long-distance lines is that between London and Paris, of which a short description is appended.

THE LONDON AND PARIS TELEPHONE LINE.

The route of the wires from London to Paris is *viâ* St. Margaret's Bay and Sangatte, the total distance being 311 miles, and the resistance 693 ohms. A complete metallic circuit is used, the wire passing from London to St. Margaret's overhead on poles, then across the channel by a special submarine cable to Sangatte, and from there to Paris by another length of overhead wires.

The lengths and resistances of the different sections of the circuit are as follows:—

	Length.	Resistance.
London to St. Margaret's Bay	84·5 miles	183 ohms
St. Margaret's Bay to Sangatte ..	23 "	143 "
Sangatte to Paris	199 "	294 "
Paris	4·8 "	70 "
	311·3 "	693 "

On the completion of the line a trial was made with the Ader, Berliner, D'Arsonval, De Jongh, Gower-Bell, Roulez, and Hunnings' transmitters in conjunction with double-pole Bell receivers, with a view to ascertain which was the most suitable instrument, those finally selected being the Gower-Bell (without hearing tubes) for the London, and the Roulez for the Paris end. The Roulez microphone is a modification of the Hunnings with broken incandescent lamp carbon filaments instead of the granules. The charge for the use of the London and Paris line is 8*s.* for three minutes' conversation, and the average number of times it is used per day is about 86, the maximum being 108. At a special trial to test the capabilities of the combination, 150 words per minute were transmitted, being dictated in Paris and transcribed in London by shorthand.

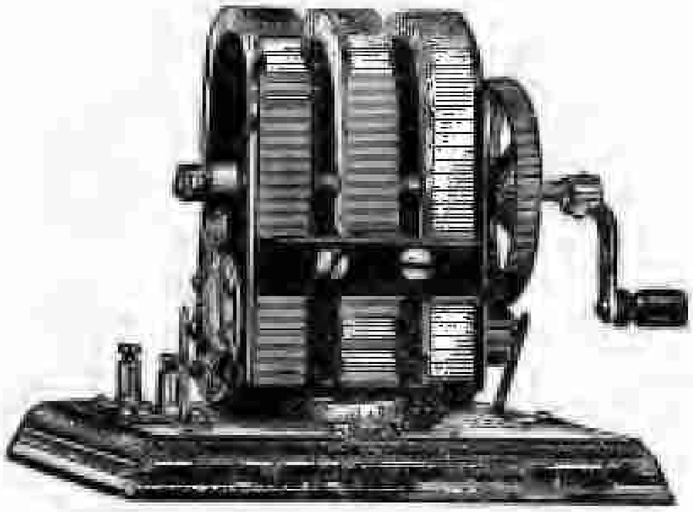
Paris being in communication with Brussels, speaking between London and Brussels was tried with satisfactory results, and also between London and Marseilles, a distance of over 900 miles. According to experiments made with the London and Paris line, long-distance speaking appears to be more a question of the circuit and its environs than the kind of transmitting or receiving apparatus used.

CHAPTER V.

THE MAGNETO GENERATOR AND BELL, BATTERY BELLS, AND RELAYS.

THE apparatus required for signalling by magneto bells consists of two parts—the generator and the bell. In Fig. 80 is shown the most usual form of the magneto-generator divested of its outer wooden case. When the handle seen to the right of the generator is turned, it drives the armature by means of

Fig. 80.

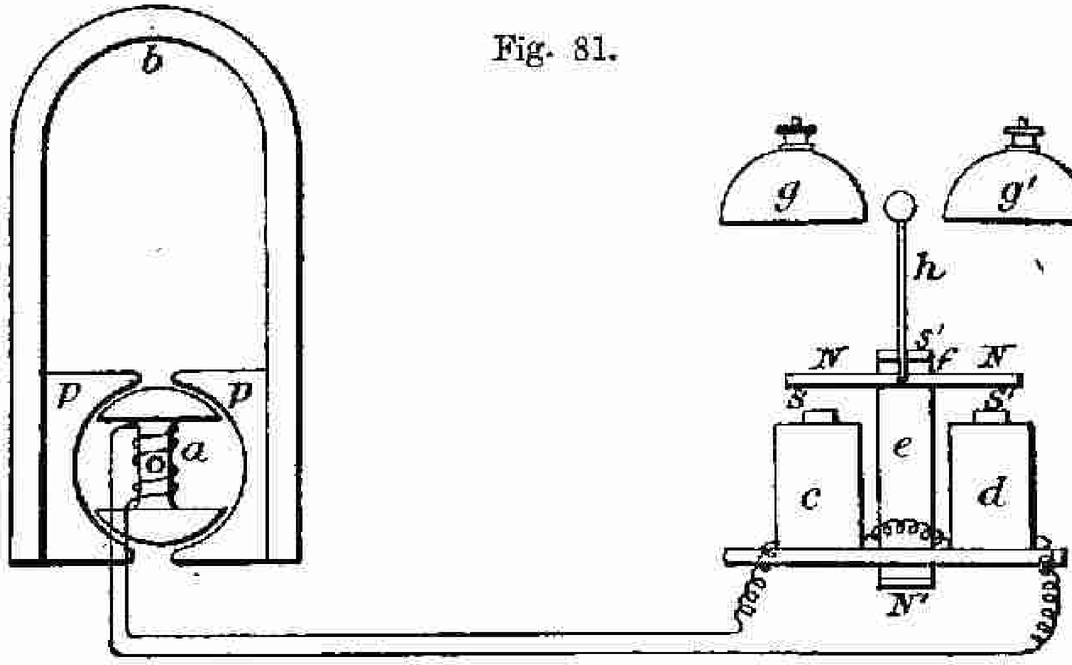


Magneto Generator.

cog gearing, causing it to rotate rapidly between the poles of the three permanent horseshoe magnets. The principle on which the generator acts is the same as that on which is based the action of all dynamos, and, in fact the generator finds in the dynamo almost its exact counterparts. The theory of the action of the magneto generator and bell will be best understood by referring to Fig. 81, where both the generator and the bell are shown diagrammatically.

In the figure the generator is on the right, and the bell on the left. The armature of the generator consists of an iron shuttle *a*, wound with fine silk-covered copper wire, which is caused to rotate rapidly between the soft iron polar extensions

Fig. 81.

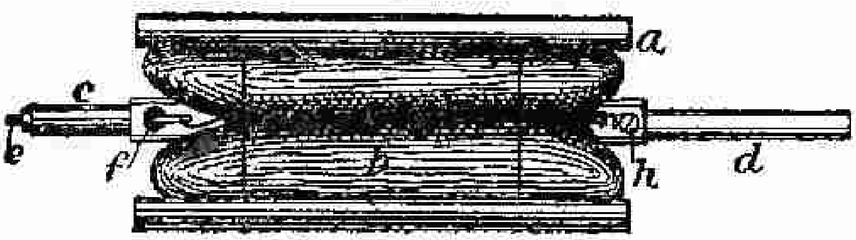


Magneto Generator and Bell.

p p of the permanent magnet *b*. Faraday discovered that *by moving a wire or other conductor near the pole of a magnet in such a manner as to cut lines of force, a current of electricity is generated in that wire.* Hence if the circuit of the armature coil is closed and the armature rotated, a rapidly alternating current is generated which flows by means of the two wires to the bell. This bell consists of an electro-magnet *c d* having before its poles the soft iron armature *f*, pivoted in the centre, from which centre springs the hammer *h*. Adjoining the electro-magnet is the permanent magnet *e*, so arranged that its south pole *s'* comes in close proximity to the armature *f*, and its lower or north pole N' near to the yoke of the electro-magnet. The effect of this is, that the south pole of the permanent magnet magnetises by induction the soft iron armature *f*, causing it to exhibit south polarity at its ends. The north pole of the permanent magnet similarly magnetises the iron cores of the electro-magnet, the poles of which thus exhibit north polarity. When, therefore, no current is flowing round the electro-magnet, both ends of the armature are attracted alike, and the hammer will remain against either gong if once placed there. If now a current from the generator flows round the electro-magnet in such a direction that the left-hand pole becomes north and the right-hand south, the north pole powerfully attracts one end of the armature and the south pole repels the other, throwing the armature over and causing the hammer *h* to strike the gong *g*. When at the half revolution of the generator armature, the direction of the current is reversed, the right-hand pole becomes north and the left-hand south, throwing the armature over to the other side and causing the hammer to strike the gong *g'*. As the armature of the generator is rotated very quickly, the reversals of the current are very rapid, and the ringing becomes similar to that of the ordinary electric bell.

In Fig. 82 is shown the wound armature of the generator, *c* and *d* being the bearings of the iron shuttle *a* on which is wound

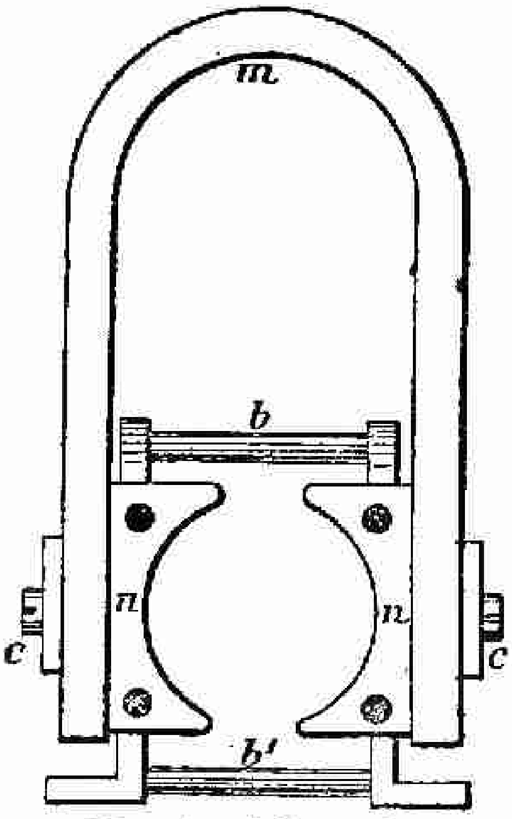
Fig. 82.



Armature of Generator.

the silk-covered wire *b*. One end of this coil is fastened direct to the iron frame of the shuttle while the other is attached to the pin *f*, which is insulated from and passes through the inside of the bearing *c*, after the manner shown in Fig. 87. The pin *f* terminates on the point *e*, against which presses the spring G, see Fig. 52. One connection from the generator is taken from the frame, and the other from the spring G. Fig. 83 shows the framework of the generator, *m* being one of the permanent magnets, and *n n* the two pole-pieces between which the armature revolves. The pole pieces are fixed together and kept at the proper distance from one another by the brass rods *b* and *b′*, and the magnets are fastened to the pole-pieces by the clamping pieces and screws *c c*.

Fig. 83.



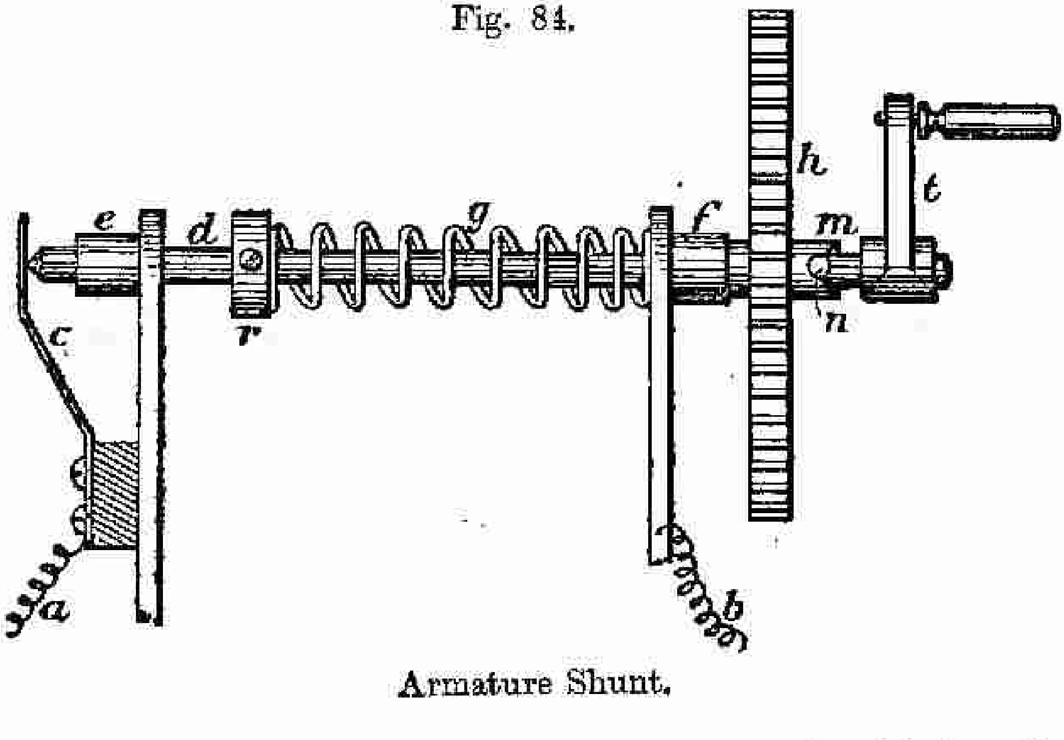
Magnets of Generator.

The armature of the generator being wound with very fine wire, has necessarily a high resistance; and since both the generator and bell are arranged in the same circuit it will be seen that the current from the generator at station No. 1 must, in passing through the bell at station No. 2, pass also through the armature of the generator No. 2, and if many stations are in the series the combined resistance of the generator armatures becomes considerable. Again, in the case of two stations a long distance apart, and an "earth" being used at each end, should a leak to earth occur anywhere along the line between the two stations, the resistance of the generator armature at station No. 2 would cause more current of the generator No. 1 to get to earth by the fault, than would otherwise take place if there was merely the resistance of the bell. Moreover when there are many generators and bells in the series, should any disconnection occur in the armature of one generator, if an armature shunt is provided to the generators, the fault merely incapacitates that one generator from ringing, instead of causing a breakdown in the entire circuit, as would be the case were no armature shunts provided.

In order, therefore, to do away with these disadvantages an "armature shunt" or "automatic cut-out" is provided, which when the armature is at rest, bridges across the high-resistance armature coil by a low-resistance circuit. If the generator is merely required for working a call-bell in buildings, &c., or for use on only short circuits, an armature shunt will be to a great extent superfluous; but if for use on long circuits, or where there are many generators and bells in series, it will be found advantageous to employ one for the reasons stated above. Various forms of armature shunts or automatic cut-outs have from time to time been devised, some of which are fitted to the driving gear, while others are contained in the armature itself. The simplest method of shunting the armature of the generator when not in use is by an ordinary electric bell switch fixed on the wooden base or case of the generator; but as the efficiency of this depends entirely on the memory of the operator, it is not to be compared with any of the automatic forms.

In Figs. 84, 85, 87 are shown three forms of armature shunts, the forms shown in Figs. 84 and 85 being those most generally employed.

Fig. 84.



Armature Shunt.

In the form shown in Fig. 84 the driving wheel *h* fits nicely, but runs loose on the spindle *d*, which works in the two bearings *e* and *f*. In the right-hand side of the hub *m* of the wheel *h* is cut a V-shaped notch, in which works the pin *n* fixed to the spindle *d*. On the part of the spindle between the two bearings *e* and *f* is fixed the collar *r*, against which presses the spiral spring *g* in such a manner as to always keep the pin *n* (when the spindle is at rest) in the centre of the V-shaped notch. Against the end of the spindle *d* presses the stiff brass spring *c*, insulated from the framework by an ebonite block. The action of the shunt is as follows:—In its normal

Fig. 85.

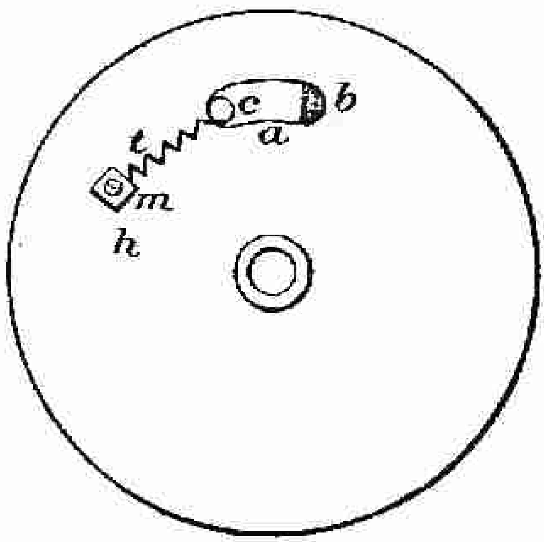
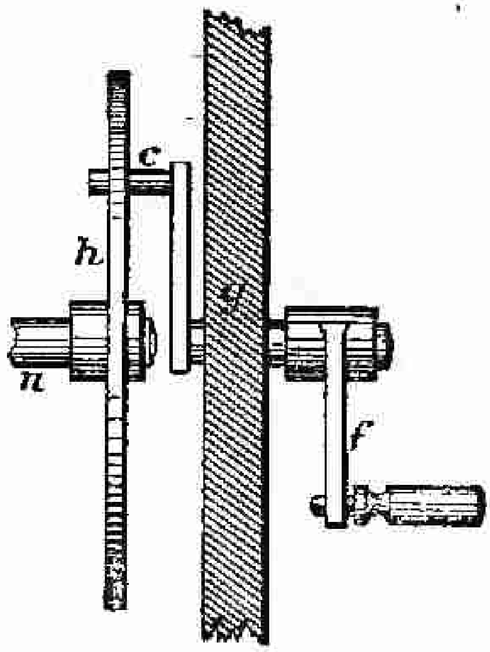


Fig. 86.



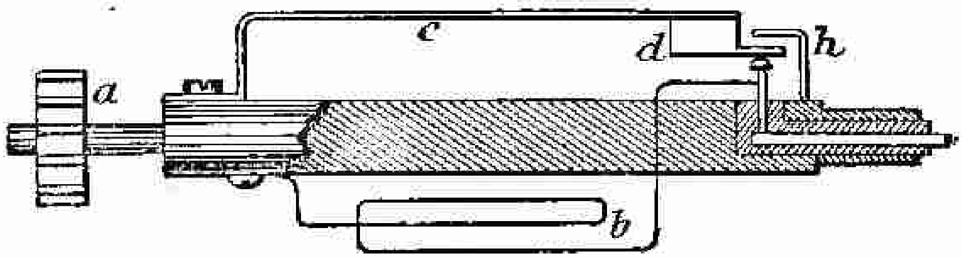
Armature Shunt.

position, the spring *g* pressing against the collar *r* forces the pin *n* into the V-shaped notch and causes the end of the spindle to make contact with the spring *c*. In this position, which is the one in which it is shown in the figure, it forms a low resistance shunt across the coil of the generator armature (see Fig. 52). When now an attempt is made to turn the handle *t* of the generator (the wheel *h* refusing to move until a certain pressure is put on) the pin *n* rides up in the V-shaped notch, drawing the spindle *d*, away from the spring *c*, against the pressure of the spring *g*. This breaks the shunt circuit, throwing the current of the generator to "line," the shunt being completed again as soon as the handle is released.

In the form of armature shunt illustrated in Figs. 85 and 86, *h* is the cogged driving wheel, and *n* the spindle on which it runs, *f* the handle of the generator, and *g* the side of the wood case in which it is contained. This side is bushed with a brass bush in which the handle turns, and to this bush is connected one wire of the armature shunt, the other being connected to the frame of the generator. In a slot *a* of the wheel *h* projects the pin *c*, which is kept in the position shown in Fig. 85 by the spiral spring *t* fixed at one end to the pin *c*, and at the other to the ebonite block *m* fastened to the wheel *h*. The shunt works as follows :—In its normal position (which is that shown in Fig. 85) the pin *c* makes contact with the wheel *h*, and a low resistance shunt circuit is formed, but when the handle is turned the pin *c* moves forward and presses against the ebonite block *b* fixed in the groove *a*, thus opening the shunt circuit. When the handle is released the spiral spring *t* draws the pin *c* back against the uninsulated end of the groove *a*.

The form of armature shunt shown in Fig. 87 (which is that employed in the Post magneto generator) is fitted on the

Fig. 87.

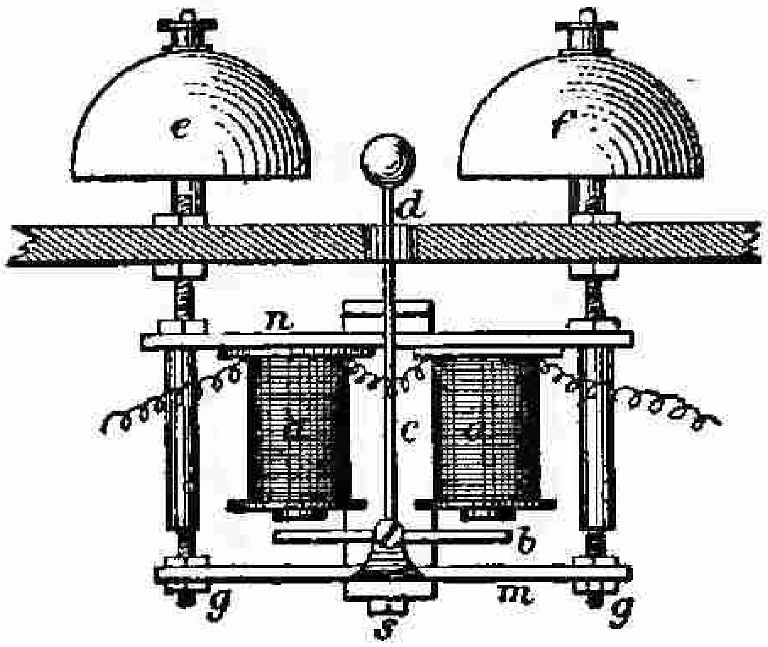


Armature Shunt.

armature itself, and works by the action of centrifugal force on the bob *d*. In the illustration the armature, small cog wheel, and spindle only are shown, being part in section and part in elevation. The bob *d* is fixed to the end of the thin spring *c*, and in its normal position presses against the platinum-tipped pin *f* which is insulated from the armature, and in connection with the stud *e* also insulated. *b* represents the armature coil, one end of which is fastened to the pin *f* and the other connected to the iron of the armature by the screw on the left. When at rest the bob *d* and the spring *c* form a low-resistance shunt across the armature coil *b*; but when the armature is rapidly rotated, the bob flies out and breaks the shunt circuit, the bob being prevented from flying out too far by the stop *h*.

There are three methods now employed of communicating the power from the big driving wheel to the small one on the armature: 1st cog-, 2nd friction-, and 3rd belt-gearing. Cog-gearing is the form most generally used, though friction-gearing has the advantage of silent and smooth running. Belt-gearing is now but rarely employed, on account of its not being durable enough.

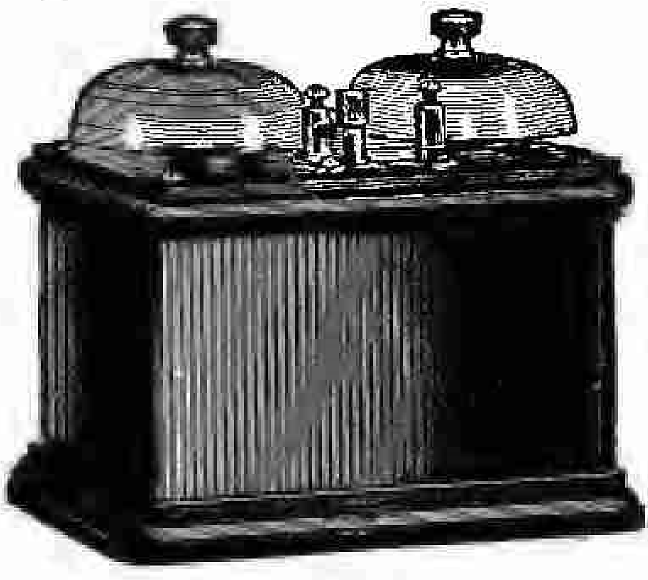
Fig. 88.



Magneto Bell.

Fig. 88 is a side elevation of the magneto bell with its wooden case removed. *a*, *a* are the two bobbins of the electro-magnet, the iron cores of which are riveted to the top bar *n*, also of iron. This top bar *n* is fastened to the two brass upright rods by nuts, the bottom brass bar *m* being also similarly fastened to the rods. This bottom bar carries the armature *b*, from the centre of which springs the hammer *d* which works between the gongs *e* and *f*. *c* is the permanent magnet attached to the bottom bar *m* by the screw *s*. The adjustment of the bell is effected by the screws *g*, by means o which the armature can be made to approach or recede from the poles of the electro-magnet. The gongs *e* and *f* are also adjustable towards or away from the hammer *d*. The first forms of the magneto bell were similar to the Siemens polarised relay, the armature being a permanent magnet, and working between two electro-magnets. It had many faults, however, the chief

Fig. 89.



Magneto Bell.

of which were its sluggish action and the liability of the armature to lose its magnetism. The great improvement of the modern magneto bell over the old form consists in the substitution for the polarised steel armature of a soft iron one inductively magnetised by a permanent magnet placed in close proximity to it. Fig. 89 shows the magneto bell complete in polished wood case.

BATTERY BELLS.

We will now pass on to a short description * of the various forms of battery or ordinary electric bells in use.

Fig. 90 shows the external appearance of the ordinary electric bell, and this is the form generally employed whether its movement be a vibrating, single-stroke, or short circuit one. There are five different kinds of movements that may be employed: 1st vibrating; 2nd single stroke; 3rd continuous ringing; 4th short circuiting; and 5th differentially wound, these last two being best suited for working in series.

Fig. 90.

Battery Bell.

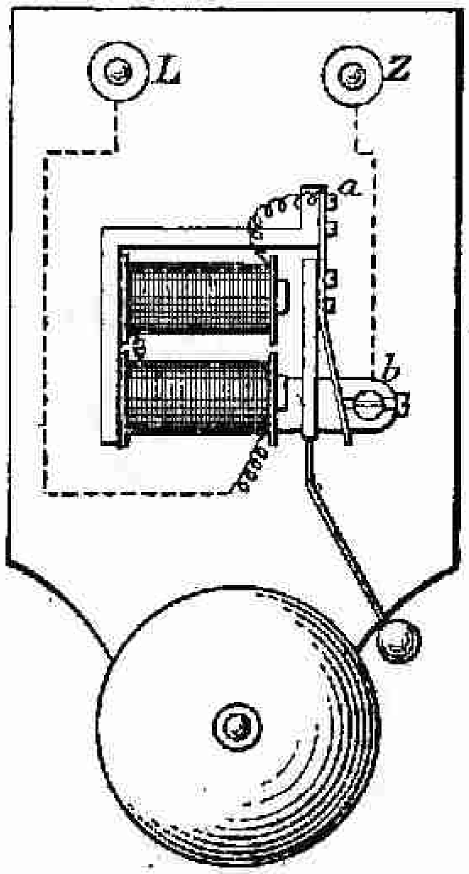
THE VIBRATING BELL.

In Fig. 91 is shown (with cover removed) the vibrating electric bell, which is the form in most general use. It is probably too well known to need much description, but consists of an electro-magnet fastened to an iron frame, which is screwed to a wooden back-board that forms the base of the bell. In front of the poles of the electro-magnet is a soft iron armature, one end of which is fitted with a hammer and the other fixed to the iron frame by a thin steel spring, the lower end of which carries a platinum contact. Fixed to the iron frame, but insulated therefrom, is a contact post fitted with a contact screw, the platinum pointed end of which comes opposite the end of the contact spring. The current entering at the terminal L passes through the coils of the electro-magnet to the iron frame and contact spring, contact screw,

* For a detailed description see 'Practical Electric Bell Fitting.'

contact post, and thence to terminal Z. This causes the electro-magnet to attract the armature, bringing with it the hammer, which is impelled against the gong, and at the same time the contact spring is pulled away from the contact screw, thus breaking the circuit. As the cores of the electro-magnet are of soft iron, all magnetism now ceases, and the armature, impelled by the spring, moves back into its former position, only to repeat the previous operation so long as the circuit is closed.

Fig. 91.



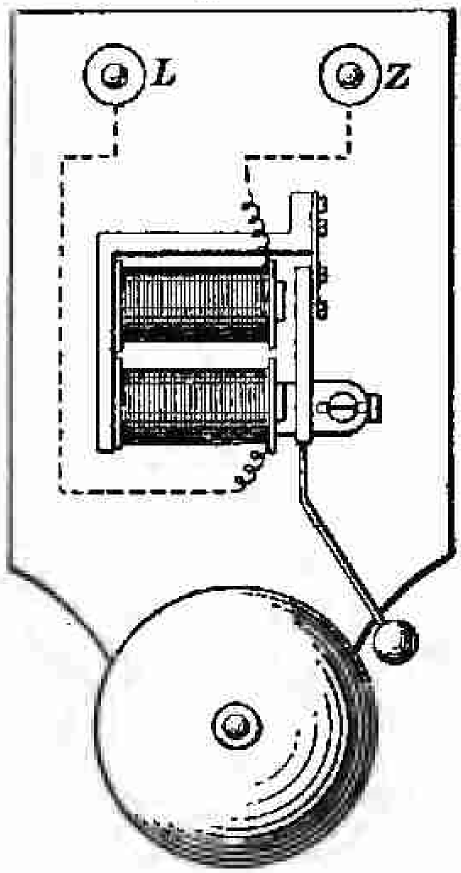
Vibrating Bell.

To adjust a vibrating bell, first make sure all the connections are tight; then (holding the hammer against the gong) screw up the adjusting screw till its point is just clear of the platinum contact on the spring. Then let go the hammer and see if the spring draws it back properly. See also that the armature when attracted does not touch the poles, or there will be a disagreeable tapping noise while ringing. The strength of the sound can be varied by means of the adjusting screw, since the further it is screwed back the less will be the force with which it reaches the gong. Sometimes a bell rings badly from the spring either setting the armature back too strongly, or from being so weak that it does not bring it back with sufficient rapidity. To find out which is the cause, take a piece of watch-spring, and whilst the bell is ringing, press the armature towards the poles; then if the ringing is improved the spring is too strong, and must be taken off and set a little inwards. If, on the contrary, the ringing improves when the armature is pressed away from the poles, the spring is too weak, and must be set a little outwards.

THE SINGLE-STROKE BELL.

The single-stroke bell is shown in Fig. 92. It represents the electric bell in its simplest form, and has no contact breaker. The current entering at the terminal L passes through the magnet coils to the terminal Z, so that when the circuit is closed the armature is attracted up to the poles, and remains there so long as the ringing key is kept pressed in. A stroke of the bell is thus obtained each time the ringing key is depressed, so that for signalling to a pre-arranged code the single-stroke bell is well adapted. To adjust a single-stroke bell so that a clear sound is obtained, push the armature up to the brass studs in the ends of the poles and bend the rod till the hammer is just clear of the gong. Then let go the hammer and adjust the stop-screw till the loudest stroke is obtained. The hammer should not touch the gong before the armature reaches the stops, or a harsh sound will be the result, owing to the hammer stopping the vibrations of the gong.

Fig. 92.

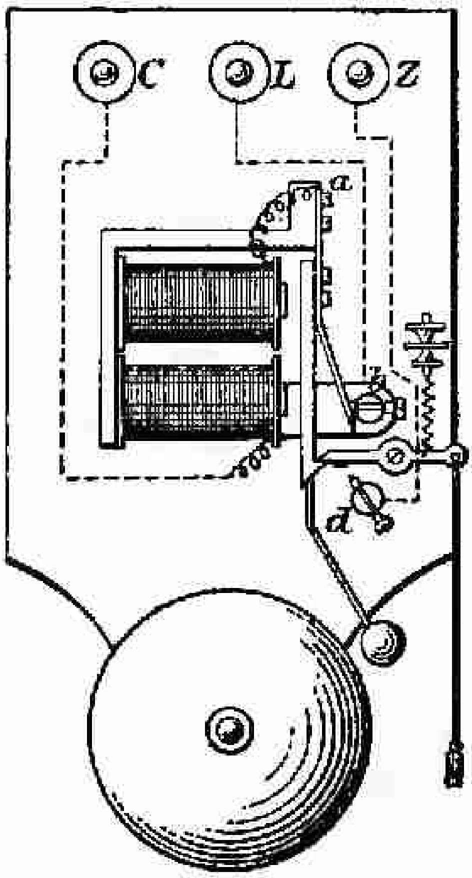


Single-stroke Bell.

THE CONTINUOUS-RINGING BELL.

The continuous-ringing bell is shown in Fig. 93, and when once started, continues to ring until stopped, which is generally done by pulling a cord at the side. The movement, it will be noticed, is similar to that of the vibrating bell (Fig. 91), with the addition of a lever and the extra contact post *d*. This lever is pivoted in the centre and supported at one end by the catch on the lower end of the armature. When the armature is attracted the lever slips off the catch, and, impelled by the spiral spring, makes contact with the contact post *d*. The lever is reset by pulling the cord at the side.

Fig. 93.



Continuous-ringing Bell.

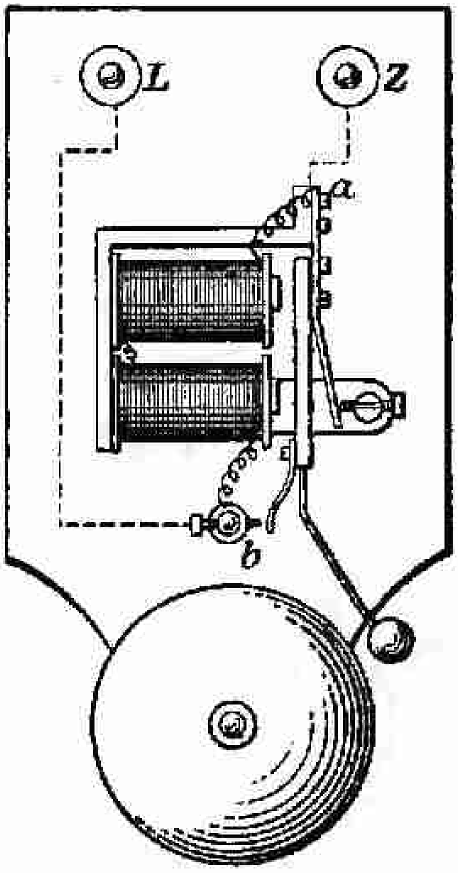
The action of the bell is as follows:—The current entering, let us say, by the terminal C, passes through the magnet coils to the screw *a*, armature, contact spring, contact post, and thence to terminal L. This starts the bell, at the first stroke of which the lever is released and makes contact with the contact post *d*, the circuit now being from terminal C, to magnet coils, screw *a*, spring, contact post *b*, lever *c*, contact post *d*, and thence to terminal Z. The bell ceases to ring when the cord at the side is pulled, which resets the lever.

In adjusting a continuous-ringing bell, the movement is first adjusted as was described (p. 109) for the vibrating bell. The lever *c* is then released and the tension of the spiral spring adjusted so that only such pressure is put on the lever as is sufficient for good contact. The more the tension, the greater the pressure on the lever, and more battery power is thus required to release it.

The Short-circuit Bell.

It is very often necessary to place two or more bells in series on one circuit. This, if the bells are single-stroke, presents no difficulty, but on attempting to do this with the ordinary vibrating bell, the ringing becomes at the best very indifferent and spasmodic, arising from the fact that as the bells are not exactly similar, they do not make and break the circuit in unison. One way of getting over this difficulty is to have one of the bells a vibrating and the rest single-stroke, the vibrating bell governing the vibrations of the single-stroke; but even when arranged thus, unless the bells are very much alike, the ringing is rarely satisfactory.

Fig. 94.



Short-circuit Bell.

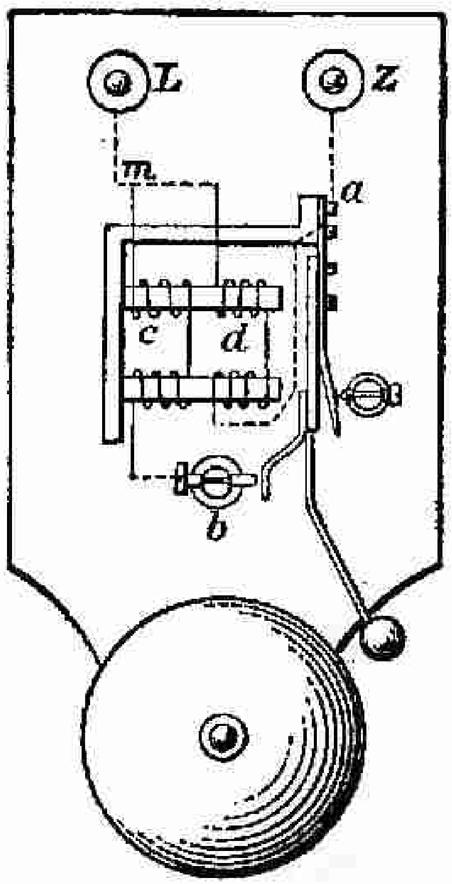
For bells in series, therefore, the best plan is to use those with movements either *short-circuiting* or else *differentially wound.*

The short-circuiting form of electric bell is shown in Fig. 94, and, as will be seen from the figure, governs its vibrations not by breaking the circuit, but by shunting its coils. The current entering, let us suppose, at the terminal L, passes to the contact post *b*, from there through the magnet coils to the screw *a*, and from thence to terminal Z. This attracts the armature, causing the spring on its lower end to make contact with the contact post *b*. There now exists a path across the magnet coils of practically no resistance; the current, therefore, is diverted from the magnet coils, and passes by the armature and contact post *b* to the next bell. Thus, no matter how many bells there may be in the series, the circuit is never broken.

THE DIFFERENTIALLY-WOUND BELL.

Another form that works well in series is that known as the differentially-wound bell, a form of which is shown in Fig. 95. As regards its arrangement of parts, it is similar to the short-circuit form just described, but differs from it in respect to its magnets, which are wound with two coils, the one, *c*, in an opposite direction to the other, *d*. On the current entering at the terminal L the action of the bell is as follows:—Starting from terminal L, it passes through the coil *d* to the screw *a*, and thence to terminal Z. The circuit of coil *c* being open, the iron cores are magnetised by the current in the coil *d*; thus the armature is attracted, and makes contact with the contact post *b*. This closes the circuit through the coil *c*, which neutralises the magnetism imparted by the coil *d*, and the armature falls back against the stop, only to repeat its previous operation. Besides being admirably adapted for series working, this form is almost sparkless at its contact, a matter of great importance in some cases.

Fig. 95.



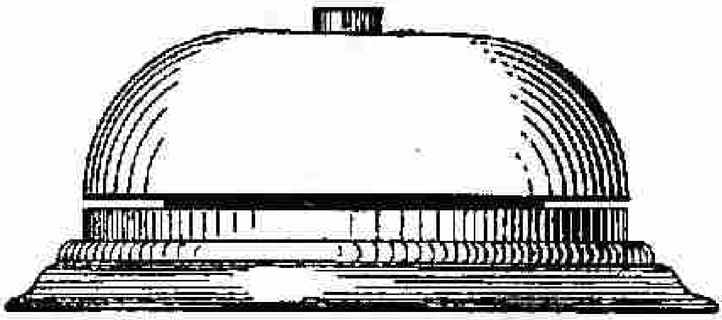
Differentially-wound Bell.

Speaking of this method of winding, Professor Sylvanus Thompson, in his excellent lectures on "The Electro-magnet," delivered recently before the Society of Arts, says:—"When equal currents flow in both circuits there is no magnetism. If you break the circuit of either of the two coils the core at once becomes magnetised. You get magnetism on breaking, you destroy magnetism on making, the circuit; it is just the inverse case to that of the ordinary electro-magnet. There the spark occurs when magnetism disappears; but here, since the magnetism disappears when you make the circuit, you do not get any spark at make, because the circuit is already made. You do not get any at break, because at break there is no magnetism."

Circular Bells.

Bells with the movement contained within the gong are very suitable for mounting on telephone sets. The form most

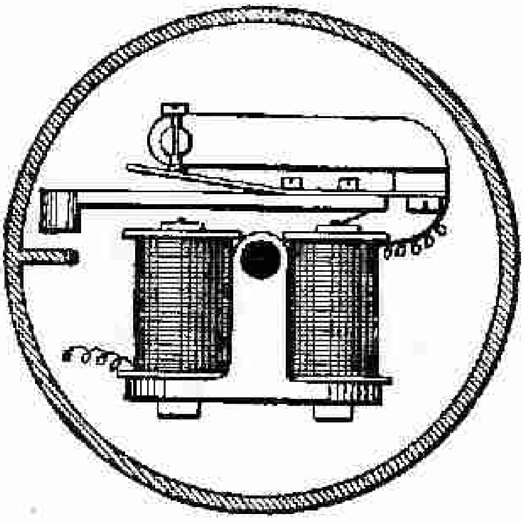
Fig. 96.



Circular Bell.

usually employed is shown in Figs. 96 and 97, Fig. 96 being a side view of the complete bell, while Fig. 97 is a plan with the upper part of the gong removed. The movement can of course be vibrating, single-stroke, or short-circuiting, as desired, that shown in the figure being a vibrating one. The hammer, it will be seen, strikes on a lug cast on the gong, while the gong is supported on a projecting arm of the iron frame. In the figure the bell is shown mounted on a special wooden base, as is the case when the bell is used separate, but if for a telephone set, it is mounted directly on the wooden base-board.

Fig. 97.



Circular Bell.

Fig. 98 shows another form of the circular bell, known as the "Shield," from the shape of its iron base. Fig. 99 shows

Fig. 98.

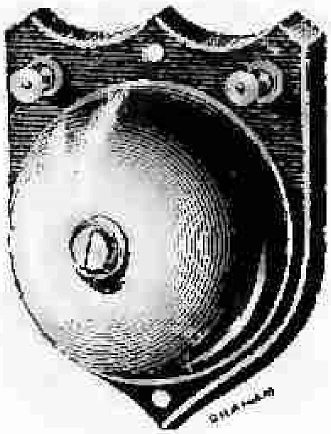
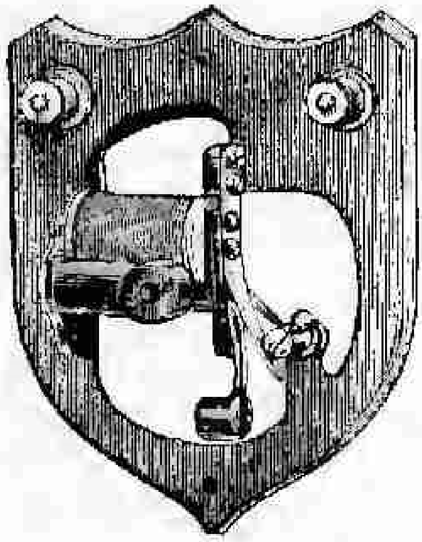


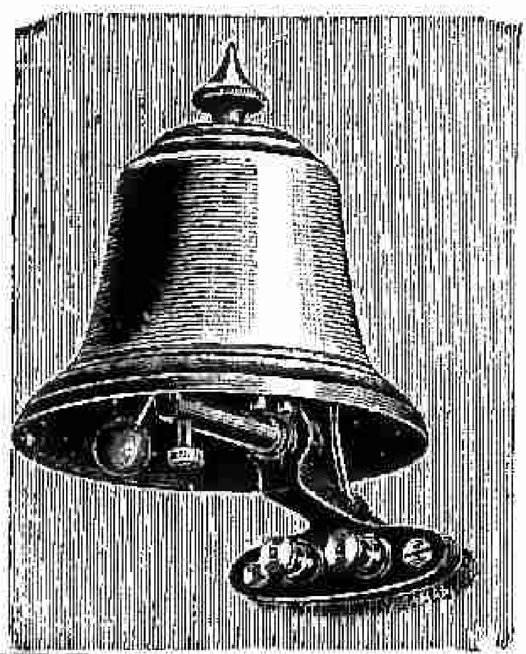
Fig. 99.



Circular Bell.

the bell complete, while Fig. 99 is a plan with the gong removed. Only one bobbin is employed, and the hammer strikes, as is the case with the previously described form, on a lug on the inside of the gong.

Fig. 100.



Church-shape Bell.

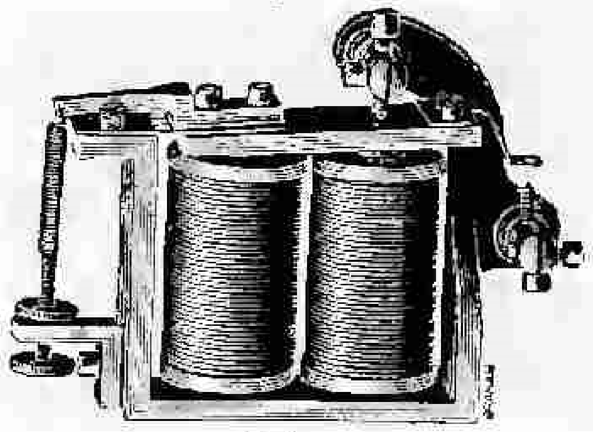
Another form of bell with the movement inside the gong is shown in Fig. 100. The gong is of the church-bell shape, by employing which shape it has been found the most agreeable tone is obtained.

Relays.

Relays will often be necessary on long circuits where, from the resistance of the line, the current has not strength enough to ring the bell, but quite sufficient to attract the delicately poised armature of a relay. The duty of a relay is to close a local circuit when actuated by a current circulating through its coils. Formerly, when battery switch-bells were so much used, the relay was very frequently called into requisition, but with the change to magneto switch-bells they will not be so much required, owing to the ability of the magneto to ring through a high resistance.

A form of the single-current relay is shown in Fig. 101. It consists of an iron frame, similar to that used for the electric bell movements previously described. Above the electro-magnet is fitted the armature, kept off the magnet poles by the spiral spring seen to the left, the tension of which can be adjusted by the milled nuts. The distance the armature moves back from the magnet poles can be regulated by means of the top set-screw. The magnet coils of the relay are connected in the "main" or "line" circuit, and one end of the local circuit is connected to the bottom contact post, while the other is connected to the frame of the relay. Thus when a current circulates in the main circuit, the armature of the relay is attracted, closing the local circuit.

Fig. 101.



Relay.

Much of the satisfactory working of a relay depends upon its proper adjustment, and the following is the right way to set about adjusting a relay:—First screw up the contact screw, so that when the contact spring makes firm contact with it there is just room to slip a piece of writing paper between the armature and poles of the electro-magnet. Then adjust the stop screw so that the contact spring only fairly leaves the contact screw. The tension of the armature spring should only be such as will just bring the armature back against the stop screw. A relay should be adjusted according to the purpose for which it is required. If for sensitiveness, as would be necessary on long lines, it should be adjusted as described, but if for use with an indicator, a little more movement for the armature may be allowed.

CHAPTER VI

SWITCHES AND SWITCH-BOARDS.

AMONGST the various auxiliary apparatus used in telephony, switches must certainly be placed in the foremost rank. Hardly a single instrument, whether private or exchange, can be erected without employing some form of switch, either automatic or worked by hand, and in the "switch-room" of an exchange system they may be reckoned up by thousands. They may be divided into two classes: 1st, those employed in the switch-room of an exchange, and 2nd, those used by the subscribers themselves, with which latter we shall confine ourselves in this chapter.

Switches of the first class may be either the ordinary electric bell switch as shown in Fig. 102, or the telephone pattern as in Fig. 103. The form shown in Fig. 102 is the simplest form of switch, and is either one, two, three, or four-way, &c., according to the number of directions in which the current can be diverted.

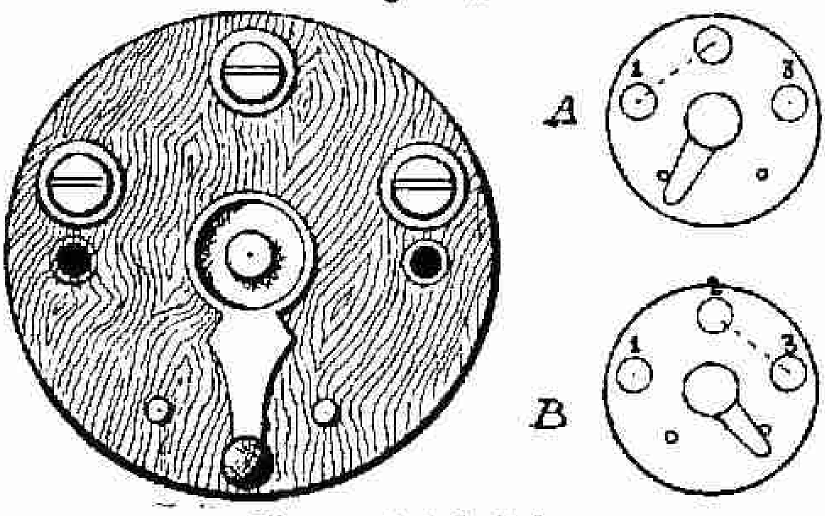
Fig. 102.

Two-way Switch.

The other form of switch is the one most used in telephony, and consists of a wood base, the underneath side of which is hollowed out and contains the working parts. On the front are the terminals and the lever arm, by moving which from side to side the connections are changed. In some switches the terminals also are beneath the base ; but this form is very inconvenient, the whole switch having to be taken down should it be desired to alter the connections. The purposes to which these switches are applied are for connecting two or more instruments to the same line, or connecting an extra, or extension, bell, as it is called, to ring at some distance from the instrument, as the exigencies of the case demand. In an exchange system they are also employed to prevent subscribers making an illicit use of lines or instruments, as might be done in certain cases.

These switches are designated by the number of terminals

Fig. 103.



Three-point Switch.

or points, and the simplest form is the three-point shown in Fig. 103. It is used either for connecting one line to two different instruments, or for putting in an extension bell. For instance, take the case of an office in which there is a telephone in connection with the stores half a mile off, in which the telephone there is in a room on the ground floor, and the person who usually attends to the telephone calls is often at a distant part of the building. Then an extension bell would be placed in the distant part of the building, and a three-point switch fixed near the telephone below, and the attendant would before leaving the room switch on the extension bell, so that all signals would be communicated to him by the bell.

Figs. 103 A and B are a key to the switch, showing which terminals are connected together when the handle of the switch is in the two different positions. When the handle is to the right-hand side, terminals 1 and 2 are connected together, but when to the left 2 and 3.

Fig. 104 shows the circular pattern four-point switch. When the handle is to the right-hand side, terminals 1 and 2

Fig. 104.

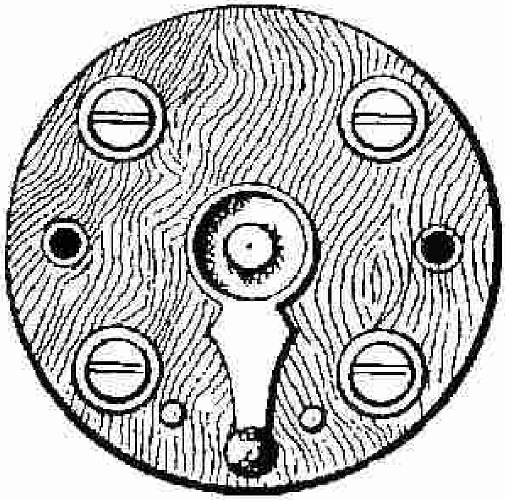


Fig. 105.

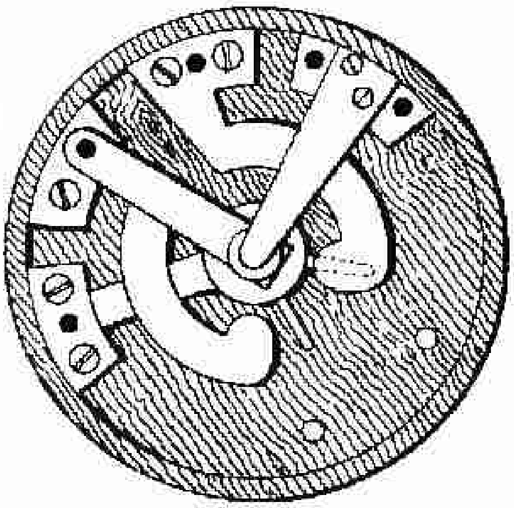


Fig. 106.

Four-point Switches.

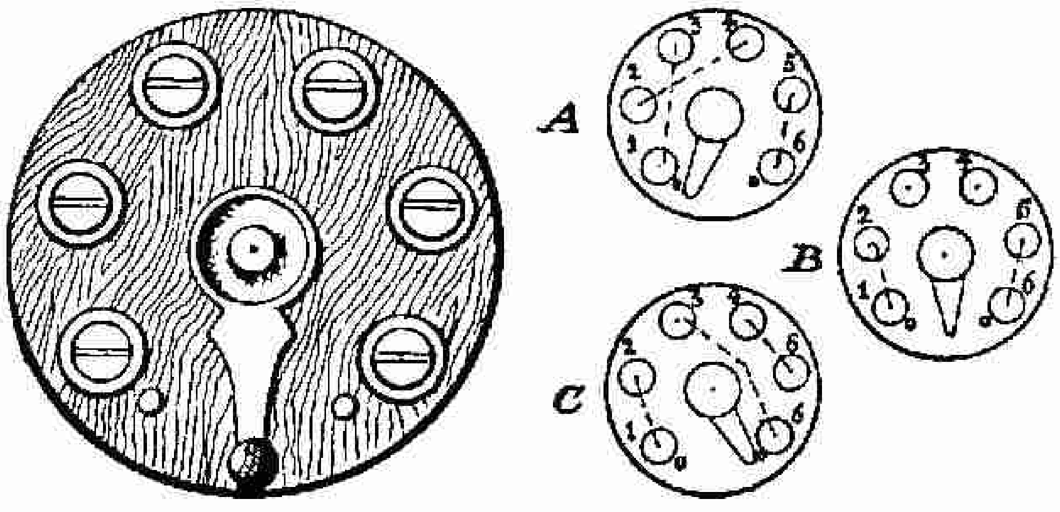
are connected together (see Fig. 182), and also terminals 3 and B. If the handle is moved to the right, terminals 1 and 3 are connected together, and also 2 and B.

Fig. 105 shows the four-point switch from the back, showing the interior arrangement.

Another form of the four-point switch is shown in Fig. 106, this being known as the square pattern. The switch is worked by moving the handle from one side to the other, the connections to the terminals being shown by the dotted lines. The connections in the form of switch shown in Fig. 104 are somewhat different to those in Fig. 105, but either switch can be connected to effect the same object. The method of employing this switch is shown in Fig. 182.

The six-point switch is shown in Fig. 107, with the key diagrams A, B, and C. When the handle of the switch is to the left, terminal 1 is in connection with terminal 3, terminal 2 with terminal 4, and terminal 5 with 6. If the handle is put in the centre, as in B, terminal 1 is connected to terminal 2, and terminal 5 to 6. When the handle of the switch is put to the right, terminal 1 is connected to 2, 3 to 6, and 4 to 5.

Fig. 107.



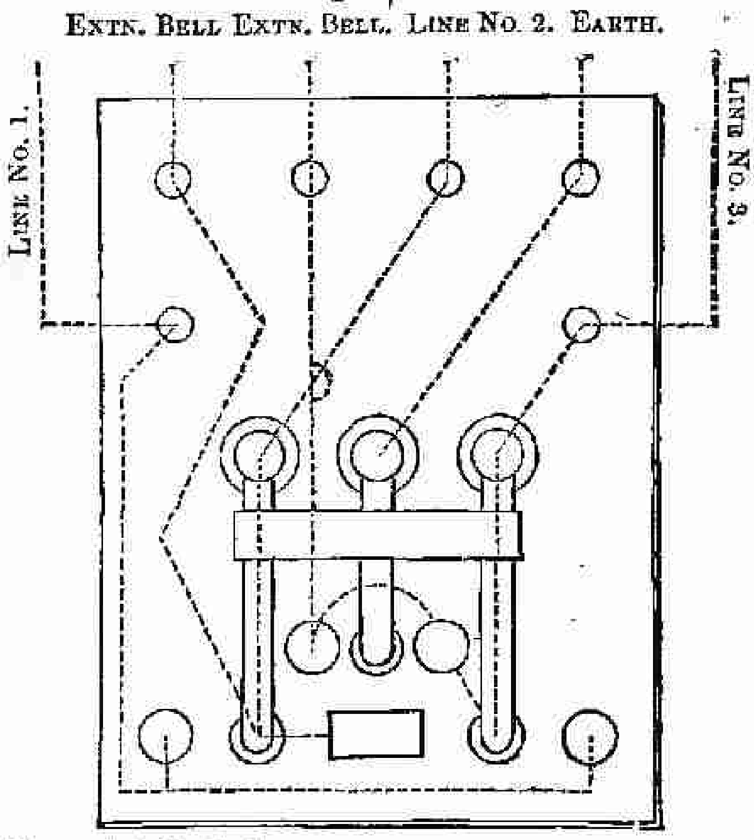
Six-point Switch.

The square pattern six-point switch is shown in Figs. 108 and 109, Fig. 109 showing the connections. As with the circular pattern it has three positions in the centre, one of which is shown in Fig. 109.

Another form of switch is shown in Figs. 110 and 111. These are known as plug switches, and form one of the cheapest and best means of connecting up telephone instruments to meet special requirements, owing to the number of different forms in which it can be made. The form shown in Fig. 110 is the simplest form, and often called an "interrupter," since it can only be used for making and

Fig. 108.

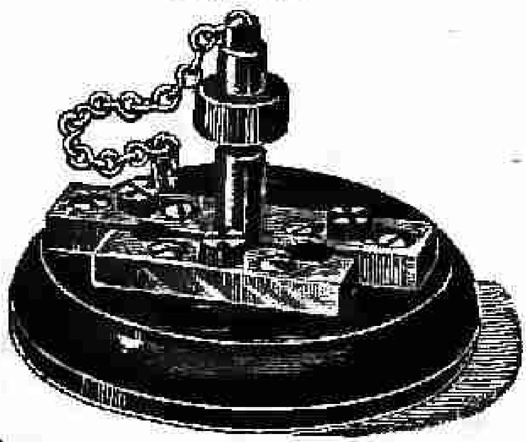
Fig. 109.



Six-point Switch.

Fig. 110.

Fig. 111.



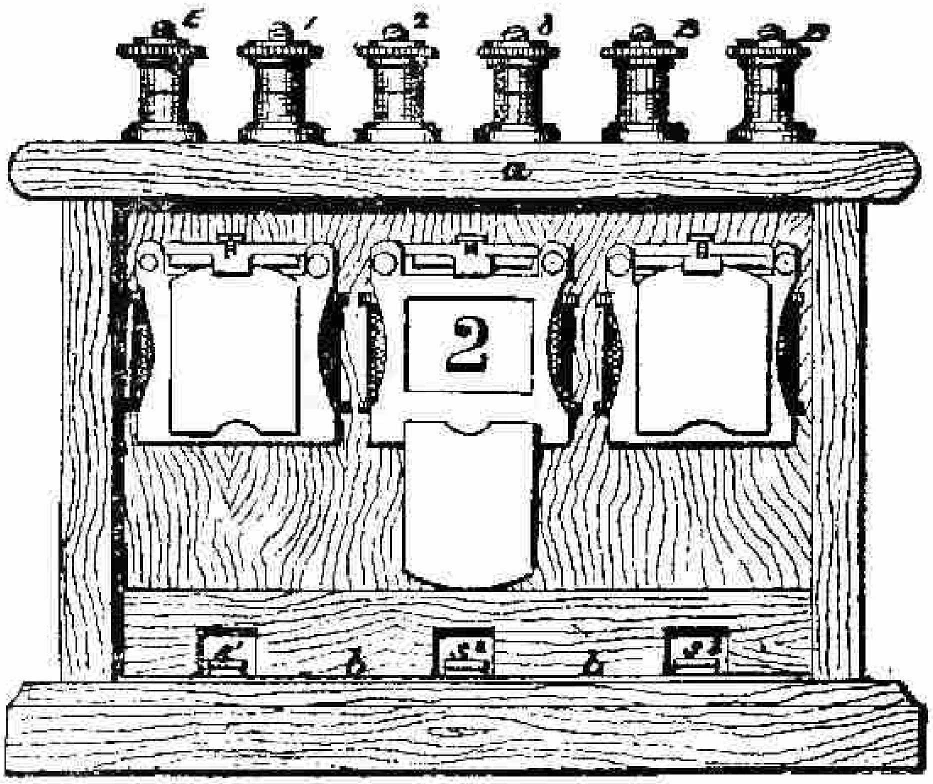
Plug Switches.

breaking the circuit, and not for giving it a different direction. When the plug is inserted between the two blocks as in the figure, the circuit is closed, but on withdrawing it the circuit is opened.

The form shown in Fig. 111 is a three-block one, with a hole between each block, thus enabling any two of the blocks to be connected together. This form is very convenient for use with three telephone stations, as by inserting the plug in the proper hole any one telephone can be put into communication with either of the remaining two.

Fig. 112 (a front elevation) shows a small switch-board suitable for four stations, one of which is used as the

Fig. 112.



3-drop Annunciator.

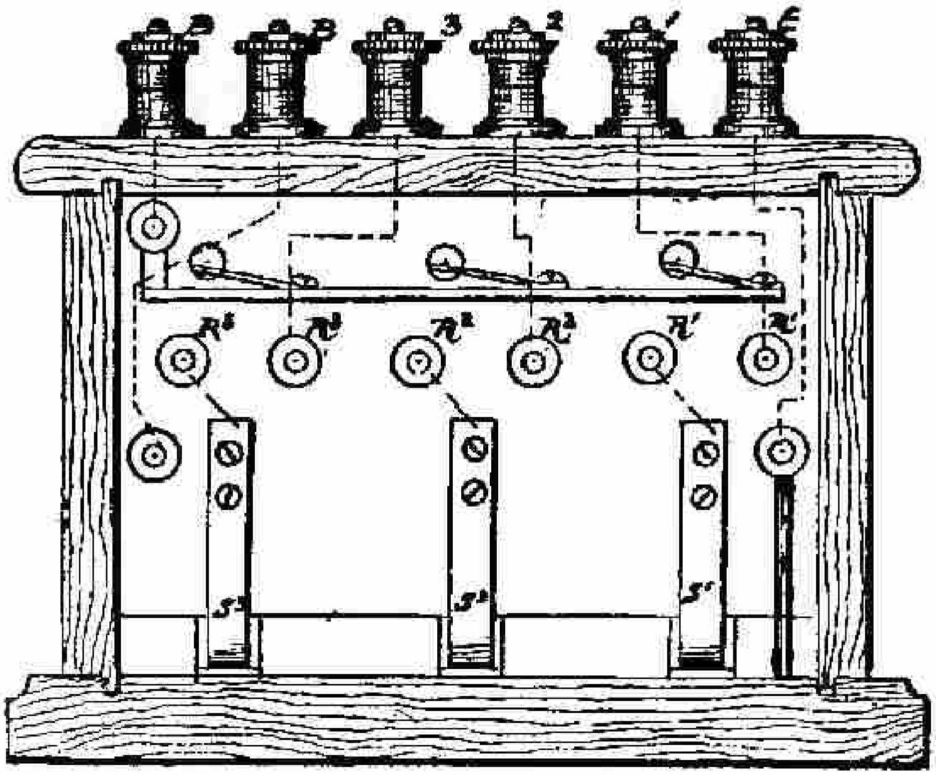
central station or switch-room. Fig. 113 is a view from the back, showing the connections. The switch-board consists of the three annunciator drops, 1, 2, and 3, contained in a polished mahogany case, *a*. At the bottom of the case are three brass springs, s^1, s^2, s^3, the lower ends of which press firmly against the brass plate *b*. The annunciator drops are of a similar construction to those shown in Figs. 127 and 128 'Practical Electric Bell Fitting'*; the connections from the

* Published by E. and F. N. Spon.

coils pass through the back of the containing case by means of the two rods supporting each drop, and are marked respectively R^1, R^2, R^3. The connections to the terminals at the top of the case are shown by the dotted lines in Fig. 113.

The method of operating the switch-board is as follows:— Supposing the switch-board to be situated at station No. 4, and station No. 2 wishes to speak with No. 3; then when the person at station No. 2 presses the ringing key of his instrument, the current enters the switch-board at terminal No. 2, passes through the annunciator No. 2, thence to spring s^2, to

Fig. 113.



3-drop Annunciator.

plate *b*, terminal E, and "earth." This causes the coils of No. 2 annunciator to attract its armature, thus releasing the shutter and disclosing the number, as in Fig. 112. The person at No. 4 station hearing the bell ring (which is done by the shutter of the annunciator falling on to a contact and closing the local circuit of the bell), looks at the annunciator board, and sees that No. 2 station is ringing. He then takes what is called a "plug" (Figs. 114 and 115, Fig. 115 being a side view of Fig. 114), which consists of a brass piece *b*, the bottom part being insulated, as shown, by the ebonite face *a*, and presses it under the spring s^2, the point of the plug passing between the spring and the plate *b*, thus insulating the spring from earth, and putting it into connection with the

Fig. 114.

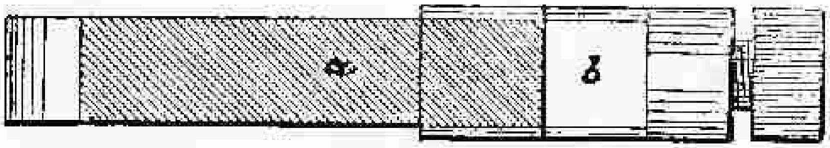
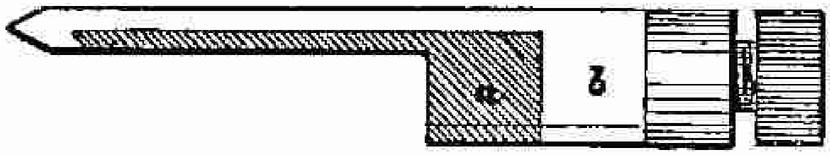


Fig. 115.

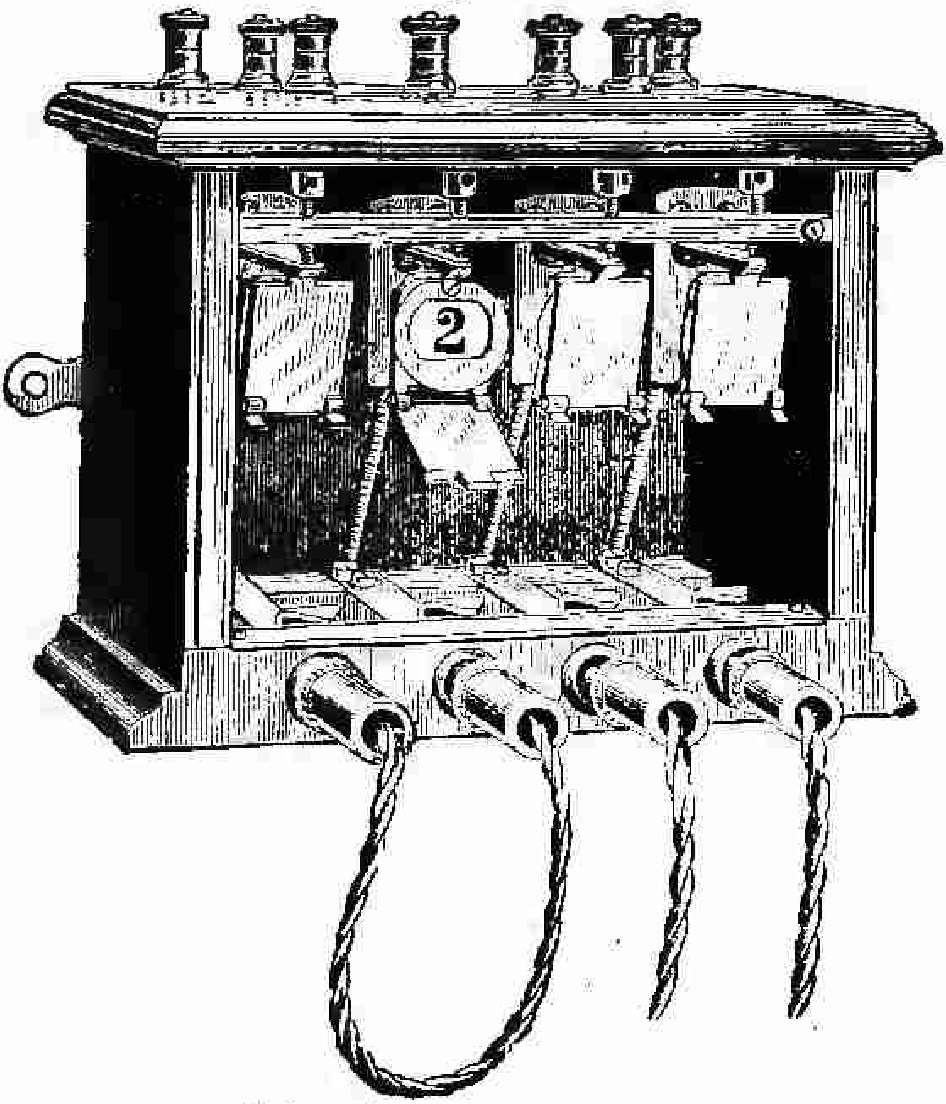


Connecting Plug.

telephone at No. 4 station by means of a flexible wire, one end of which is connected to the plug and the other to the telephone. The person at No. 4 station can then carry on conversation with the person at No. 2 station. No. 2 station now informs No. 4 that he wishes to be put into communication with No. 3. The person at No. 4 station then takes two plugs, which are connected together by a short length of flexible wire, and, pulling out his own plug, slips one plug under No. 2, and the other under No. 3, spring, thus putting No. 2 station in connection with No. 3. If No. 2 station presses his ringing key now, he rings the bell at No. 3 station, and conversation can be carried on. By means of what is called a "knife plug" (which is like the plug shown in Figs. 114 and 115, but without the ebonite piece *a*) the person at station No. 4 can, by sliding this knife plug on top of the ordinary plug, ring or converse with either station No. 2 or No. 3 without breaking the connection between them. In a similar manner No. 2 station is put into communication with

No. 1, or No. 1 with No. 3. In an exchange worked on this system, which is called the "slipper-board system," every subscriber has an annunciator drop in the switch-board of the exchange, and is connected to any other by the attendant by means of the plugs. The outside connections for the switch-board are not shown in the Figs. 97 and 98, as these will be shown later on amongst the diagrams.

Fig. 116.



4-drop Annunciator.

Fig. 116 is a perspective view of a 4-drop annunciator board, similar to that just described. At the foot of the board are the plugs with which the connection between the different lines is made. In this form of annunciator board it will be seen the plugs are circular in form.

CHAPTER VII.

BATTERIES.

THE form of battery used in telephony is almost exclusively the Leclanché, and preferably the agglomerate block form. In exchange work a Gravity Daniell is often employed in connection with a pole changer at the switch-room in preference to a magneto generator. Before the introduction of the magneto switch-bell, a large number of batteries were necessary in an exchange system, there being generally four Leclanché cells at each subscriber's instrument, and a battery of ten or twelve gravity cells at the exchange. With the general adoption, however, of the magneto switch-bell, the ringing batteries were done away with at the subscribers' instruments, one cell only being retained for the transmitter. At the exchange, either the batteries were retained and a pole-changer employed for sending alternating currents, or else a small magneto generator is employed, which is run continuously by a small water or gas motor. In private line work, the No. 2 size is the one generally employed, the number of cells at each end depending on the distance between the two stations. Except for short lines, it is better and cheaper to employ magneto switch-bells for ringing, one Leclanché cell being used for the transmitter. In the case where the transmitter and receiver are both of the magnetic type, the magneto bell for signalling only is required.

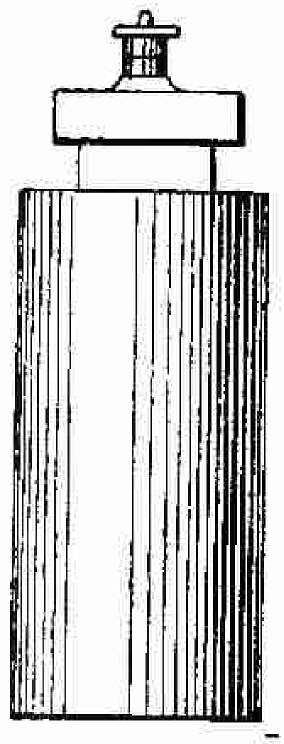
The reason that the agglomerate block form is to be preferred for telephones, is because this kind has a lower resistance than the porous pot form. This is not, as a rule, of so much importance on the ringing circuit as for the local circuit of the transmitter, since the ringing circuit itself has generally a high resistance, while the local circuit through the microphone is very low, and therefore it is important that the battery has also a low resistance.

There are two kinds of the Leclanché cell, the "porous pot" and the "agglomerate block" form.

The "porous pot" form is shown complete in Fig. 117, and consists of a glass jar (Fig. 120) in which is contained the

Fig. 117.

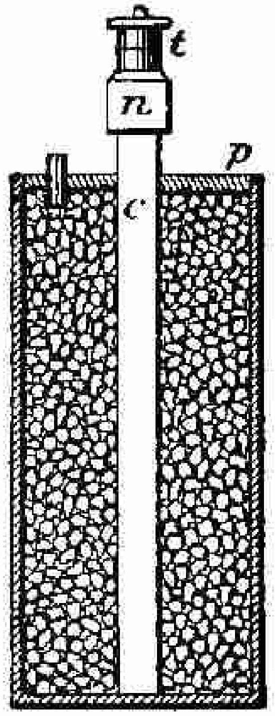
Fig. 118.



Porous Pot form Leclanché.

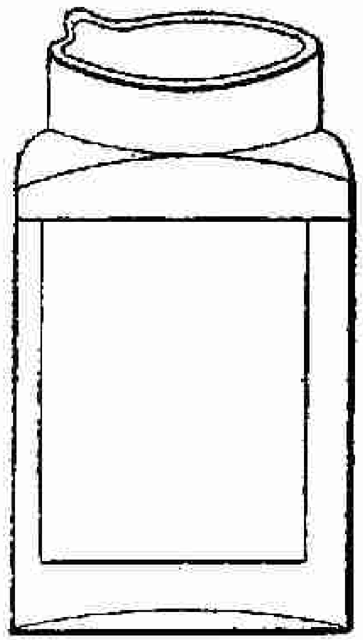
amalgamated zinc rod forming the positive element. The negative element (which is shown in Fig. 118, and also in section in Fig. 119) consists of a carbon plate *c*, placed inside a porous pot *p*, and surrounded with a tightly packed mixture of carbon and peroxide of manganese, the top of the pot being run in with melted pitch. The Leclanché is a single-fluid cell, the porous pot serving not to keep two fluids separate, but merely to contain the broken carbon and manganese, and keep it in intimate contact with the carbon-plate. The exciting fluid is a solution of sal-ammoniac.

Fig. 119.



Porous Pot.

Fig. 120.



Glass Cell.

This solution has no chemical effect, either on the zinc (provided it is pure) or the peroxide of manganese, so long as the circuit is broken and the cell not at work. On the circuit being completed a current flows from the carbon to the zinc pole, the action in the cell being as follows:—The solution of chloride of ammonia (sal-ammoniac) is decomposed; the chlorine, attacking the zinc, forms chloride of zinc, which is soluble in the surrounding liquid; while the ammonia, developing at the surface of the carbon, forms a soluble compound with the oxygen which it extracts from the manganese. While the cell is at work, then the zinc is consumed and chloride of zinc accumulates in the solution, the carbon remaining unaltered, and the peroxide of manganese loses some of its oxygen. After a time, however, the supply of oxygen gets reduced and hydrogen accumulates on the surface of the carbon-plate, producing polarisation. If the circuit is broken, however, and the cell left to rest for a time, it will depolarise: the peroxide of manganese absorbing oxygen from the air.

The terminal *t* is fixed to the carbon-plate by means of the lead cap *n*, which is cast on to the plate. Great care is necessary in fixing this lead cap to the carbon-plate, as if improperly done, the salts creep up and rapidly eat away the connection. Before the lead cap is fixed the carbon-plate is

Fig. 121.

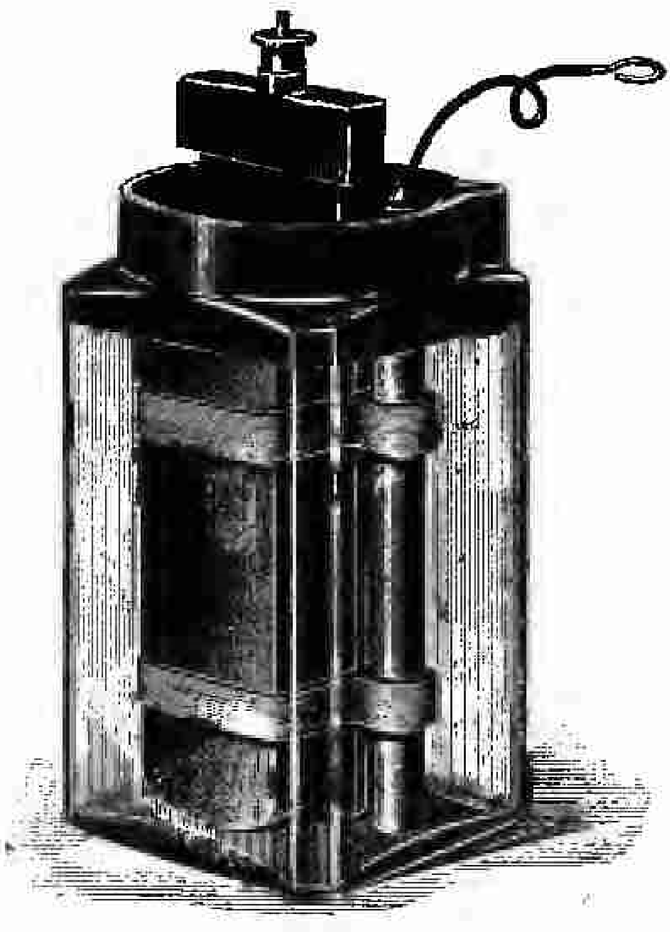
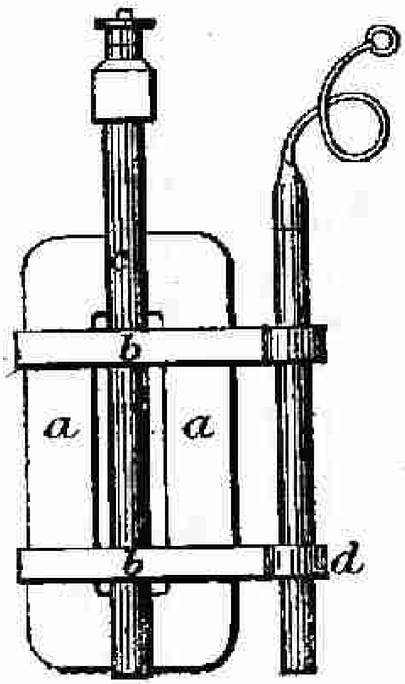


Fig. 122.



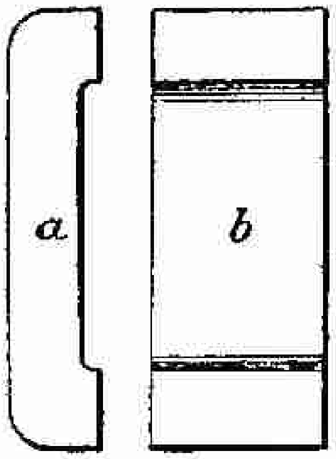
Agglomerate-block Form Leclanché.

soaked for an hour or so in melted paraffin wax, at a temperature of 110° C., to prevent the salts creeping.

The "agglomerate block" form is shown complete in Fig. 121. In this form of the Leclanché cell a porous pot is not used, the depolarising mixture being applied to both sides of the carbon-plate in the form of a block. The materials used in the construction of these blocks are similar to those contained in the porous pot, with the addition of from 5 to 10 per cent. of some cementing compound, such as resin.

In Fig. 122 are shown the carbon-plate, agglomerate blocks, and zinc rod removed from the glass cell, and in Fig. 123 the agglomerate block only; *a* being a view of the block in a position at right angles to that of *b*.

Fig. 123.



Agglomerate Block.

In fitting up a cell of this form an agglomerate block *a a* (Fig. 122) is placed each side of the carbon-plate *c*, and two of the indiarubber bands *b b* slipped over them. These bands have at *d* a solid part, through which a hole has been stamped to receive the zinc rod. The zinc is thus kept from touching the negative element, and both elements can (by lifting at the positive terminal) be lifted bodily out of the glass jar.

The following are the chief advantages claimed for the agglomerate block over the porous pot form:—That a better use is made of the depolarising power of the manganese, as its reduction is more complete, and that in consequence of the readier reduction of the manganese the carbon-plate is more rapidly depolarised, and consequently the E.M.F. is more sustained. That its resistance is extremely constant, whatever the electro chemical work done by the cell. That the battery is ready for use immediately on charging. That the renewal of an exhausted cell is exceedingly simple, new depolarising plates having only to be substituted for the exhausted ones. Their chief virtue is of course their low internal resistance, which makes them very suitable for a microphone cell, though in the author's opinion they are not equal to the porous pot form for ringing batteries where a low internal resistance is of no advantage. They are exceedingly dirty to handle, and subjected to an injurious local action, owing to impurities detached from the blocks settling on the tops of the rubber bands.

A creeping of the salts up the inside and over the outside of the glass jar is a fault to which the Leclanché cell is particularly liable. This can, however, be somewhat prevented by rubbing the neck of the jar with grease, or by dipping it for an inch or so in melted paraffin wax. The strength of the solution has also some effect on the creeping.

A good way to paraffin the top of the glass cells is to melt the wax in some vessel, the mouth of which is wide enough to admit of a cell being inserted. A piece of glass tube, bent to the shape of the letter U, is placed inside the vessel that contains the wax, both ends of the tube being above the surface of the wax. The glass cells, having been previously warmed, are then dipped (mouth downwards) into the melted wax, one end of the glass tube passing inside the cell, and the other remaining outside exposed to the air. This allows the wax inside the cell to rise at once to the level of that outside, instead of (if there was no tube) being prevented from entering by the pressure of the air.

With a view also to prevent this creeping, the cells are sometimes sealed, i. e. the top is filled in with pitch, a hole being left for charging. The use of sealed cells, however, is not economical, as when exhausted they cannot well be recharged.

The Leclanché cell is made in three sizes: No. 1, or three-pint; No. 2, or quart; No. 3, or pint, according to the amount of solution the glass cell will hold.

Position of the Battery.

The position of the battery is a matter of some importance, as in warm or moist situations the creeping of the salts is greatly hastened. It should be placed, where possible, on the floor, in a box, under the telephone instrument; but if this is objected to, it should be placed on a shelf in a cupboard or cellar, selecting as cool a place as possible.

Setting up the Battery.

In setting up a battery fill up the outer jar three-quarters full with solution, taking care not to splash the terminals or they will subsequently corrode. The best proportion of sal-ammoniac to water is about 2 oz. to a pint, though often a saturated solution is used. A saturated solution, however, greatly augments the creeping of the salts, so that if a saturated solution is used the battery should be inspected more frequently.

The battery (unless an agglomerate block) will not start at once. If the battery is required immediately, a little solution should be made in a jug, and poured into the porous pot through the little hole in the top, or a small hole may be knocked in the bottom of the porous pot, so that the liquid rises at once to the same level as that in the jar.

The battery, when once properly set up, requires but little attention, and will run without recharging for periods varying between six months to two or three years, according to the size of the battery and the amount of work it does.

Inspecting a Battery.

When inspecting a Leclanché battery the following points should be looked to :—See that the salts are not creeping over the glass jar ; if so, the faulty jar must be taken out, well dried, and the neck rubbed with grease. See that the zincs are not eaten away, and scrape off any crystals that may have formed on them. Should the zincs be very black, while a strong smell of ammonia comes off from the porous pot, it indicates excessive working, probably a short circuit on some of the wires, which must be seen to. See that the solution is not evaporated; if so, fill up with water. If the solution is opaque or milky, add more crystals till it becomes clear again, or substitute a new solution. See that none of the solution has got on the terminals, or it will rapidly eat them away. See that no white lead is forming between the lead cap and carbon plate; if this is the case, exchange the porous pot for a new one, as owing to the bad conducting power of the white lead increased resistance is thrown into the circuit.

Recharging a Battery.

When recharging a Leclanché battery it will be necessary first to see if the zincs are still in good condition, and not eaten quite thin. If the zincs are in fair condition, renew the solution, and should this effect no improvement, new porous pots or agglomerate blocks must be substituted for the old ones. Owing to the slight cost of the new porous pots, it is never advisable to attempt to recharge the old ones, which at the best is a difficult and tedious operation.

The following table shows the E.M.F. and internal resistances of the different sized Leclanché cells:—

Size.	Porous Pot Form.		Agglomerate Block.	
	E.M.F.	Res.	E.M.F.	Res.
No. 1	1·60	·75	1·55	·50
No. 2	1·60	1·10	1·55	·60
No. 3	1·60	1·50	1·55	·80

It will be noticed that the agglomerate block form has a slightly lower E.M.F., and a considerably lower resistance.

A modification of the agglomerate block form of Leclanché cells is shown in Fig. 124. It is known as the six-block agglomerate, and has a very low internal resistance. The negative element is shown in Fig. 125, and consists of a grooved carbon cylinder *a*, with the agglomerate rods *b b b*

Fig. 124.

Six-block Form.

Fig. 125.

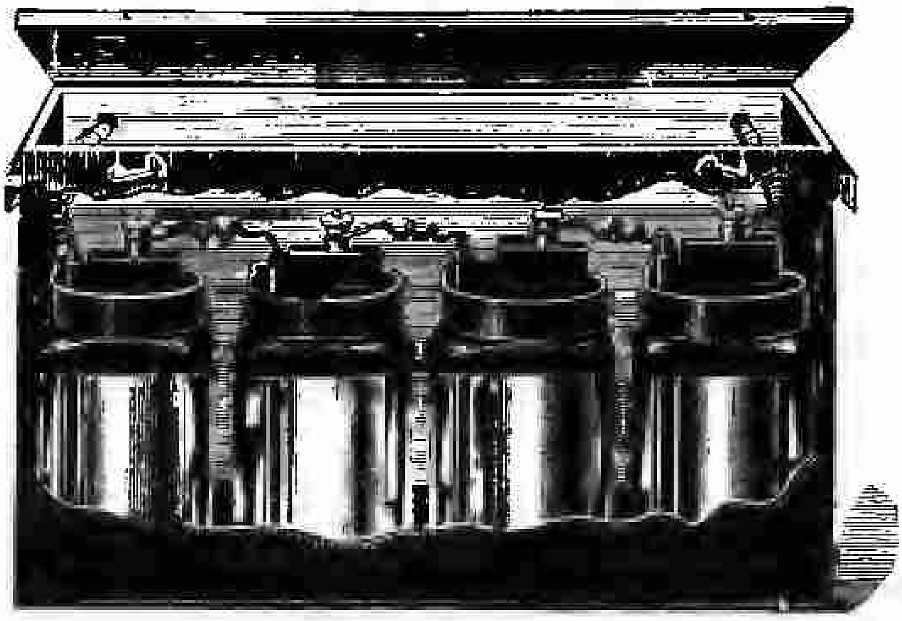
Agglomerate Block.

in each groove. The rods are kept in contact with the carbon cylinder by the wrapping of sackcloth *c*, outside which are two rubber bands.

The positive element is in the form of a zinc cylinder (such as is used in the Bunsen cell), which completely surrounds the negative element, the sackcloth preventing its coming into contact. The containing jar is of glazed stoneware. For bells in parallel, or where a large current is required, this form of cell is very useful, as owing to its construction it has a very low resistance, its E.M.F. being 1·55, and its resistance ·20 of an ohm.

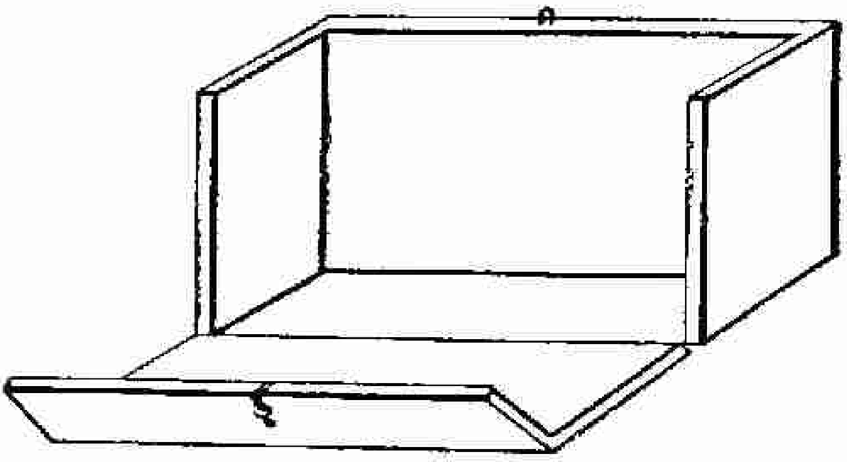
Batteries are best placed in a battery box as shown in Fig. 126, which shows four of the porous pot Leclanchés ready connected up in a box. A better form of box, however, is

Fig. 126.



Four-cell Battery in Box.

Fig. 127.



Battery Box.

that shown in Fig. 127, which is so arranged that the front and lid when released fall forward outwards, thus allowing the condition of the battery to be inspected at a glance.

CHAPTER VIII.

ERECTING TELEPHONE LINES, OVERHEAD WIRES, INSTRUMENTS, ETC.

In a telephone line there are four different portions of the line to erect. There is, first, the "line" wire, which is the outside wire connecting the two instruments, and is run either overhead or underground; second, the "leading-in" wire, which connects the outside wires with those inside; third, the "joining up" or inside wires, which are those extending from the instrument to the "leading-in" wire and to the battery; and, fourth, the "earth" wire, which runs from the instrument down to the earth connection. In places where a return wire is used, the earth wire is not, of course, required.

Line Wires.

For overhead purposes, No. 16 B.W.G. hard-drawn copper, silicium, or phosphor bronze wire should be employed, or, if a stronger wire is required, a stranded one, consisting of three strands of No. 18 copper or silicium bronze should be used. For private line work, however, No. 16 B.W.G. will be found the most suitable, and, in certain cases, where the spans are short, and not in an exposed position, No. 18 even may be erected. Formerly, iron wire, No. 8 or 11 B.W.G., was much used: but very little is ever erected now, a No. 16 copper, phosphor, or silicium bronze having taken its place. Iron wire, when used, requires to be very well galvanised, or it soon rusts, and in towns is rapidly eaten away by the sulphurous fumes from the chimneys. For this reason an iron wire, where it passes above a chimney, or even copper wire if it passes very close, should be wrapped with tape for a yard or two, and the tape served with a coating of varnish.

In running the wires they must be fixed either on insulators or shackles, insulators for preference, as they give a higher insulation.

Figs. 128 and 129 show in section the Cordeaux screw insulator, Fig. 128 being the single shed and Fig. 129 the

Fig. 128.

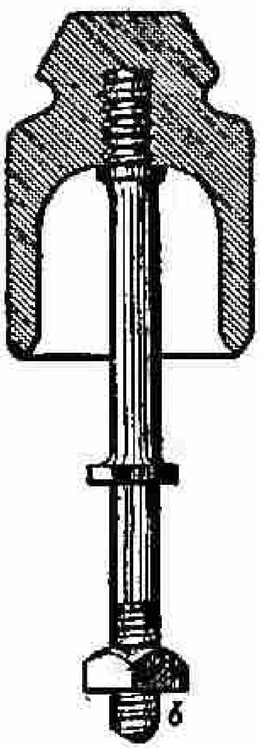


Fig. 129.

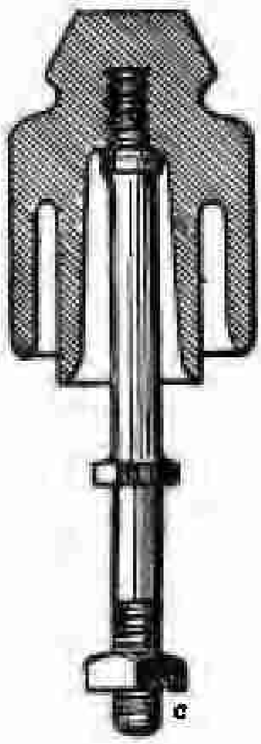
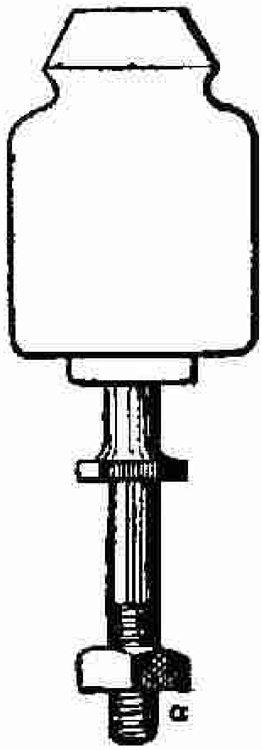


Fig. 130.

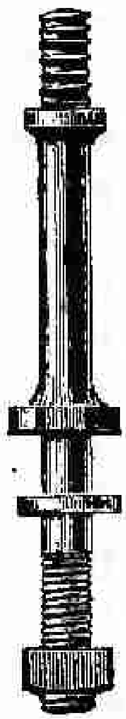


Insulators.

double shed form. Fig. 130 shows the outside appearance of the insulator complete. The insulator is of glazed porcelain, supported by the galvanised iron bolt Fig. 131, the top end of which screws into the upper part of the insulator, as shown in Figs. 128 and 129. In the single shed insulator it will be seen there is only one recess, while in the double shed there are two, thus giving better insulation. In Fig. 132

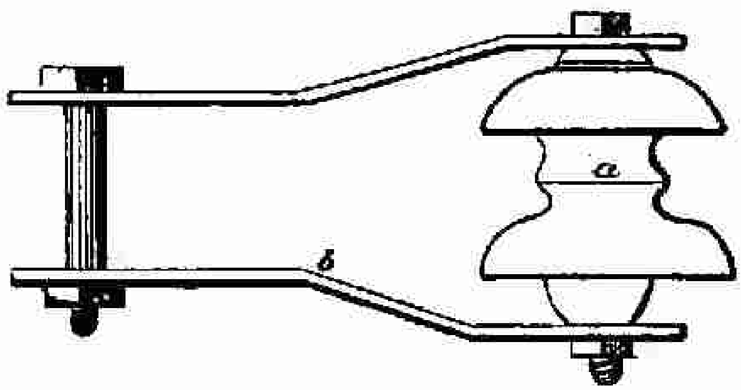
is shown the single shackle, while that in Fig. 133 is a double shackle. The part *a* in Fig. 132 is the shackle, made of glazed porcelain, and *b* is the shackle-strap of galvanised iron. In Fig. 134 is shown the shackle strap complete with bolts. In some places, such as under sheds, &c., the small form of insulator shown in Fig. 135 may be used. This form is called a "bobbin," and will be found all that is necessary in dry places. The bobbin is fixed by a screw or bolt through the centre, and to fasten the wire a turn is taken right round the groove. White porcelain insulators or shackles are the best, but if they are placed in an exposed position where they are likely to be broken by stone-throwing, the brown porcelain should be used, as offering a less inviting appearance. Shackles are generally used at the ends of a line and the insulators as intermediate supports, as shackles can generally be fixed so as to withstand a greater strain than insulators. The Telephone Companies use either insulators or double shackles, some having a preference for insulators, while others will use nothing but

Fig. 131.



Bolt.

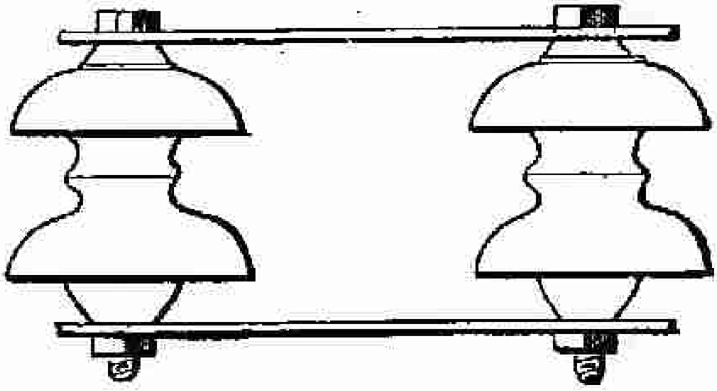
Fig. 132.



Single Shackle.

double shackles. The best insulation is undoubtedly obtained by using insulators, and if a very high insulation is desired, fluid insulators, such as the Johnson, should be employed. Private line work, however, is different from exchange; what is sufficient for the former being often quite inadmissible in the latter. In exchange work each wire, owing to its close proximity to others, and very often electric

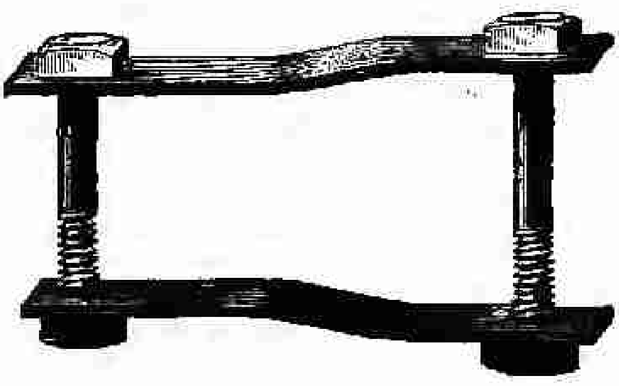
Fig. 133.



Double Shackle.

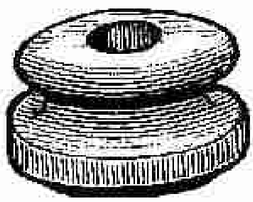
light wires carrying high-tension currents, requires to be very well insulated, while a private line wire, which, in nine cases out of ten, is of no great length, is generally in private ground, and thus removed from external disturbances. For

Fig. 134.



Shackle strap.

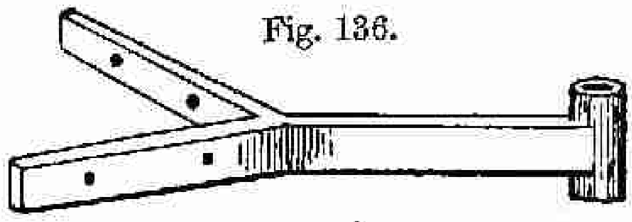
Fig. 135.



Bobbin.

short lines in towns, therefore, it will usually be found quite sufficient to fix the wire to single shackles, the shackles being fastened to the chimney stacks by $\frac{3}{16}$ galvanised iron wire taken once right round the stack, or, if the strain is great, twice, each turn being so arranged as to pull against a different course of bricks. When it is desired to fix to a chimney stack, a wrought-iron bracket, as shown in Fig. 136, should be used, and an insulator, or shackle, fixed at the end. The wire is then fixed to the insulator, and should be so arranged that

Fig. 136.



Chimney Bracket.

the only strain on the bracket is towards the chimney-stack. Wall brackets for supporting insulators take a variety of forms, and very often a bracket will have to be designed to meet special requirements. In Fig. 137 is shown a convenient form where there is only one wire to be carried. The end of

Fig. 137.

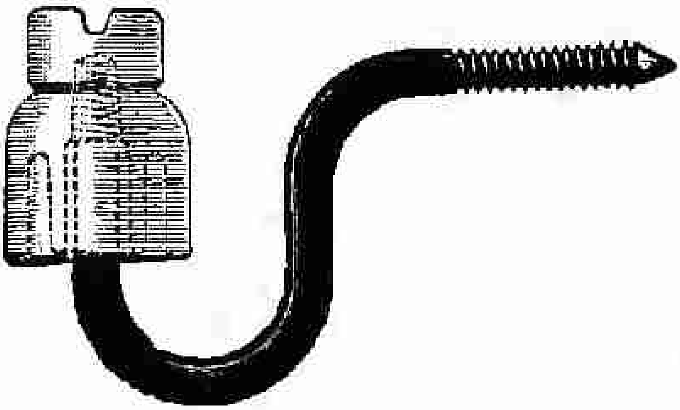
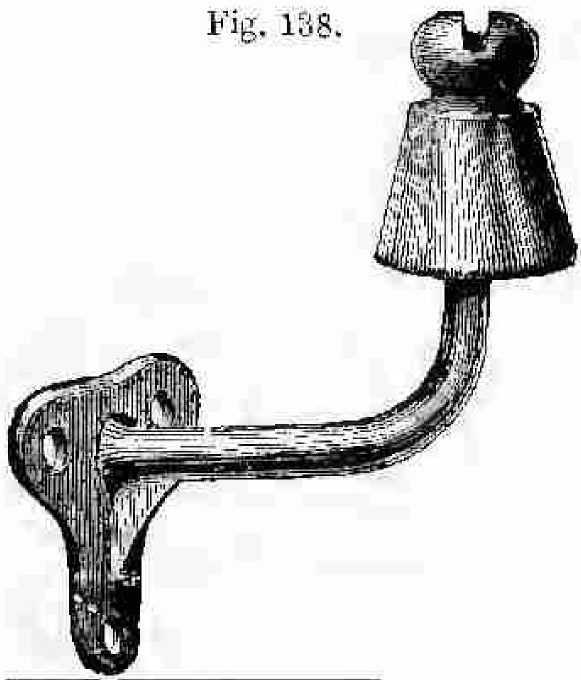


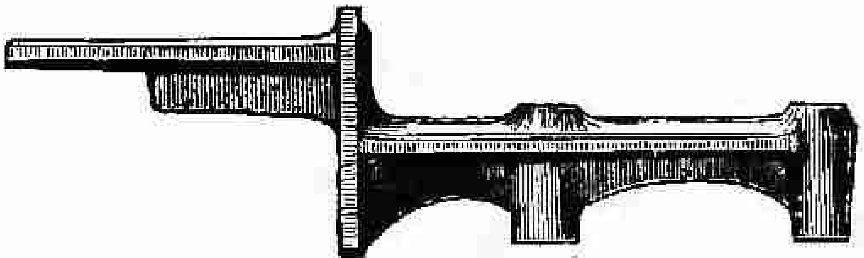
Fig. 138.



Wall Brackets.

wrought-iron rod has a wood-screw thread cut on it, by means of which it is fixed. Unless there is some suitable woodwork near, a brick must be taken out of the wall and a wood plug inserted. For nailing direct to the wall, a wall bracket of the form shown in Fig. 138 will be found more convenient. This can be attached directly to the wall by stout nails, or else fixed to any suitable woodwork by screws. Another form of wall bracket is shown in Fig. 139. It is intended for carrying two wires, the bolts of the insulators being fixed to the two shoulders seen to the right of the figure.

Fig. 139.



Wall Bracket.

Erecting Overhead Wires.

In erecting overhead wires in towns, care must be taken to see that the wires are erected in a thoroughly substantial manner; otherwise serious accidents may result. All streets should be crossed as nearly at right angles as circumstances will permit, and the wires kept off the main thoroughfares as much as possible. If a wire must be stretched across a street nearly parallel with the direction in which the street runs, extra precautions should be taken to see that the fixings are thoroughly sound and the wire properly erected. If a wire crosses a street in this direction and breaks, then the wire will fall right into the street, coiling up and twisting as it falls in a manner that cannot but cause the most serious results should there be much traffic. In crossing electric-light wires, it is best, if there are only a few telephone wires, to cross under the electric-light wires, for electric-light wires are generally so much stouter than telephone ones, and more securely erected that they are not likely to break, whereas, if the telephone wires were to fall on to a naked electric-light wire, the annunciator at the exchange would get burnt out, or subscriber's instrument damaged.

To fix overhead wires in a proper manner requires at least three men—four or five if in crowded thoroughfares. Before commencing to run the wires, the different points at which a fixing shall be taken must first be determined. This is best done by getting on the roof of the two buildings between which the wire is going to be run, and taking a survey, by which means it can generally be determined which are the most suitable places. The next thing is to get permission to take a fixing on the houses, or a "way-leave" as it is called, which must be obtained from the landlord. Very often this getting way-leaves is the most difficult part of overhead wiring, many persons having (perhaps not unnaturally) a great dislike to wires on their roof. In private line work, however, the wires are generally erected on houses belonging to the owner of the telephones, and thus there are no way-leaves to be got; but, nevertheless, it frequently happens in towns that fixings have to be made on intermediate buildings where permission has to be obtained and very often a rental paid. Permission being obtained, the insulators or shackles should next be fixed at each place, and everything got ready for running the wire.

The wire should be commenced running from one end and worked towards the other. In running each span, one man goes on top of the building from which a start is made, taking with him the coil of line wire and a ball of stout string. Another man goes on top of the building where the next fixing is to be made, also taking with him a ball of string. This string is first got through between these two points, which is done by working the string from each of the fixings, and then joining the two ends together and pulling the string up taut, when it will generally rise clear of everything; if not it must be manipulated till it does. In crossing a street the ends of the string must first be brought to the house on each side, and the two ends thrown down at the same time into the street, one of the men remaining in the road to tie the ends together, when the string must be quickly pulled up taut. After the string has been got through between two points, the man having the coil of wire ties one end of the coil to the string and pays it out to the other man, who draws the wire across, and when he gets the end makes it fast to the insulator. The other man then proceeds to draw back the slack, after which he cuts the wire, draws it up tight with the draw-vice, and makes it fast to his insulator. In the same way the other spans are run until the line is complete. If the lines end at each insulator, a small piece of wire must be soldered to the end of each span, so as to bridge over the insulator and make a good connection right through. Each span should be erected, if possible, without joins, but if joining is necessary, the joint must be well soldered, which should be done at as low a heat as possible to avoid softening the wire.

Fig. 140.

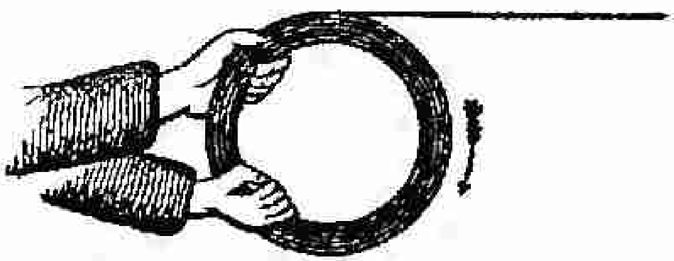
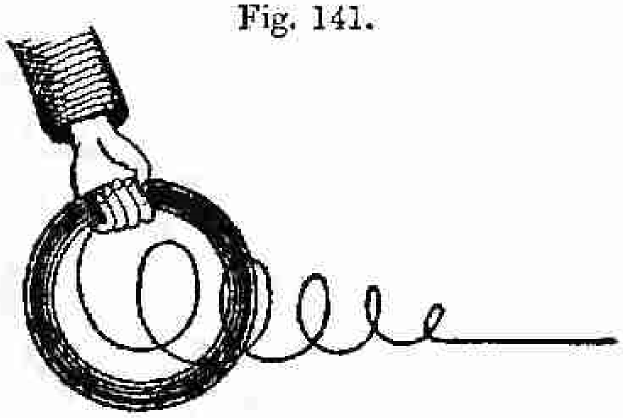


Fig. 141.



Paying-out Wire.

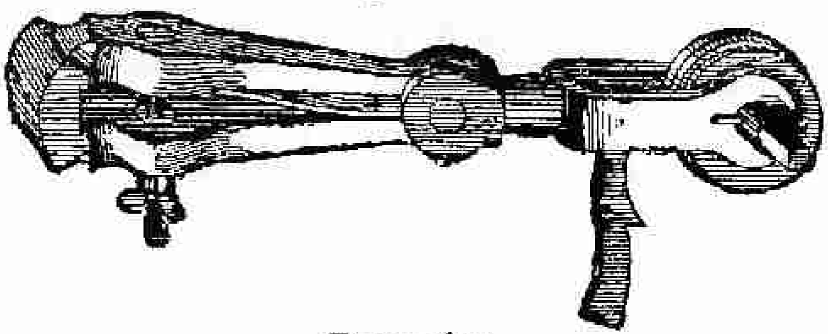
In "paying out" the wire as each span is run, a little care is requisite to prevent its going into "kinks." The coil of wire should either be let run off a reel or else it should be gripped firmly with both hands and turned round, as shown in Fig. 140, and not let slip one coil at a time, as shown in Fig. 141, which will assuredly cause it to go into kinks (see Fig. 142). These kinks, when pulled out, go into the form shown in Fig. 143, which weaken the wire, making it very liable to break at this point, besides giving the span a very unsightly appearance.

Fig. 142.

Fig. 143.

Kink in wire.

Fig. 144.



Draw-vice.

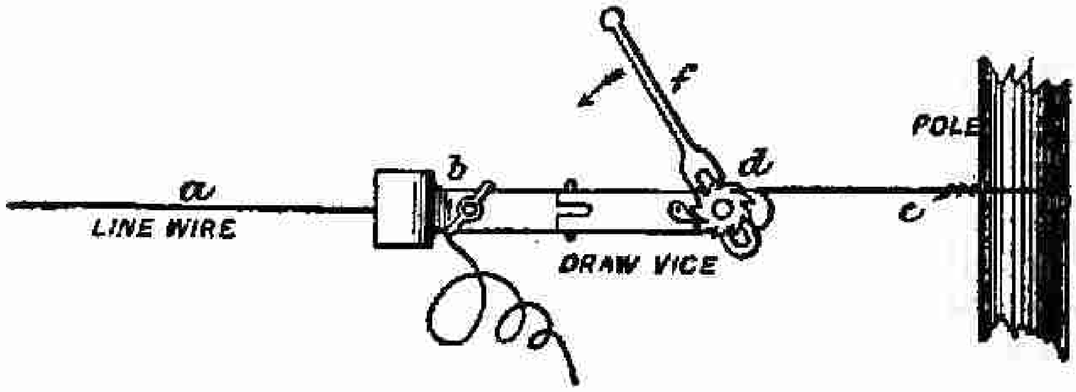
Each span must be tightened up to the required degree by means of a draw-vice, a form of which is shown in Fig. 144, and the key in Fig. 145. The method of "vicing-up" a span is shown in Fig. 146. The end of the span *a* is gripped in the jaws *b* of the vice, while the cord *c* from the barrel *d* of

Fig. 145.

Draw-vice Key.

the draw-vice is fastened to the pole or shackle strap as the case may be. When the barrel is turned by means of the key *f* the cord is wound round the barrel and the span thus tightened up. The span is afterwards fastened off when the required tension is obtained. A firepot will be found very useful for all outdoor work, as the soldering iron is constantly in requisition, or least should be, as all joints must be properly soldered.

Fig. 146.

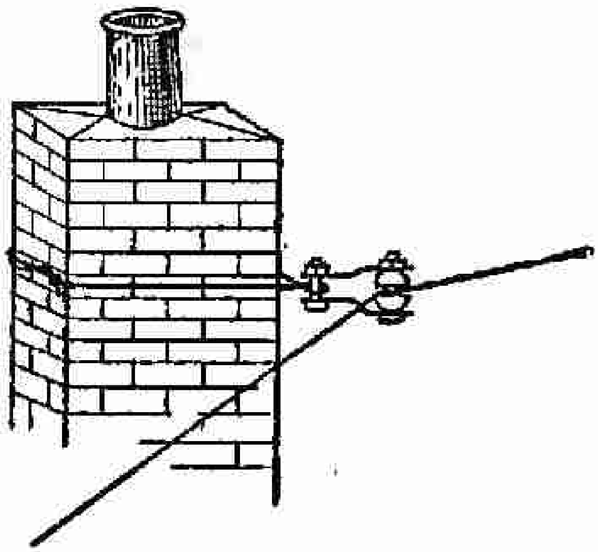


Vicing-up a Span.

As regards the length of the spans, these should not, where it can be managed, exceed 75 or 80 yards, but No. 16 silicium bronze may be safely run in 100 yard spans, though it is desirable to keep them shorter. This, however, cannot always be managed, as the shortest and best route may perhaps be debarred from use owing to inability to obtain wayleaves.

However tight a span may be viced up, there will always be a certain drop in the centre, which drop is called the *dip* or *sag* of the span. The amount of this sag will of course vary considerably, according to the temperature of the atmosphere, owing to the expansion of metals by heat and contraction by cold. For an 80-yard span it is usual to allow a sag of about 3 feet in ordinary summer temperature, which may increase to 3 feet 9 inches on a very hot day, or decrease to 1 foot 8 inches in the depth of winter. For longer spans of course the sag will be greater, and in tightening up a span the amount of sag must be regulated by eye, care being taken, if there are more than one wire, to see that they all sag in the same proportion. The easiest and most common method of running a single telephone wire is by using single shackles, which are secured round the chimney stack by a $\frac{3}{16}$-inch galvanised iron wire. This method is shown in Fig. 147, and though generally used for terminal supports, can also be used for intermediate ones. In fixing the shackle it must always be so arranged

Fig. 147.



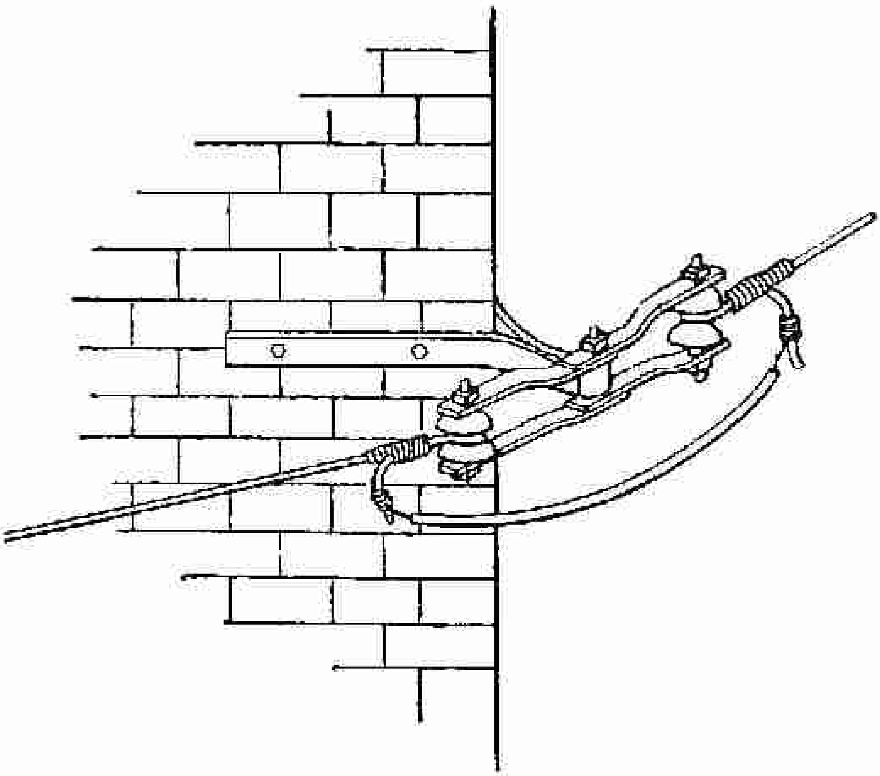
Shakle fixed on Chimney.

that the pull of the wire is away from the chimney stack, so that the shackle will swing clear of the brickwork. The illustration shows the shackle in use as an intermediate support; if used at the end of a line the wire is terminated at the shackle and the "leading-in" wire attached to the projecting end.

Fig. 148 shows how the double shackle is used, it being chiefly employed for intermediate supports or else for terminating two lines where the telephone in the building is the intermediate instrument of three or more. In the illustration it is shown fixed to a chimney or corner bracket, a method that will be found very suitable where the pull is towards the building; if the pull is in the opposite direction the shackles should be slung round the chimney as shown in the preceeding figure. With double shackles the line is terminated at each shackle, and the break bridged across by a short length of wire as shown.

The method of binding the line wire to the insulators and shackles is shown in Figs. 149 and 150. In Fig. 149 it will be seen the wire is passed round the shackle and then wrapped round with some No. 18 B.W.G. ordinary copper wire. The

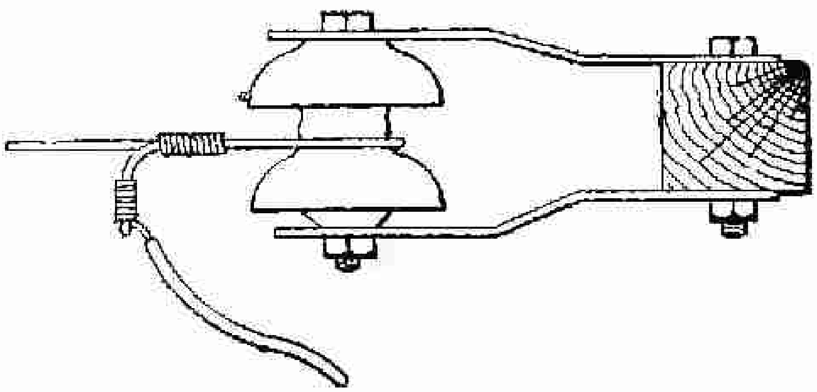
Fig. 148.



Double Shackle on Corner of Building.

end of the "leading-in wire" is attached on to the short end of the line wire, and not on to the body of the wire, so that when

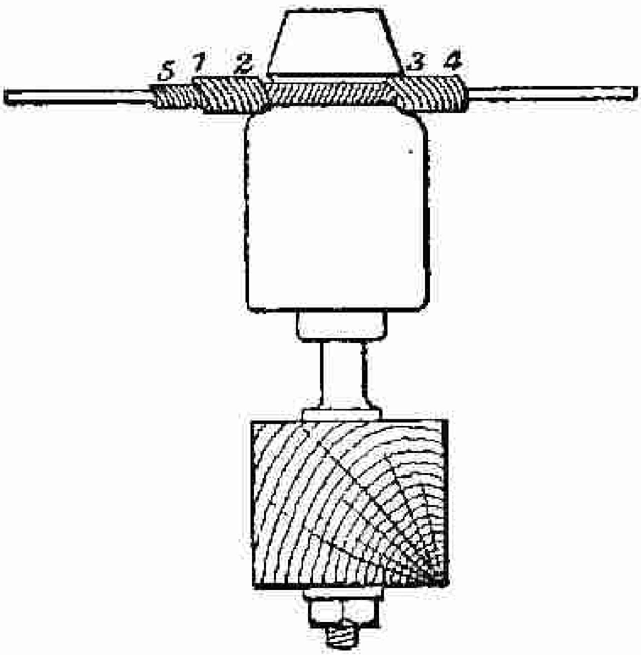
Fig. 149.



Finishing off a Span.

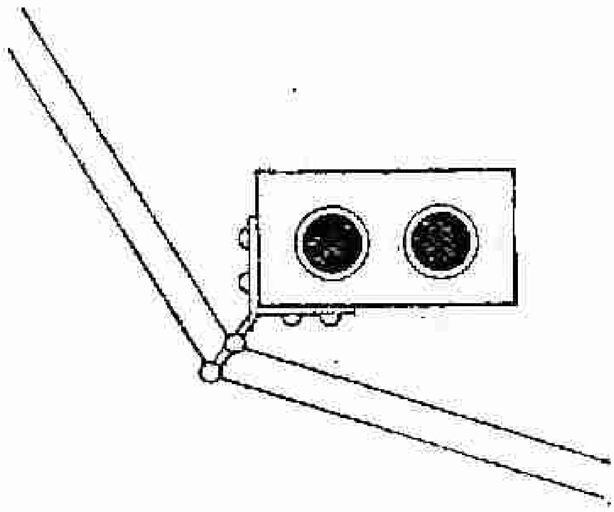
the joint is soldered the span is not weakened, as would be the case were the heat applied to any part of the wire under strain This is very important, and care should be taken to see that it is not done either in attaching the leading-in wire or bridging across the double shackles. The line wire is bound to the insulators, as shown in Fig. 150. The wire is first wrapped with the binding wire (No. 18 B.W.G.) in order to prevent the line wire *a* being injured by chafing against the insulator. The binding wire is then bound round the line wire from 1 to 2 across the insulator to 3, from 3 to 4 and back again to 3, across the insulator to 2, from 2 to 1, and then finished off in a single layer from 1 to 5.

Fig. 150.



Binding Wire to Insulator.

Fig. 151.



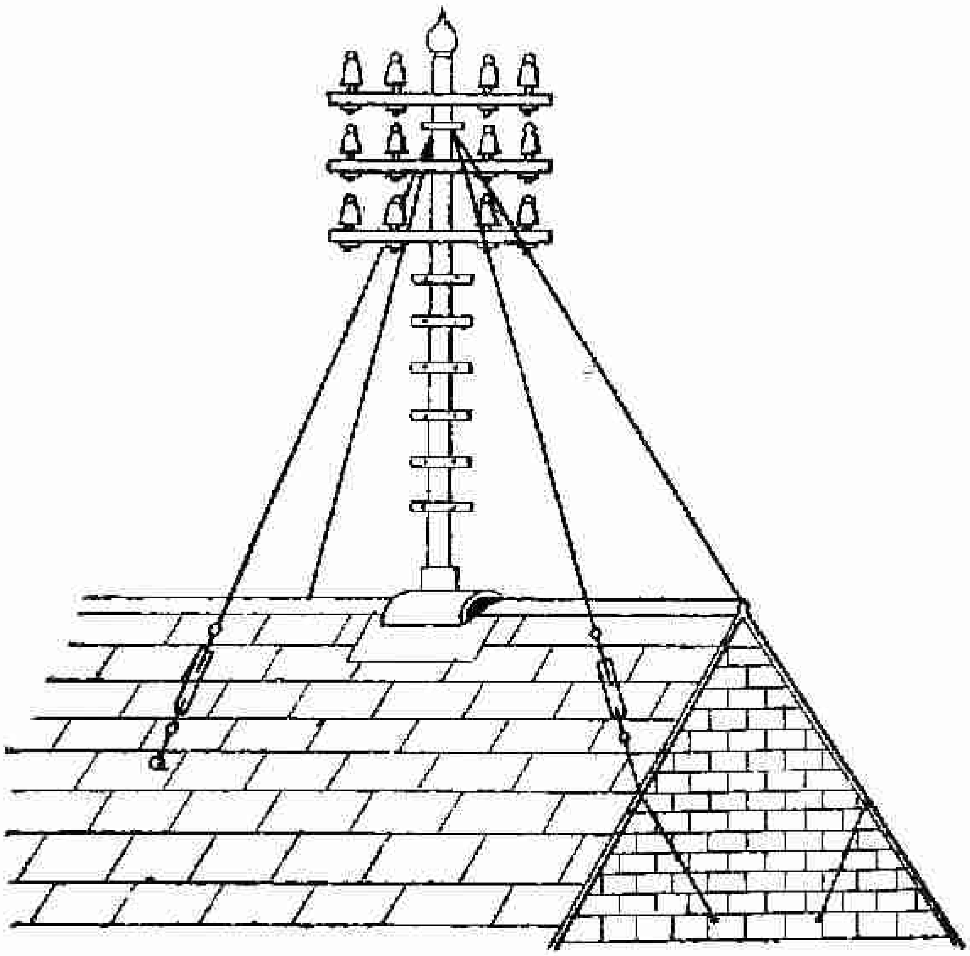
Chimney Bracket.

In Fig. 151 is shown the application of the chimney bracket, the form shown being the double insulator one for two wires. The bracket is fastened to the chimney by stout nails, and must be so arranged that the pull of the wires is towards the chimney.

Although it is best where there are only a few wires to avoid the use of poles or standards owing to the increased cost and additional dangers attached to such standards, nevertheless there are cases in which it becomes imperative to use them. The form now in most common use is shown in

Fig. 152, the number of arms and insulators varying according to the number of wires. The poles, which vary from 15 to 20 feet in length, and from 3 to 4 inches in diameter, according

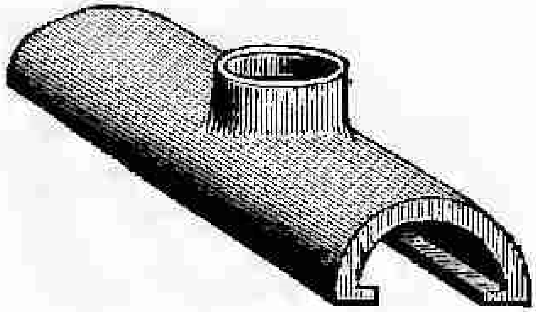
Fig. 152.



Pole on Roof.

to the height and strength required, are hollow wrought-iron tubes, and the bottom end is forced into the socket of a cast iron chair (see Fig. 153), which chairs fit on to the ridge of the roof and form the base for the pole. The arms carrying the insulators are also of wrought iron, and bolted to the pole at the desired positions. In erecting the poles several wrappings of sheet lead are first put over the ridge at the place where the chair is to rest; on roofs where there are ridge tiles one must be removed to form room for the chair, care being taken to see the roof is afterwards made perfectly watertight. The pole is then erected on the chair and must afterwards be securely stayed. These stays consist of stranded galvanised iron wire, fastened at a point about a foot below the top of the pole, the other ends being securely fastened to

Fig. 153.



Pole Chair.

stout spikes driven into the brickwork, as shown, or else to stay-eye bolts, which are bolted right through the roof beams. An adjustable swivel (Fig. 154) is inserted in each stay so they

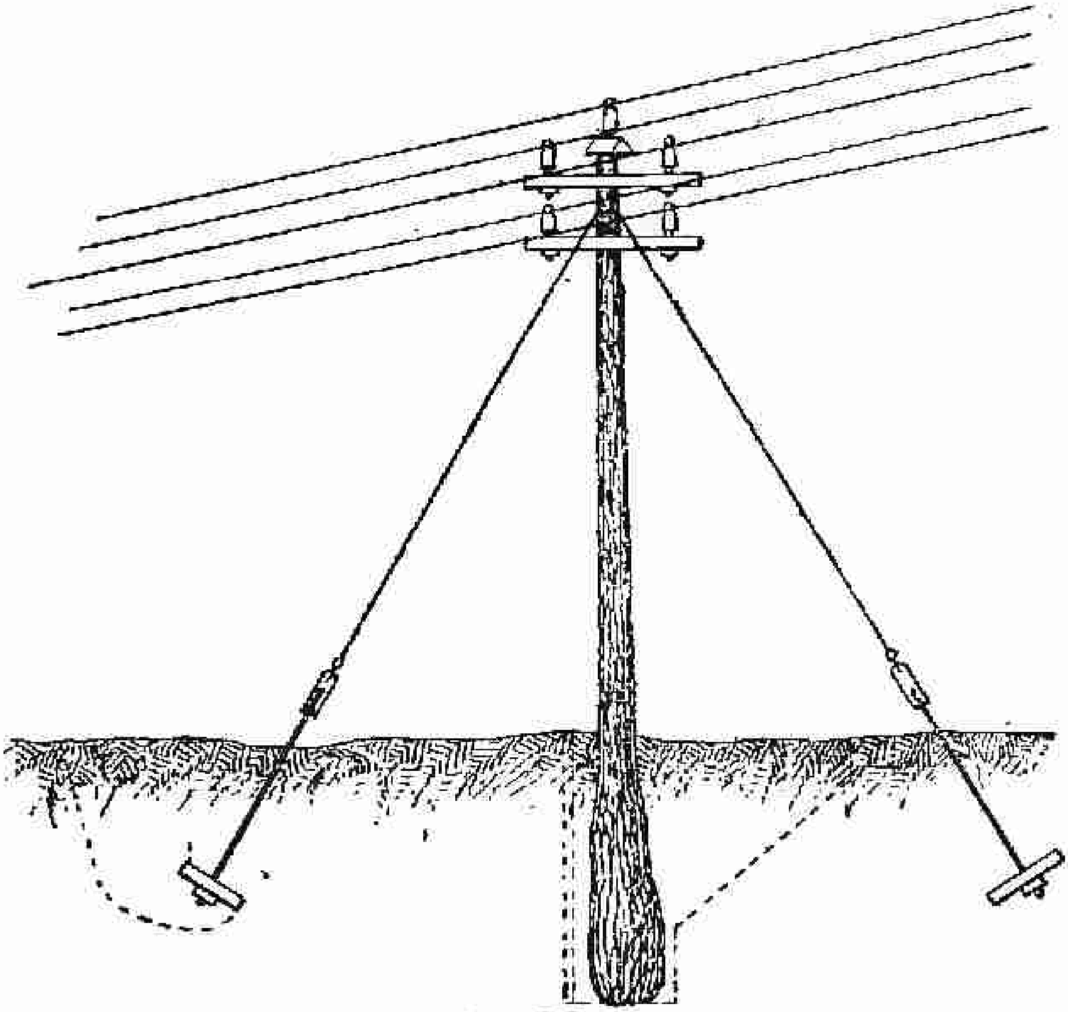
Fig. 154.

Adjustable Swivel.

can be tightened independently of one another and the pole pulled into an upright position. The short iron cross-pieces on the poles are footholds for the linesmen when fastening up the wires.

For running wires in the country, wooden poles are almost exclusively used, as being cheaper than iron, in addition to other advantages. The best poles are procured from Norway and Sweden, and before being erected must be treated in some manner to prevent decay, which would rapidly take place, especially at the ground line. Numerous methods have been tried of treating the poles, but none are so effectual as creosoting, which consists in forcing creosote into the timber (which must first be thoroughly dried) till the quantity absorbed by the pole is about 8 lbs. per cubic foot. Wood poles vary in height from 30 to 60 feet, and are light or stout, according to the number of wires they have to carry. For four to six wires a pole 35 feet in length will be found ample. The arms for the insulators, which are also of wood, are bolted to the poles, and the insulators themselves fixed by bolting through the arms.

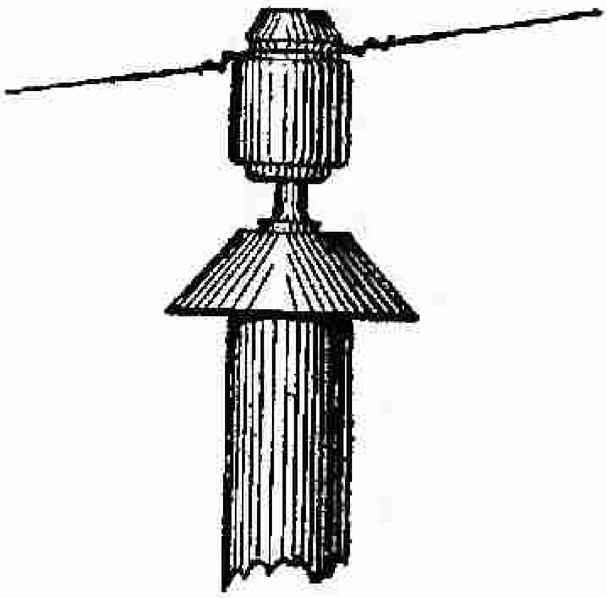
Fig. 155.



Wood Pole.

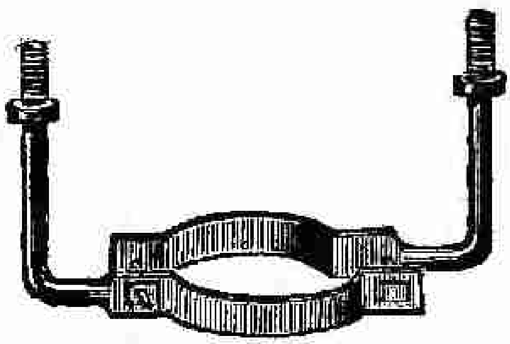
In erecting the poles they must first have the arms and insulators attached, and also be prepared for the attachment of the stay wires. A hole is then dug about 5 feet long by 2 feet wide, upright at one end and sloped off towards the other, as shown by the dotted lines in Fig. 155, which represents the pole erected. The depth of the hole will vary according to the length of the pole, poles being usually buried one-fifth or one-sixth of their length. Thus a pole 35 feet high will require to be let into the ground about 6 feet. The hole being ready a piece of plank is placed against the upright end of the hole, and the butt of the pole placed in the hole so that it rests against the plank, which prevents its penetrating the soil. Ropes are now tied to the top of the pole and the pole erected into a perpendicular position by means of ladders which are slipped underneath, and brought nearer and nearer to the base as the pole becomes more and more upright, the pole being steadied by means of the ropes. The hole must then be filled in and the earth rammed tightly down. The

Fig. 156.



Insulator on Pole.

Fig. 157.



Pole Clip.

next operation is to fit the stay wires, for which purpose a hole of the shape shown in the figure is cut and a plate or balk of timber, to which the end of the stay rod is attached, buried in it. The object of under-cutting the hole for the stay plate is to enable the plate to pull against firm solid ground. The stay wires must afterwards be attached to these stay rods and the pole pulled into a perpendicular position. Where there is only one line wire a light pole, with the insulator fixed at the top, as shown in Fig. 156, can be employed.

Fig. 157 is a pole clip to enable extra wires to be added to a pole. The insulators are attached to the upright bolts and body of the clip clamped round the pole.

The number of poles required per mile varies according to the number of wires and the course of the wire. On an average about twenty poles per mile will be found sufficient, more if there are a large number of wires or there are many curves.

Humming of Wires.

A great trouble that often arises with suspended wires is the humming produced in the wire near its supports. This is caused by the wind passing across the wire and setting it in vibration, the support acting as a sounding board. On wooden poles in the country, when the wind is strong, the sound is very loud, but it is in town chiefly where the greatest inconvenience arises. The noise is very disagreeable to the inhabitants of the house to which the wire happens to be attached, preventing many persons from sleeping at all on windy nights. Unfortunately, it is the bedrooms that are generally nearest to the wire, and this, coupled with the silence prevailing during the night, increases what is perhaps hardly heard in the day ten or twenty-fold at night. The trouble, however, can be considerably reduced by using a little judgment in selecting a fixing and by using special supports. Make your spans as short as possible, the noise is always worst on houses at the end of long spans, especially if the spans are in exposed positions. If the chimney, &c., is an intermediate support, terminate each span on the opposite side of the chimney, using separate bands (kept as far away from one another as possible) round the chimney for each support, and connect across with guttapercha covered wire. If this is not sufficient, bind round the insulator or shackle a piece of indiarubber about half-an-inch thick, fastening the wire outside the rubber. The noise can often be stopped by clamping two strips of wood about 18 inches long, 2 inches wide, and 1 inch thick on the wire close by the insulator, the proper distance of this "damper" from the support being ascertained by sliding it along the wire. Sheet lead wrapped round the wire a short distance from the insulator will also frequently stop all humming.

INDUCTION AND LEAKAGE.

Trouble will often arise in telephone lines that run side by side for any great distance from "induction" and "leakage from wire to wire." The latter can generally be remedied by a little attention to the insulation of the line, and the former by specially arranging the wires. The noises arising from induction are caused by the currents in a neighbouring wire inducing similar currents in the other wires. As we know from an ordinary induction coil, when we send a current in one direction in the primary, we get a current in the opposite direction in the secondary. In an induction coil, of course, the two circuits are coiled closely together, but the same result takes place in a less powerful manner when the circuits run straight side by side. Were the current in the primary of an induction coil perfectly continuous, there would be no result in the secondary; hence the necessity for a make-and-break or else an alternating current. Likewise, if the telephone currents were continuous, there would be no trouble from induction; but since the telephone depends for its action on undulating and varying currents, the currents given out by the microphone or the magnetic receiver are necessarily of a rapidly alternating and undulating character. It may seem incredible that a wire perfectly insulated can have any very inconveniencing effect on other wires, also well insulated, and some 3 feet or 4 feet away, but the currents required for working a telephone are of the most feeble strength. In a telephone exchange the inconveniences arising from induction are often very great; messages sent along one wire being heard distinctly in a neighbouring wire, and thus a message intended for a certain person might also reach the ears of persons from whom it was most desirable it should be kept.

Although the induction from wire to wire is bad, yet that arising from neighbouring electric-light wires is very much worse, the electric-light currents being so powerful that they make their effects felt from a great distance. Nearly everything depends on the arrangement of the electric-light circuits as to their effect on the neighbouring telephone wires. For instance, if the electric-light circuit consists of arc lamps in series, with the lead leaving the central station in one direction, and after making a whole circuit of the town returning in another, then the telephones in that town will have a merry time of it at night. Happily, however, though this method of working electric lamps was much in vogue three or four years ago, it is now rapidly giving way to the transformer systems, and as the transformers are in parallel, the return lead must necessarily be run in close proximity to the feed, thus the effect of the one wire is neutralised by that of the other.

When telephone wires run in close proximity to telegraph wires, we have noises in the telephones caused by the induction from the telegraph wires, the quick make-and-break of the circuit by the telegraph instruments being distinctly audible. With the telegraph wires an earth return is used; thus when towns are connected together for the purposes of telephonic communication, and the route along the railroad is taken, if an earth return were used for the telephones also, it would be well nigh impossible to detect what was being said, owing to the noise arising from induction. A return wire is therefore used for the telephones; though even this does not do away entirely with the induction, as one of the telephone wires is perhaps nearer to the telegraph wires than the other, and thus the neutralising effect of the two wires is lost. The telephone wires are therefore arranged so that they change position from pole to pole, first one wire and then the other being nearest the telegraph wires, as shown in Fig. 158. In the case of two telephone circuits, the wires are arranged as in Fig. 159, the one circuit being represented by the continuous, and the other by the dotted, lines. In Fig. 158 *a* is the telegraph wire, and *b* and *c* are the two wires of the telephone line, while in Fig. 159 *a a* are the two wires of the one telephone line, and *b b* those of the other.

Fig. 158.

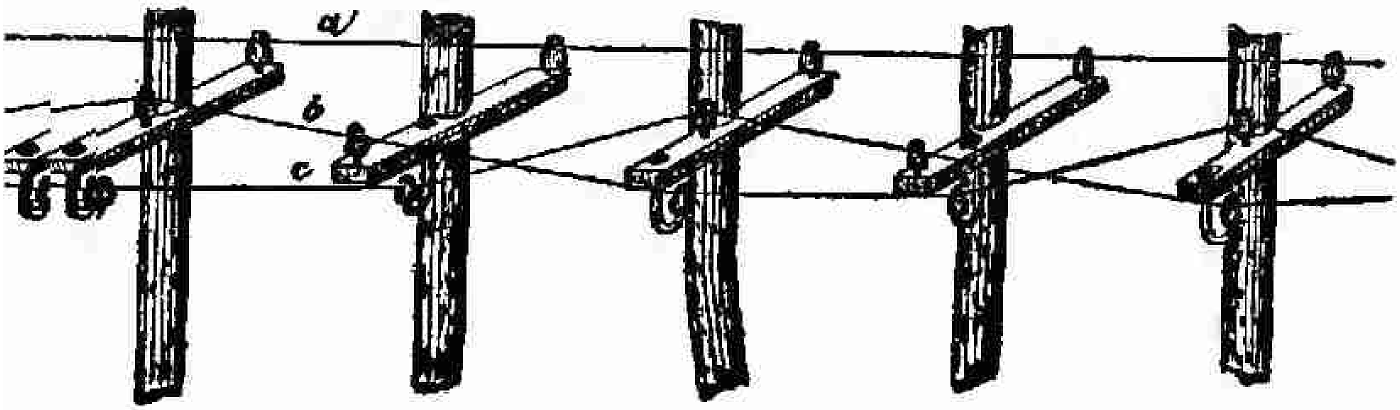
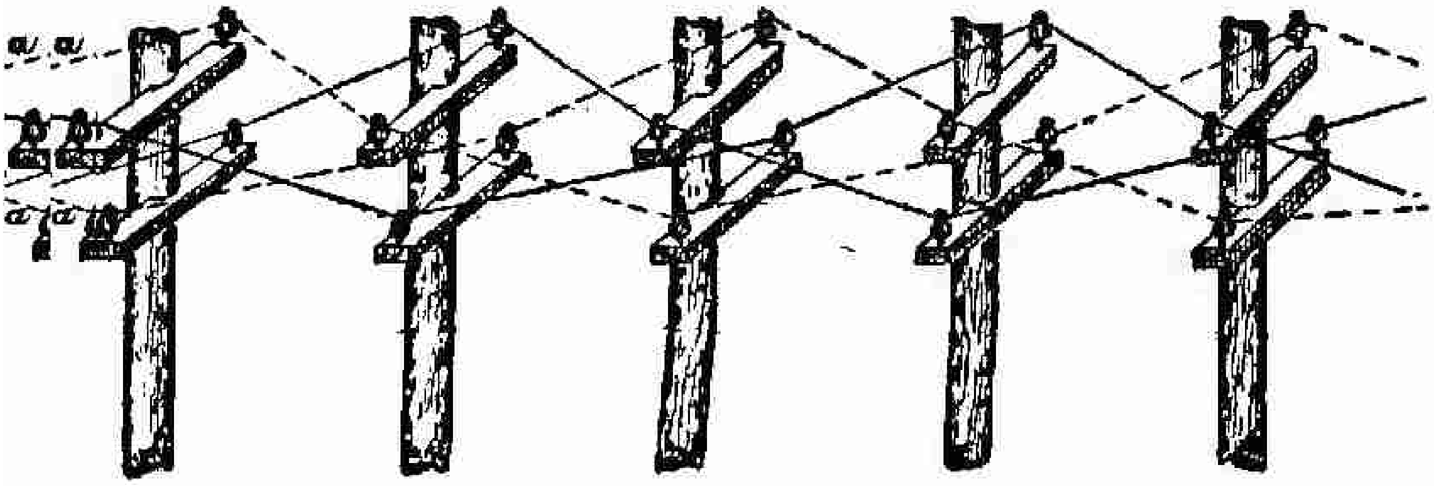


Fig. 159.



Arranging Wires to prevent Induction.

Where telephone wires run for great distances together on the same poles or supports, another trouble that arises is that of leakage from one wire to another, causing noises in the telephone and "cross talk." This is caused by the current from one wire passing, by means of the pathway formed at every insulator by the dust and moisture that collect on the surface, to the neighbouring wires, all of which have a common return, viz. the earth. The greater the number of insulators on the lines, the more numerous the pathways from one wire to another, and the less the insulation resistance between the wires. Where trouble does arise from leakage and cross talk, it will generally be found that the insulation at some parts of the line has become defective. A film of dirt will often coat rapidly over the insulators, especially in smoky towns, and this when wet forms a path of leakage. It is best to expose the insulators of a line as much as possible, as then the heavy rains will from time to time wash them, and they will dry comparatively clean; but if sheltered in any way, the dirt quickly accumulates. In the case of telegraph circuits, where the currents are more powerful, the chief inconvenience caused by the leakage is that it reduces the strength of the current at the sending station; but in telephony, where the currents are so feeble, the trouble is rather to prevent these stray messages passing from one line to another than to provide against the reduction of the current strength.

Underground Wires.

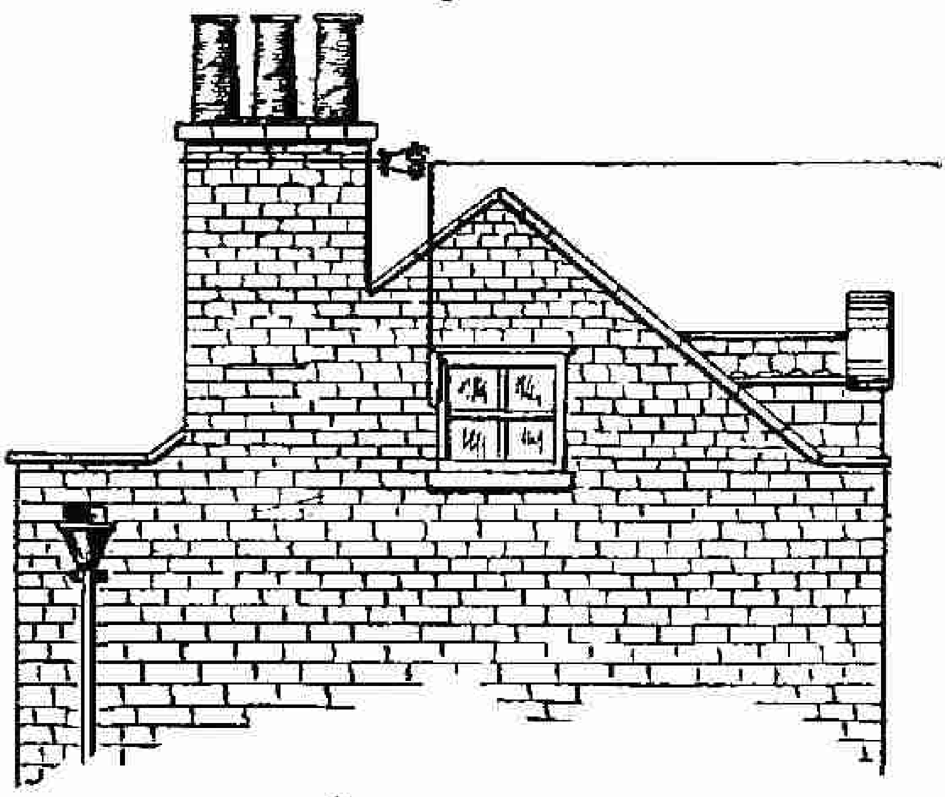
Where the wires are run underground, No. 16 B.W.G., gutta-percha covered, and taped or braided, must be used. Braided wire is more expensive than taped, but is to be preferred, owing to its not unravelling so easily, and also because it will draw better into pipes. The wire should have been well served with Stockholm tar, which preserves it from decay, though it somewhat lowers its insulation. Bitumen-covered wires, either taped or braided, are also much used for underground purposes. It is considerably more expensive to place telephone wires underground than overhead; but the unsightliness and danger of overhead wires is done away with, and the expense of repairing them when broken by snow-storms, &c. Underground wires should be laid in iron pipes, the pipes being laid about 12 in. below the surface of the ground. When the pipes are being laid, a naked wire is drawn through, by means of which the covered wires are afterwards drawn in. A method which allows of the wires being accessible at all parts is to lay the wires in small creosoted wood troughing, fitted with a loose lid, the troughing being buried, like the iron pipes, 12 in. beneath the surface. Thus, if at any time the insulation of the wire should break down at any point, the earth can be removed from above the casing, and the wire inspected at the point where it is believed the fault lies. With iron pipes, nothing can be done save pulling out the faulty wire and drawing in a good one by means of it. The method adopted by the Post Office with their underground wires in towns is that of iron pipes, with junction-boxes at certain distances. These pipes are laid underneath the pavements and roads, and into them is drawn a cable containing a number of wires. If a fault occurs in one or two of the wires, the whole cable between the two junction-boxes is drawn out and a new cable drawn in by means of it, the old cable being sent to the works for repairs, and when repaired is used at some future time.

If there are many wires in the same pipe or troughing, it will be found best to use a separate return-wire for each instrument, owing to the trouble arising from induction if an earth is used. The method adopted by the writer with underground wires is to lay them in wood troughing, and twist each pair of wires together throughout the entire distance. This method not only prevents trouble arising from induction, but also allows (if each pair is neatly laid side by side and one marked at intervals) each circuit being readily identified should it be necessary to test or repair the wires at any place.

THE LEADING-IN WIRES.

For the leading-in wires No. 18 B.W.G. copper wire, gutta-percha covered, to No. 9 B.W.G., wound with tape and well covered with Stockholm tar, should be used. In places not much exposed to the weather No. 20 to 12 may be employed; but in most cases No. 18 will be found the most durable, which should also be double taped if likely to be subjected to any mechanical strain. The leading-in wire is joined to the line wire close to the last shackle or insulator, the joint being carefully soldered. The wire is best brought into the building through the window frame, a hole being bored in the frame

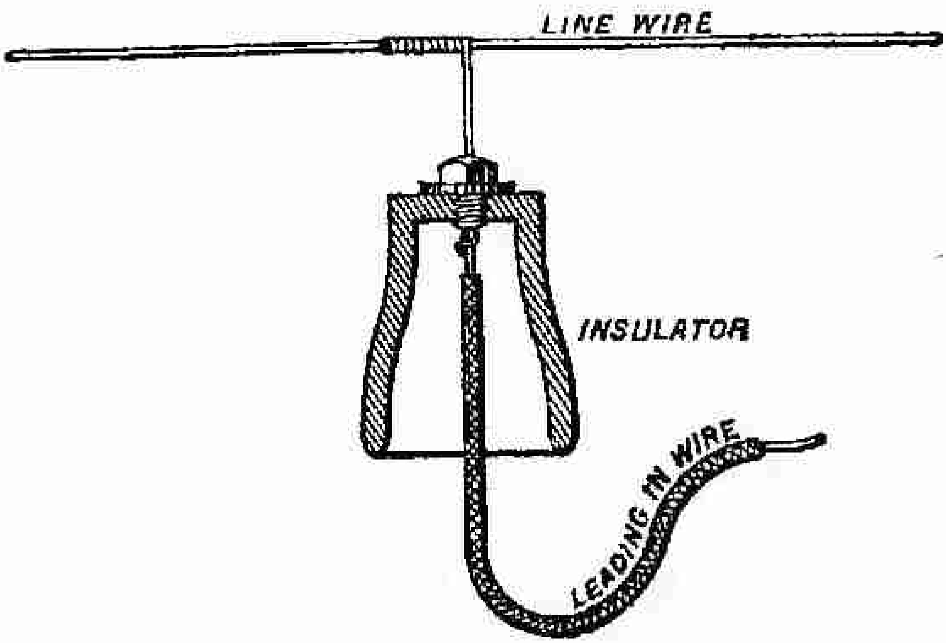
Fig. 160.



Method of Leading-in the Wire.

for this purpose, though if there is no window near, other means must be resorted to. The leading-in wire, before it enters the wall or window frame, should make a short dip below and then rise to the hole where it enters, as shown in Fig. 160, so that rain may run down and drip off at the bend instead of running into the building. As there is in wet weather considerable leakage from the line-wire to earth by reason of the outside covering of the leading-in wire being wet and forming a conducting film, a porcelain cup (see Fig. 161)

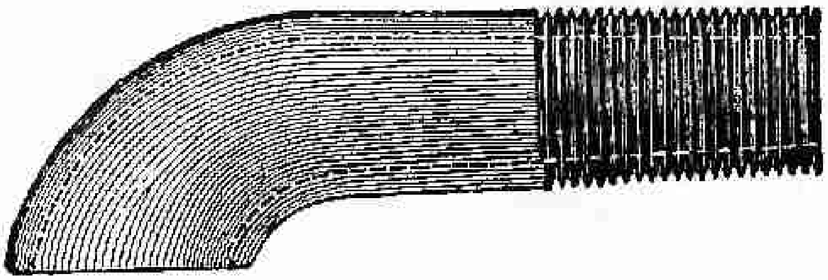
Fig. 161.



Leading-in Insulator.

is often fixed just above the joint between the line-wire and leading-in wire. This, by keeping the upper part of the leading wire dry for a space of 3 or 4 in., makes a break in

Fig. 162.



Leading-in Tube.

the conducting film, and preserves the insulation of the line. Porcelain "leading-in tubes," a form of which is shown in Fig. 162, are very convenient, and tend to increase the insulation of, besides protecting, the wires. The tube is fitted at one end with a thread, which either screws into the hole in the woodwork, or is cemented into the wall. It is perhaps hardly necessary to mention that the mouth of the tube must be turned down and not upwards, so as to prevent any water entering. In bringing the wire down the side of a building, it should, if possible, be tied to the rain-water or other pipe; but if neither of these is procurable, the wire must be fixed by big staples, or tied to pipe hooks driven into the wall. Great care is necessary in driving these staples to see that the staple is not driven quite home, which would injure the insulation of the wire. Where the wire passes over the edge of the roof or the corner of a chimney stack, a short piece of the wire should be wound round where it touches the brickwork, to prevent the insulation being frayed off by the wind blowing the wire about.

Inside or Joining-up Wires.

If the telephone instrument is near the place where the "leading-in" wire enters the building, it is best to continue the guttapercha wire right to the instrument; but if the distance is far, the leading-in wire should be stopped just inside the building, and the continuation made to the instrument with less expensive and more suitable wire. For inside wiring plain guttapercha-covered wires are unsuitable, as in dry situations the insulation cracks off in time. The best wire for inside wiring and joining up the battery is No. 20 B.W.G., served with a layer of rubber, then double cotton-covered and paraffined. This wire can be obtained in almost any colour to suit the decoration; but a drab or neutral tint is the least noticeable. These wires should be run along the skirting-board and up the side of the wall, the wires being fastened by staples. Never, however, place two wires under one staple, or let two staples touch one another, as if this is done a short circuit is almost certain to be caused sooner or later. The different wires should be so arranged as always to retain the same position relative to one another, as this greatly facilitates tracing a fault. If the wires are likely to be interfered with they should be either stapled so as to be out of reach or else placed in wooden casing, such as is used for electric light wires. In passing from room to room the best plan is to bore a hole in one corner of the woodwork above the door ; if there are a number of wires the holes being bored so that the wires retain their relative position to one another. If there are electric-light wires in the same building, these must be kept as far away from as possible. If the telephone wires are obliged to be put near the electric-light wires, under no circumstances should they run parallel to them, owing to the disturbances arising from induction. It is best also to avoid passing too near gas-pipes, especially if they are only "compo," as in the case of lightning striking the outside wire, it is liable to "jump" from the inside wire to any neighbouring conductor in connection with the earth, and if this took place the discharge would probably fuse the pipe and set fire to the gas. If a joint has to be made it must be carefully soldered (rosin being used as a flux), after which the joint must be insulated with sheet guttapercha, or rubber strip, and wound with tape. A little judgment is necessary in seeing that the joints do not come in inconvenient or bad positions, and also that the most suitable course for the wire is taken.

Earth Wires and Earth Connections.

The importance of a "good earth" is frequently underrated by many persons in erecting a telephone line, though they are ever so careful when a return wire is used in seeing that a good connection right through is obtained. Since, when an earth return is used, the ground takes the place of the return wire, it is obviously very important that a good connection to the ground is obtained at both ends of the line.

A main water-pipe makes the best earth connection; but if this is not obtainable, the earth wire may be attached to the gas-pipe. Care must be taken, however, to see that the water-pipe is really a main, and not a cistern pipe, as, if this latter is the case, there will be a "bad earth," caused by the break in continuity at the ball-cock in the cistern. With the gas-pipe also connection must be made on the street side of the meter, owing to the red lead used in the joints being a bad conductor. If connection is made on the house side, the meter must be bridged over with a piece of wire; but even this is liable to be interfered with by the gas inspector. The earth wire should never be connected to a composition gas-pipe, owing to its liability to being fused should the line be struck by lightning. Should neither a water nor gas-pipe be obtainable, a pump pipe leading to a well makes a good "earth"; but if this is not to be had, an artificial earth must be resorted to. A good artificial earth is made as follows:—Suspend 5 ft. or 6 ft. of sheet lead 6 in. wide in the centre of a hole about 4 ft. deep; then ram in with ordinary gas-coke till within 6 in. of the surface, when fill in with soil. The earth wire must then be soldered to the projecting end of the lead. Care should be taken to obtain as moist a situation for the hole as possible. Never connect the earth wire on a gas-pipe at one end and a water-pipe at the other, as permanent currents are thereby often set up which may in certain cases give rise to noises in the telephone. In country places, where an artificial earth has often to be resorted to, care should be taken to see that the same material is used for the earth plate at each end of the same line. For instance, sheet lead should not be used at one end and an iron plate at the other, or permanent earth currents will be the result.

For the earth wire, No. 18 B.W.G. copper wire, guttapercha-covered, taped, and tarred, such as is advised for the leading-in wires, should be used; but if this is objected to on the score of economy, No. 18 naked copper or 3-18 galvanised iron can be employed. If a naked wire is used, No. 18 copper is to be preferred, but it is never advisable to use the cotton-covered and paraffined, such as advised for inside wires, as, in all probability, in getting to the water-main the wire has to pass through places where it will be liable to injury from dampness and other causes. If obliged to use paraffin wire, a short length of stout wire should be soldered to the water-pipe, and the other wire should be soldered to the projecting end. Care must be taken to see that a really good soldered connection is made to the pipe, otherwise the joint soon oxidises, and a bad "earth" is caused. If it can be managed, it is best to let the water out of the pipe while the joint is being soldered. In making the connection, the pipe must be scraped clean with a knife for the length of about 3 in., and the cleaned copper wire twisted tightly round it, the joint being soldered with resin as a flux, though in the case of gas-pipes it will be necessary to use "spirits." It is generally sufficient if the stout earth wire starts from the zinc of the battery, the connection from the zinc to the instrument being made with the small wire as used for inside wiring.

Fixing the Instruments.

The telephone line having been got through between the two places and the "earth" wire run, the next thing is to fix the instruments, which should previously have been tested with a cell or two to see that they are in good condition. Having set up the battery so that the sal-ammoniac can be dissolving while the instruments are being fixed, the first thing is to ascertain the best position in which to fix the telephone. In deciding on the position, care should be taken to see that the instrument is not placed on a partition or wall where there is much vibration, such as is likely to be caused by machinery or the opening and shutting of doors, as this would cause noises in the telephone owing to the microphone being set in vibration. Noisy positions, such as near a window or door opening into the street, should also be avoided. The position being determined, we next ascertain the nature of the wall, so that the fixing can be obtained accordingly.

There are three different kinds of fixings generally met with in buildings—1, woodwork; 2, laths and plaster; and 3, brick, faced with plaster. The construction of the wall can usually be found out by tapping on it with a hammer or the end of a screwdriver. If the wall is woodwork, it will generally give out a loud sound; if laths and plaster, a hollow sound; and if brick or stone a dull sound. In a lath and plaster partition the upright posts to which the laths are nailed can be found by probing with a bradawl or similar instrument. If the wall is wood, the fixing will be comparatively easy, as the instrument can be screwed to it with ordinary wood-screws; but if laths and plaster, lath screws must be used, the proper length of which can be ascertained by probing for the laths with a bradawl. Should one of the screws pass between two laths, the position of the instrument should be altered until a lath is obtained for each screw. For a brick wall, the position for the screws must first be marked by holding the instrument against the wall and passing a bradawl through the screw-holes in the instrument, and, the position being marked, the wall must be plugged at these points. To plug the wall an inch cold chisel will be required, with which a hole must be cut in the wall about 3 in. deep and $1\frac{1}{4}$ in. wide. The hole is cut square, the back part being slightly smaller in diameter than the opening. Wooden plugs must now be made, being cut square like the hole, but slightly thicker and shorter, and with a slight taper. It is better also to so cut the plugs as to give them a slight twist, as this form takes the best hold of a square hole. The plugs are afterwards driven into the plug holes flush with the surface of the wall, and the instrument fixed by means of wood-screws.

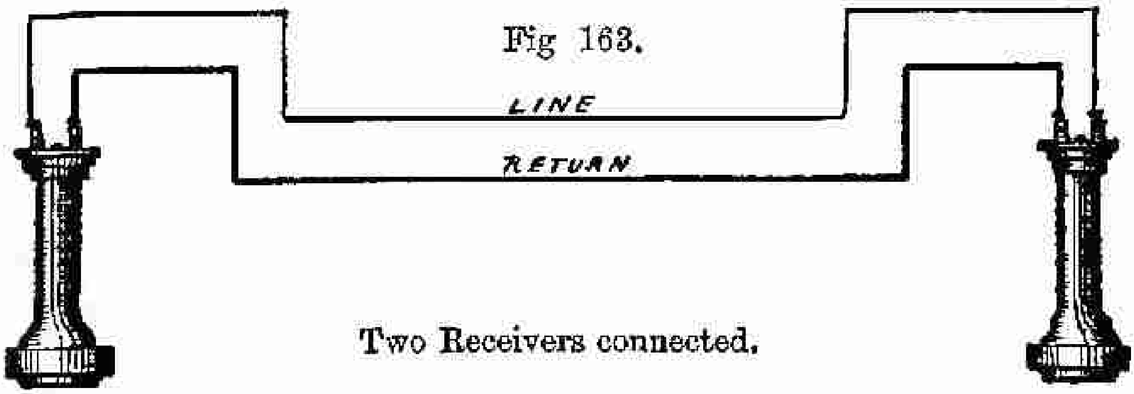
In fixing the ends of the wires under the terminals of the instrument, the ends of the wire should be so placed under the terminal that when the terminal is screwed up it tends to twist the wire round the body of the screw, and not to unwind it, as this would cause the wire to work out from underneath the screwhead. In terminals where the wire passes into a hole, and the screw bears directly on it, the end of the wire should be neatly doubled back on itself before being passed into the hole. In finishing off the ends of the wire where they join the instrument, a short length of the wire should be spiralled round a pencil, as this gives the instrument a more finished appearance.

CHAPTER IX.

CONNECTING-UP.

In the diagrams of connections that will now be given, it has been the aim of the writer to include all the most important cases that are likely to be presented to the fitter; but it must be borne in mind that special requirements are more the rule than the exception in telephony, and that to get at these special requirements one diagram requires to be read in conjunction with another. In the connections of the instruments also, the different parts of the telephones are arranged with a view to increase the clearness of the diagrams; thus the relative position of one part to another must not be taken as a guide to the arrangement of parts that would be found in actual practice. The ringing key is in most instances shown as a separate Morse-key push, and the switch-hooks considerably simplified, nevertheless all the component parts are there and the con-

Fig 163.



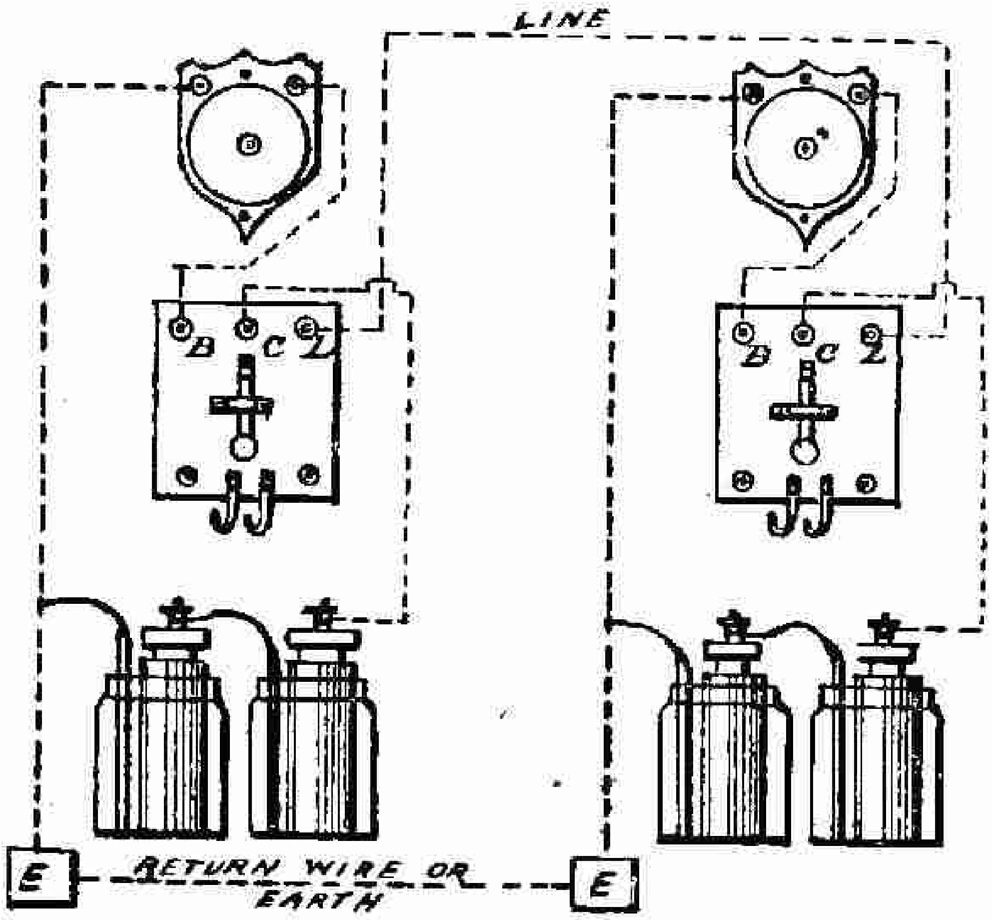
Two Receivers connected.

nections can be easily traced. The main principle governing the connections of one instrument will be found to underlie the connections of all other instruments of the same class, the difference being generally merely in the mechanical arrangement to effect certain operations.

Simple Telephone Circuit.—Fig. 163 shows a simple circuit consisting of two magnetic receivers connected together, but without any arrangement for signalling between them. For E.M. or membrane receivers a battery of two or three cells requires to be interposed in the circuit. The earth, or return wire, is shown darker than the line-wire.

Two Instruments with Battery Switch-bells and Magnetic Receivers.—Fig. 164 shows the connections for the form of

Fig. 164.



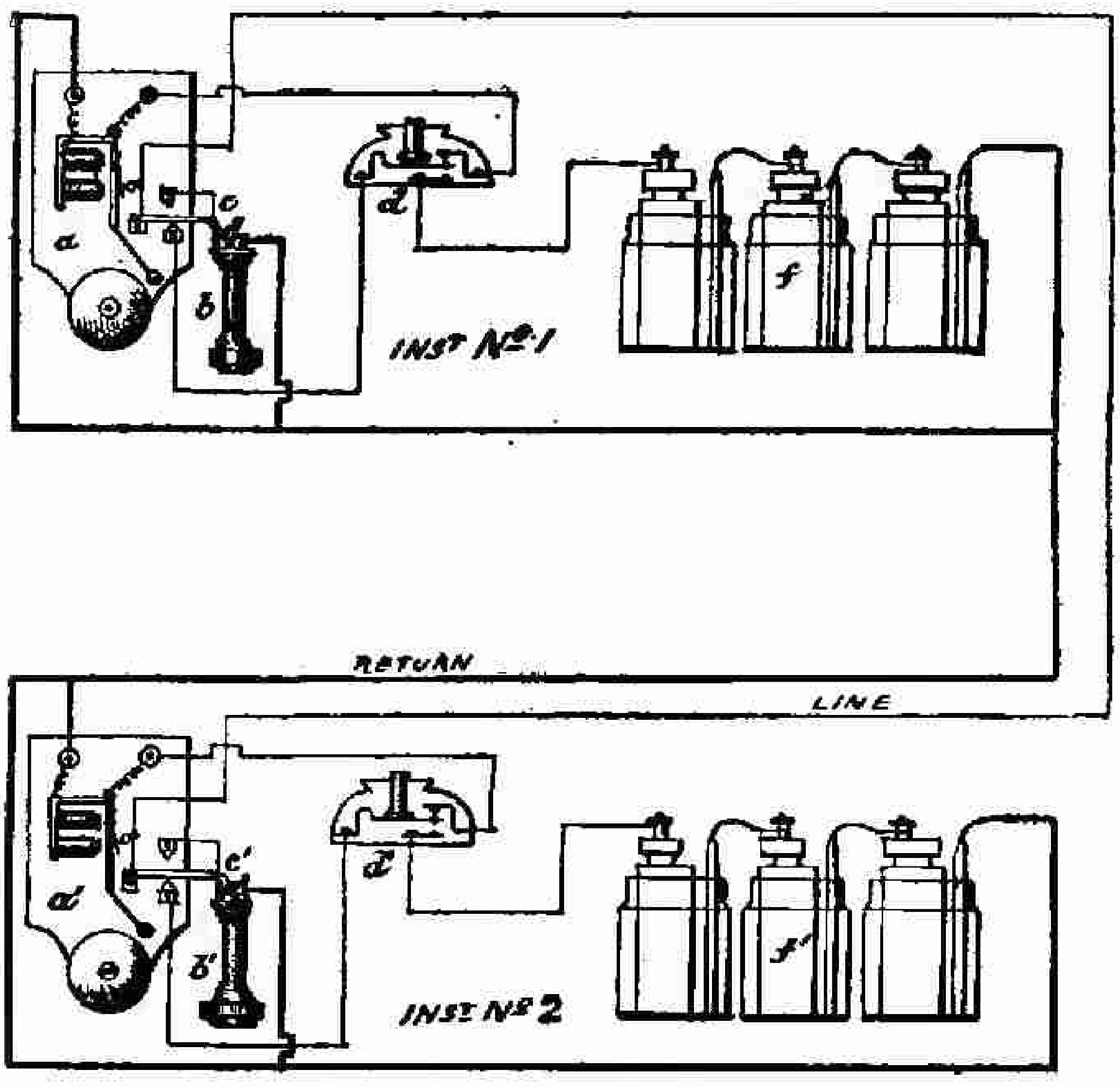
Connections for Instruments shown in Figs. 59 and 60.

instruments illustrated in Figs. 59 and 60, page 75. The automatic switch is formed by the two hooks, which are short circuited by the ring of the receiver when hung on the hooks.

Fig. 165 shows the connections for the same class of instrument, except that it has a movable switch-hook of the ordinary kind.

In the figure, *a* is the switch-bell, *b* the receiver, *c* the automatic switch, *d* the ringing key (shown for the sake of

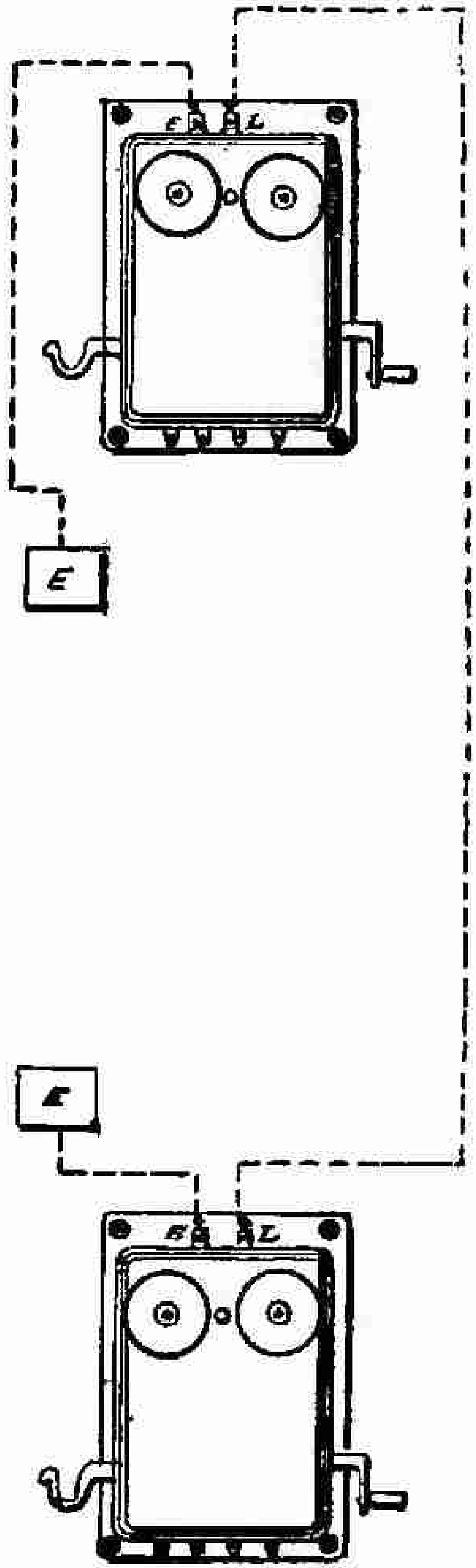
Fig. 165.



Internal Connections of Instruments with Magnetic Transmitters.

clearness as a separate key-push), and *f* the batteries for instrument No. 1; *a'*, *b'*, *c'*, *d'*, and *f'* being the corresponding parts of instrument No. 2. When the receiver *b* is on the spring-hook of the automatic switch *c*, the hook is in contact with the bottom contact; but when the weight of the receiver is taken off, the hook moves up, and is in connection with the top contact. When the push *d* of instrument No. 1 is pressed, the current flows from the carbon pole of the battery *f* to the bottom contact of the push, thence to the push-spring and bottom contact of the automatic switch *c*, from there to the spring-hook, line-wire, spring-hook of the automatic switch belonging to instrument No. 2, bottom contact of switch, spring of push *d'*, top contact of push, right-hand terminal of bell *a'*, through the bell to return wire, and from thence to zinc pole of battery *f*. This causes the bell of instrument No. 2 to ring, calling the attention of the person at that end, who presses the button of his push, causing the bell at instrument No. 1 to ring in reply. The receivers are now taken off the switch-hooks, and conversation is carried on. The "speaking" circuit is, starting, let us say, from receiver *b*—receiver *b*, top contact of automatic switch *c*, spring-hook of switch (the circuit being now closed owing to the receiver being removed), line-wire, spring-hook of automatic switch of instrument No. 2, top contact of switch, receiver *b'* return wire, and from thence back to receiver *b*. Thus there is, when the receivers are off the hooks, a complete circuit

Fig. 166.

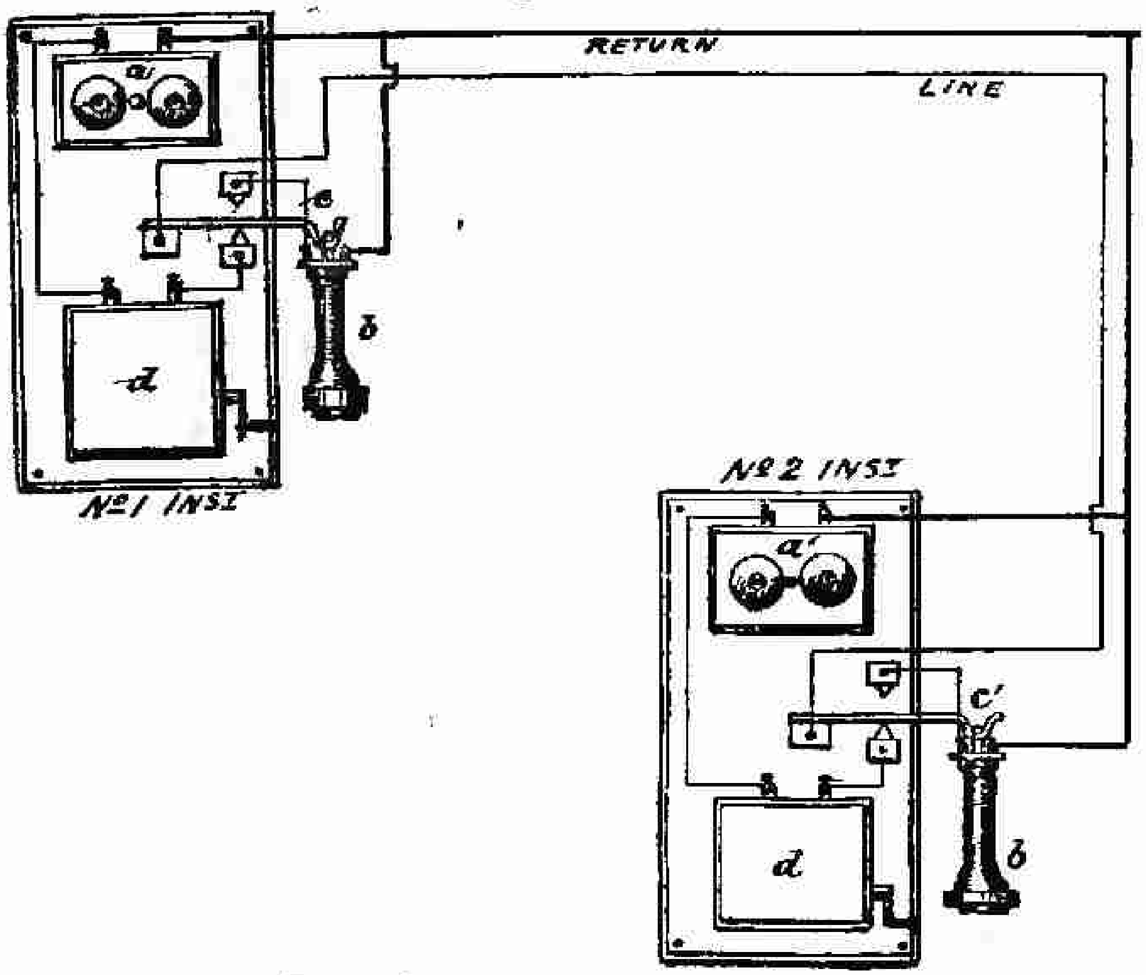


Two Magneto Switch-bell Instruments connected.

without the batteries, the batteries not being required owing to the receivers having permanent magnets.

Two Instruments with Magneto Switch-bells and Magnetic Receivers.—Figs. 166 and 167 show the connections for the form of telephone instruments shown in Figs. 61 and 62, p. 76. Fig. 166 shows the external connections of the instru-

Fig. 167.



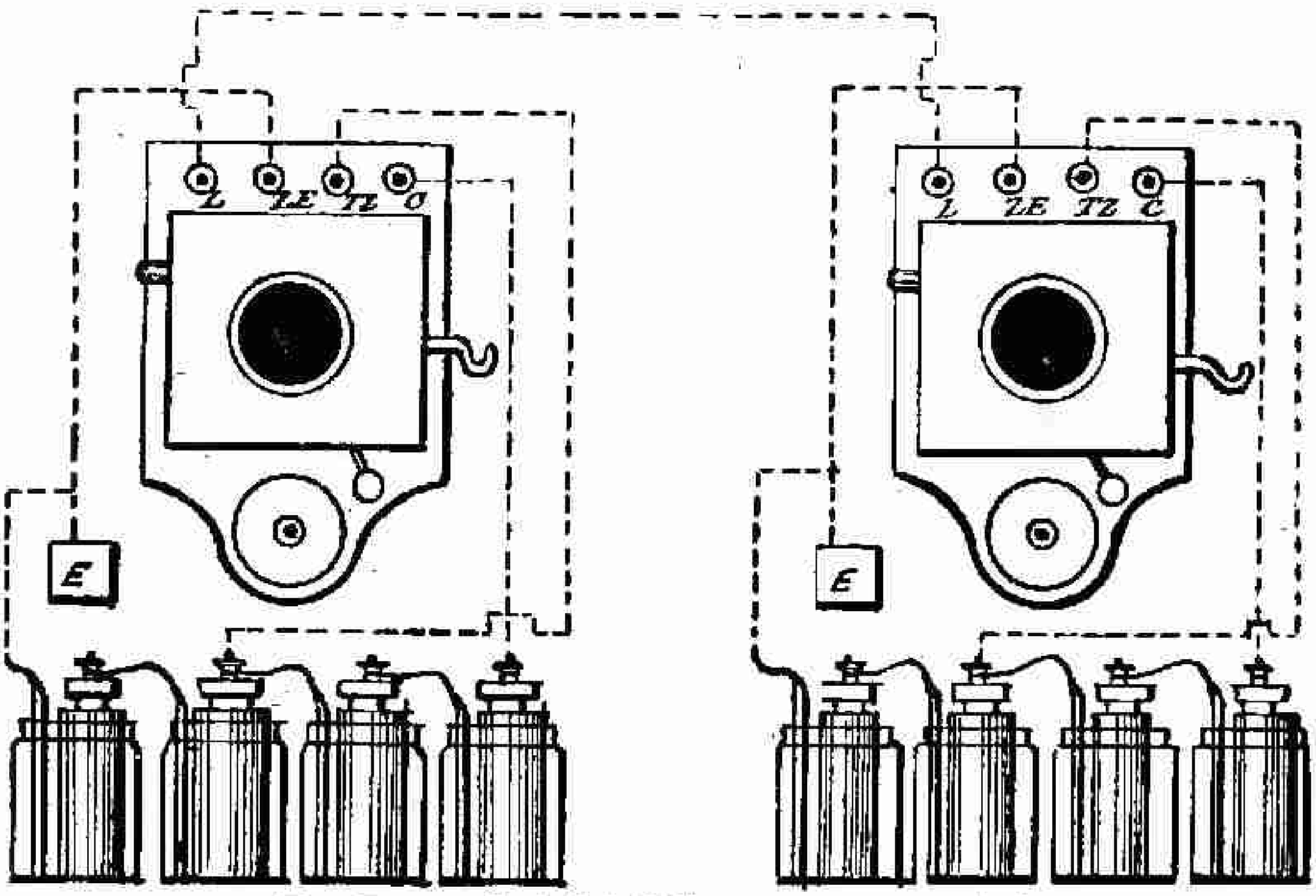
Internal Connections of Fig. 166.

ment, and Fig. 167 the internal. The connecting-up of two of these instruments is, it will be seen from Fig. 166, a very simple matter; the instruments having merely to be erected, and a wire run from one terminal (it is immaterial which of top two) of one instrument to that of the other. The remaining terminal of each instrument is connected to "earth."

In Fig. 167 *a* is the magneto bell, *d* the generator, *c* the automatic switch, and *b* the receiver of instrument No. 1, *a'*, *b'*, *c'*, *d'* representing similar parts of instrument No. 2.

The "ringing" circuit is as follows:—When the handle of the generator *d* is turned, the current flows, let us say, from the right-hand terminal of the generator to bottom contact of automatic switch *c*, spring-hook of switch, line-wire, spring-hook of automatic switch *c′* (instrument No. 2), bottom contact, generator *d′*, bell *a′*, return wire, bell *a* (instrument No. 1), and thence to left-hand terminal of generator *d*. Ringing from the other end a similar action takes place. The "speaking" circuit, when the receivers are off the hooks, is as follows:—Starting from receiver *b*, the circuit runs to top contact of automatic switch *c*, spring-hook of switch, line-wire, spring-hook of switch *c′* (instrument No. 2), top contact of switch, receiver *b′*, return wire, and thence back to receiver *b*.

Fig. 168.

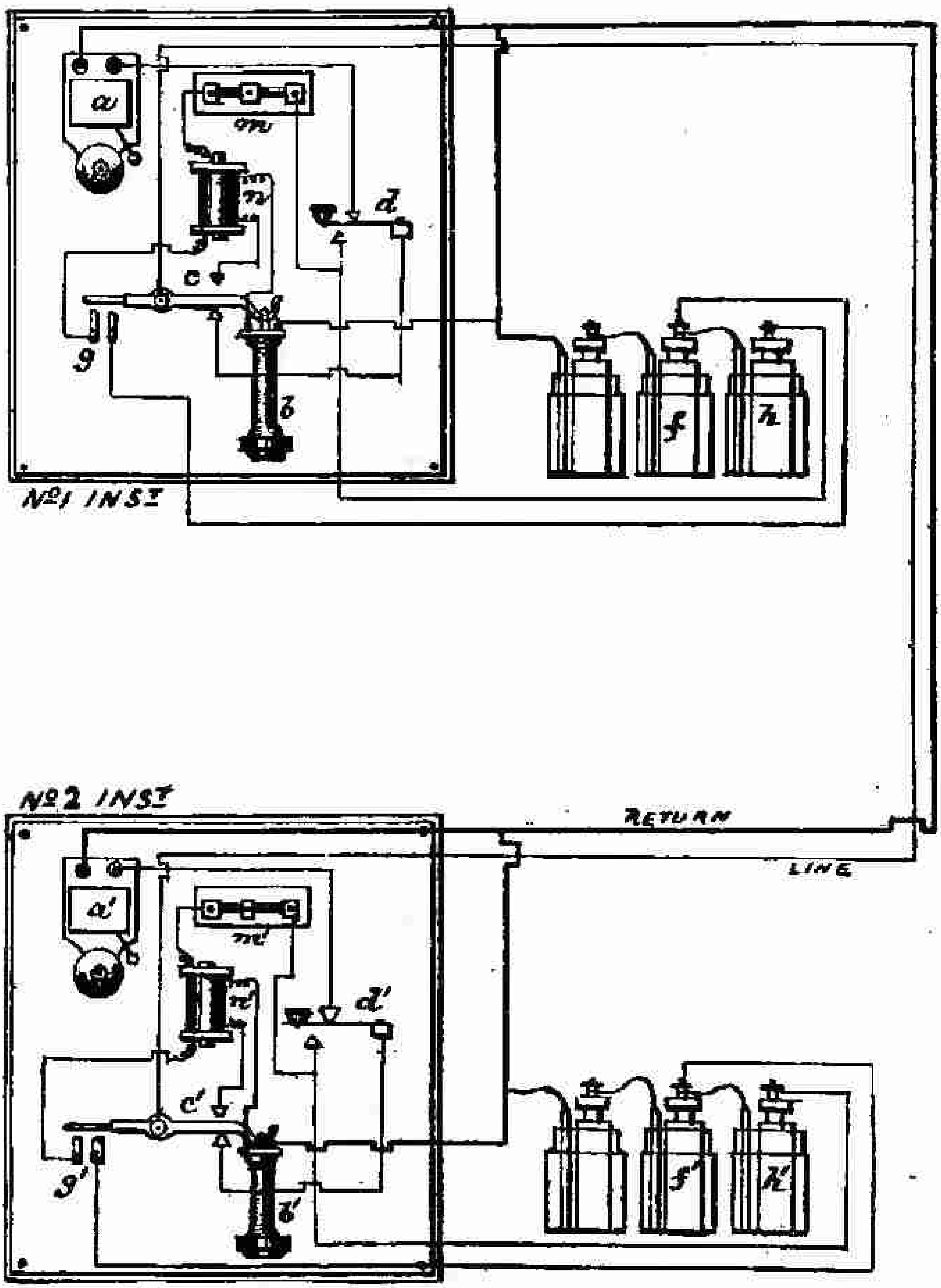


Two Battery Switch-bell Instruments connected.

Two Instruments with Battery Switch-bells, Microphones, and Receivers.—Figs. 168 and 169 show the connections for the form of instrument shown in Fig. 64, p. 78. Fig. 168

showing the external, and Fig. 169 the internal connections. It will be seen from figure there are four terminals at the top of the instrument, marked L, Z E, T Z, and C, being "line," "zinc" and "earth," "transmitter zinc," and "carbon" respectively.

Fig. 169.



Diagrammatic View of Battery Switch-bell Instruments.

In Fig. 169 *a* is the bell, *b* the receiver, *c* the automatic switch, *d* the ringing key, *m* the microphone, *n* the induction coil, *g* the two contact springs (connected across by the back part of the automatic switch when the receiver is off the hook), by means of which the local circuit through the microphone is opened and closed, *f* the ringing battery, one cell *h* of which is the local cell for the microphone. The corresponding parts in instrument No. 2 are designated by *a′ b′*, *c′*, *d′*, &c., similar letters denoting similar parts.

The "ringing" circuit, when the ringing key *d* of instrument No. 1 is pressed, is, starting from the carbon pole of battery *f*, bottom contact of key *d*, key-spring, bottom contact of automatic switch *c*, hook-lever of switch, pivot of switch, line-wire, pivot of switch *c′*, instrument No. 2, hook-lever of switch, bottom contact key-spring, top contact, right-hand terminal of bell *a′*, left-hand terminal, return wire, and zinc pole of battery *f*. When the receivers are lifted off the hooks, the hook-lever moves up and makes connection with the top contact, and at the same time connection is made between the two hooks *g*, thus closing the local circuit.

The local circuit runs from the carbon pole of the cell *h* to the microphone *m*, from there through the primary of the induction coil *n*, springs *g*, and from thence to the zinc pole of the battery.

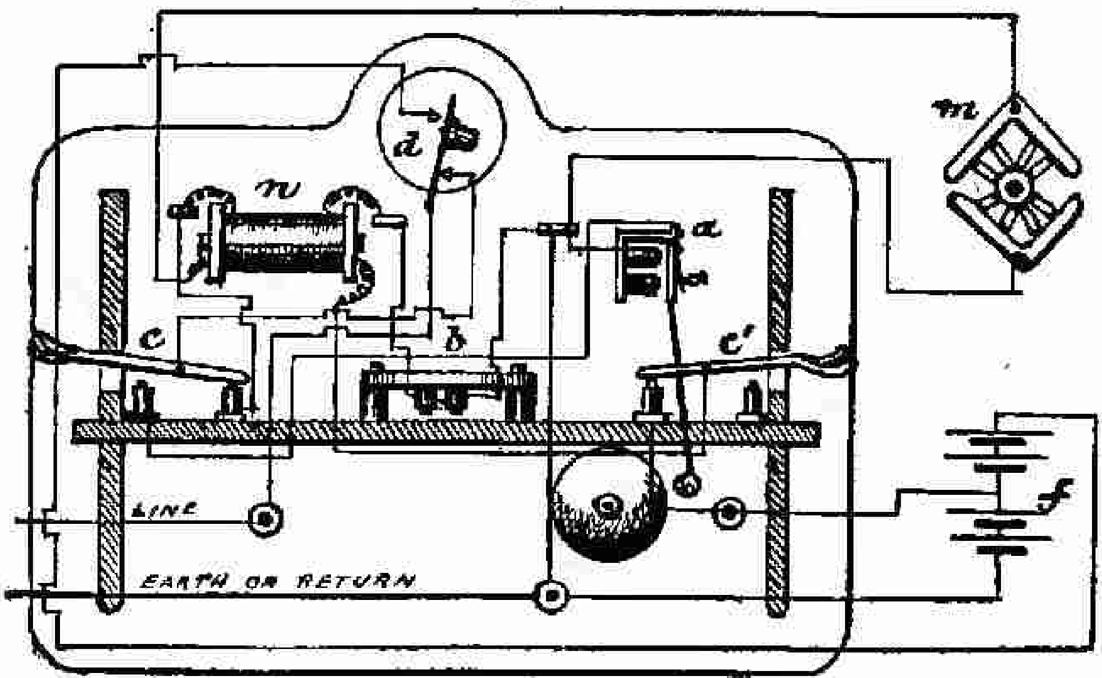
The "speaking" circuit is (the receivers being off the hooks), starting from the secondary of the induction coil *n*, top contact of automatic switch *c*, hook-lever, pivot, line-wire, pivot of automatic switch *c′* (instrument No. 2), hook-lever, top contact, secondary winding of coil *n′*, receiver *b′*, return wire, receiver *b*, and from there back to secondary of induction coil *n*.

The internal connections of two other instruments coming under this class will now be shown.

Connections for the Gower-Bell Telephone.—Fig. 170 shows the connections for the Gower-Bell instrument. In the figure *a* is the bell, *b* the receiver (the listening tubes of which are not shown), *c* and *c′* the automatic switches, *d* the ringing key, *m* the microphone, *n* the induction coil, and *f* the battery, two cells of which are used for the microphone. It will be noticed there are two automatic switches, the one *c* making the changes from "ringing" to "speaking," and the other opening and closing the local circuit through the microphone.

The local circuit runs from the carbon pole of the two cells of the battery *f*, to back contact of automatic switch *c′*, switch-hook, primary of induction coil *n*, microphone *m*, and then to zinc pole of battery.

Fig. 170.



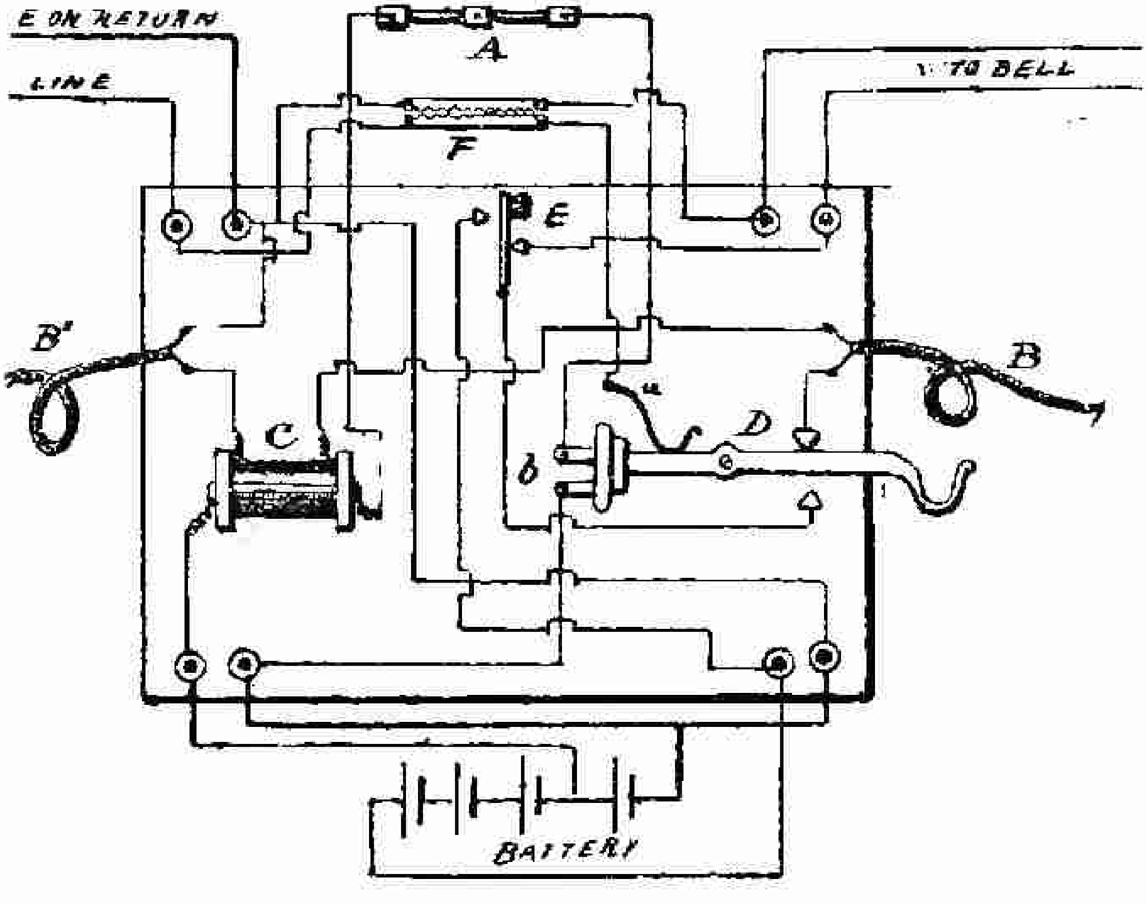
Internal Connections of Gower-bell.

The "ringing" circuit is from carbon pole of battery to bottom contact of ringing key *a*, key-spring, line-wire, instrument No. 2 (not shown in the figure), return wire, and zinc of the battery.

The "speaking" circuit is from secondary windings of induction coil *n*, back contact of automatic switch *c*, switch-hook, back contact of ringing key, key-spring, line-wire, instrument No. 2, return wire, receiver, and from there back to secondary of induction coil. If a relay is required the bell must be cut out, and the two wires going to the bell taken to the relay.

Connections for the Ader Telephone.—Fig. 171 shows the connections for the Ader instrument. In the figure, A is the microphone, B and B′ the two receiver cords, C the coil, D the automatic switch, E the ringing key, and F the lightning-arrester. The receivers are not shown in the figure. The current entering at "line" passes through the bottom plate of

Fig. 171.



Internal Connections of Ader.

the arrester to the spring *a* on the top of the automatic switch. From there it passes (if the receiver is on the hook) to bottom contact, ringing key-spring, back contact of key to bell, and from thence to top plate of arrester and "earth" or return line.

If the receiver is off the hook, as shown in the figure, the current passes from spring *a* to top contact receiver B, secondary coil, receiver B′, to "earth" or return line.

The "local" circuit runs from the positive pole of one cell of the battery to primary of coil, microphone, spring *b* (closed by the brass pieces on the end of the switch-hook), and from there to the zinc of the battery.

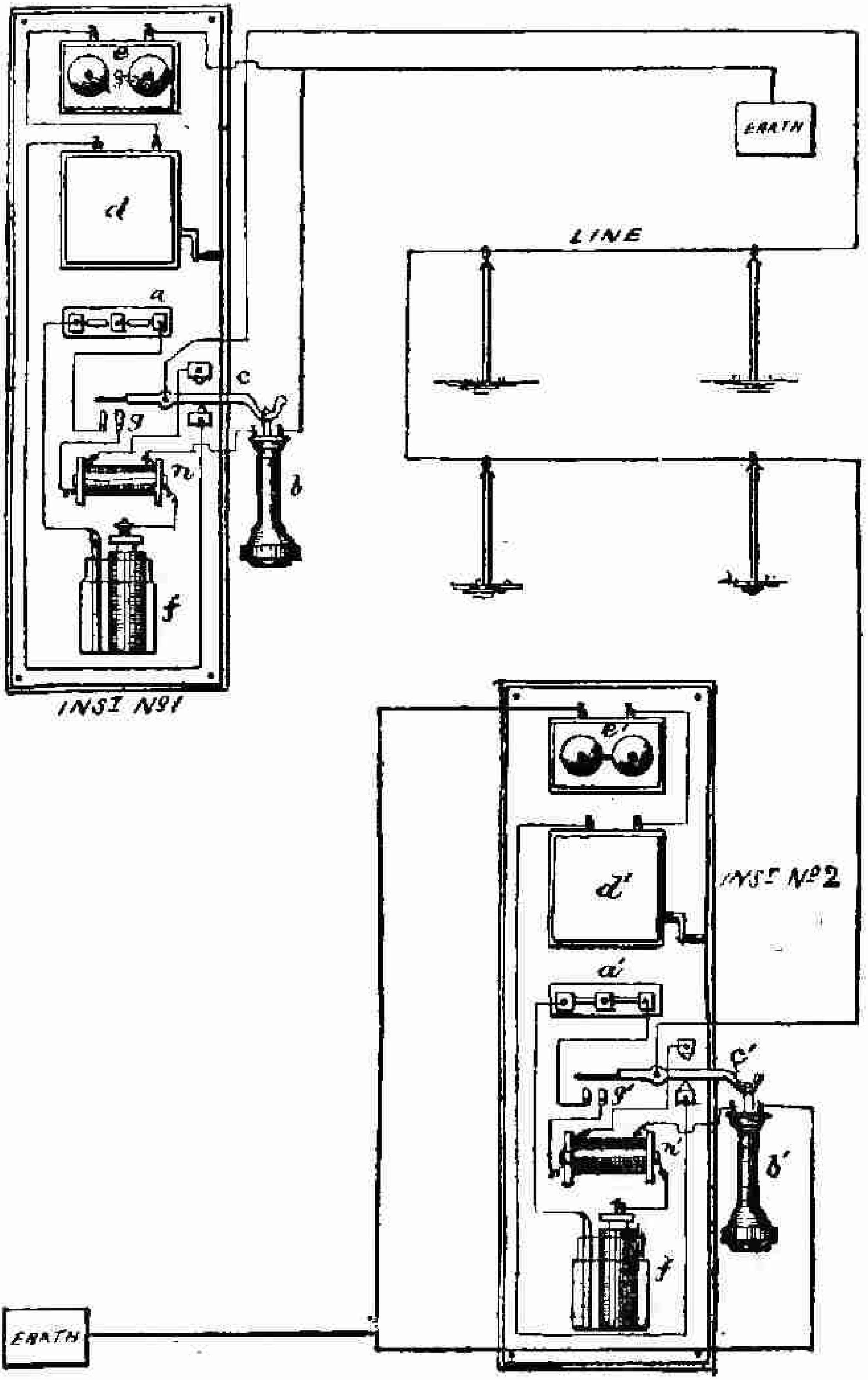
The "ringing" circuit is when the key E is pressed, from the positive pole of the battery to bottom contact of key, key-spring, switch-hook, spring *a*, bottom plate of lightning-arrester, to "line," other instrument, and back by "earth" or return line.

Two Instruments with Magneto Switch-bells, Microphones, and Receivers.—Figs. 172 and 173 show the connections for instruments of the magneto switch-bell type, a form of which is shown in Fig. 66.

It will be seen there are three terminals at the top of the instruments, that on the right, L, being the "line," and the other two, E, the "earth," which two terminals must be joined together and connected to earth as shown in the figure when the instrument is at a terminal station. As this centre terminal is therefore only required at intermediate stations, many forms of these instruments have only two terminals, the L and E. In connection with the instrument at the right-hand side station is shown an extension bell and two-way switch, so that if the operator wishes to leave the instrument, he can, by moving the lever of the switch, cause the calls from the other station to be received on the extension bell, which would be fixed in another part of the building. Another method of adding an extension bell is to connect it in the earth wire, though this method is objectionable in some cases, as the bell will always ring whether the operator is near the instrument or not.

In Fig. 173, which is a diagrammatic view, showing the internal arrangement and connections, *a* is the microphone, *b* the receiver, *c* the automatic switch, *d* the generator, *e* the bell, *g* the two springs, by means of which the local circuit is opened and closed, *f* the battery for the microphone, and *n* the

Fig. 172.



Internal Connections of Fig. 172.

induction coil; *a′*, *b′*, *c′*, *d′*, *e′*, &c., being the corresponding parts of instrument No. 2.

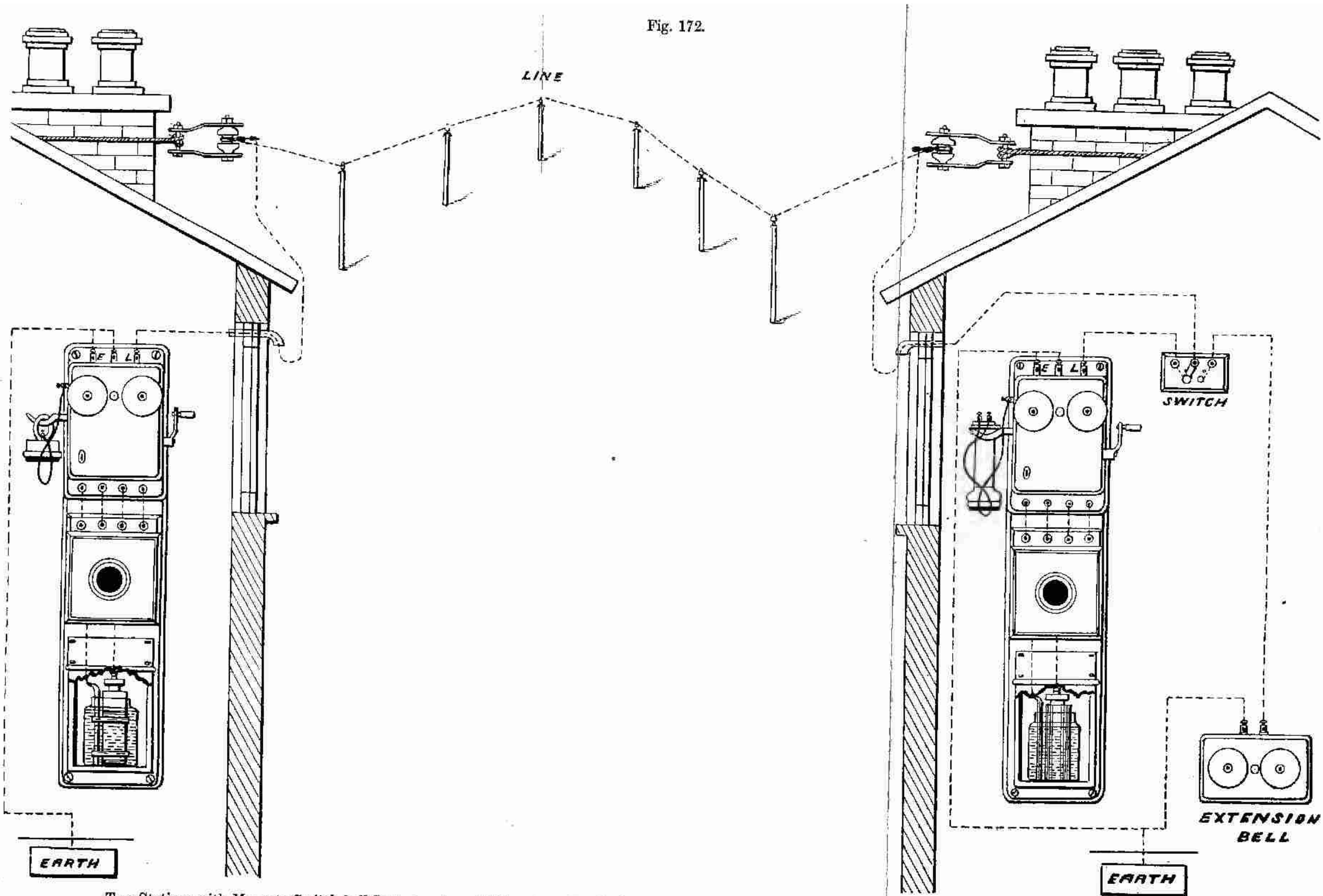
When the handle of the generator *d* (instrument No. 1) is turned, and the receivers are on the switch-hooks *c* and *c′*, the "ringing" circuit is, starting from the left-hand terminal of the generator *d*:—generator *d*, bottom contact of automatic switch *c*, switch-hook, pivot, "line" wire between the two instruments, pivot of automatic switch *c′* (instrument No. 2), switch-hook, bottom contact of switch, generator *d′*, bell *e′*, "earth," right-hand terminal of bell *e* (instrument No. 1), left-hand terminal, and from there back to generator *d*. When the handle of the generator *d′* is turned, a similar action takes place, and it will be noticed that both bells ring when the handle of either of the generators *d* or *d′* is turned.

When the two receivers, *b* and *b′*, are off the switch-hooks, the circuits are as follows:—The "local" circuit runs from the carbon pole of the battery *f* to induction coil *n*, springs *g*, microphone *a*, and from there to the zinc pole of the battery. The "speaking" circuit is, starting, let us say, from the secondary windings of the coil *n*: coil *n*, top contact of automatic switch, switch-hook, pivot, line-wire between the two instruments, pivot of switch *c′* (instrument No. 2), switch-hook, top contact of switch, secondary of coil *n′*, receiver *b′*, "earth" or return wire, if such is used, from "earth" to receiver *b*, and back to secondary of coil *n*.

Different Methods of Arranging Instruments.

The diagrams that have so far been given relate chiefly to the internal connections of the instruments; but those that now follow show the various ways of connecting up several instruments to meet certain requirements. The form of instrument shown is chiefly of the magneto switch-bell kind, the connections of which have just been given in detail in Fig. 173.

Fig. 172.



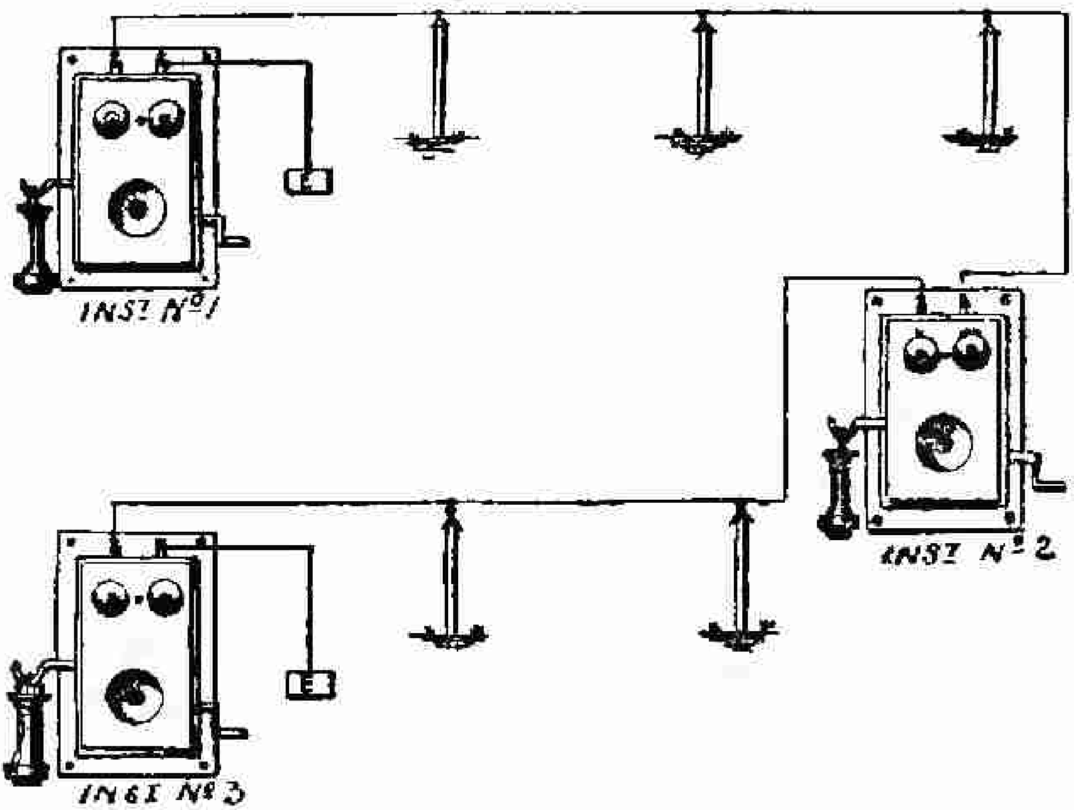
Two Stations with Magneto Switch-bell Instruments and Microphone Transmitters. An Extension Bell and Two-way Switch are also shown at the Right-hand Station.

The "line" and "earth" terminals only are shown, as all the other connections are internal, and do not in any way affect the connection of one instrument with another. Every telephone has its "line" and "earth" terminals—i. e. a terminal to which the "line-wire" is connected, and another for the "earth" or "return-wire," irrespective of whether it has a battery or magneto switch-bell, microphone or no microphone. The form shown in the following figures contains a magneto generator and bell (the two gongs of which are visible at the top of the case), a microphone transmitter (the mouthpiece of which is shown at the bottom), with induction and local cell inside the case. The receiver is shown hanging on the hook at the left-hand side of the case, and on the right-hand side is the handle of the generator.

If in any of the diagrams it is wished to follow the inside connections of any one of the instruments, it is only necessary to refer to Fig. 173, and follow the circuit through the instrument shown there, from the "line" wire to the "return," or the "return" to "line," as the case may be. If it is wished to follow the connections, presuming the instrument has a battery switch-bell, the same process must be pursued, only with the instrument shown in Fig. 169. The form of instrument shown in the diagrams has been adopted, purely because, being compact, it adds to the clearness of the diagrams.

Three Telephones in Series.—Fig. 174 shows how three or more telephone stations are connected in series, so that any one station can communicate with any other on that circuit. In order to be able to distinguish which station is wanted, a code of signals must be arranged, such as one ring for No. 1, two for No. 2, and so on. Thus, if No. 2 station wishes to communicate with No. 1, he gives one ring; with No. 3, three rings. When No. 2 receives a reply, he takes off his receiver, which cuts his bell out of circuit and puts the microphone and receiver in, enabling him to carry on conversation with No. 1 or No. 3, as the case may be. Thus, when any one station rings, the bells at all the other stations ring also; but only that station replies whose number corresponds to the signal given. If the instruments are of the battery switch-

Fig. 174.

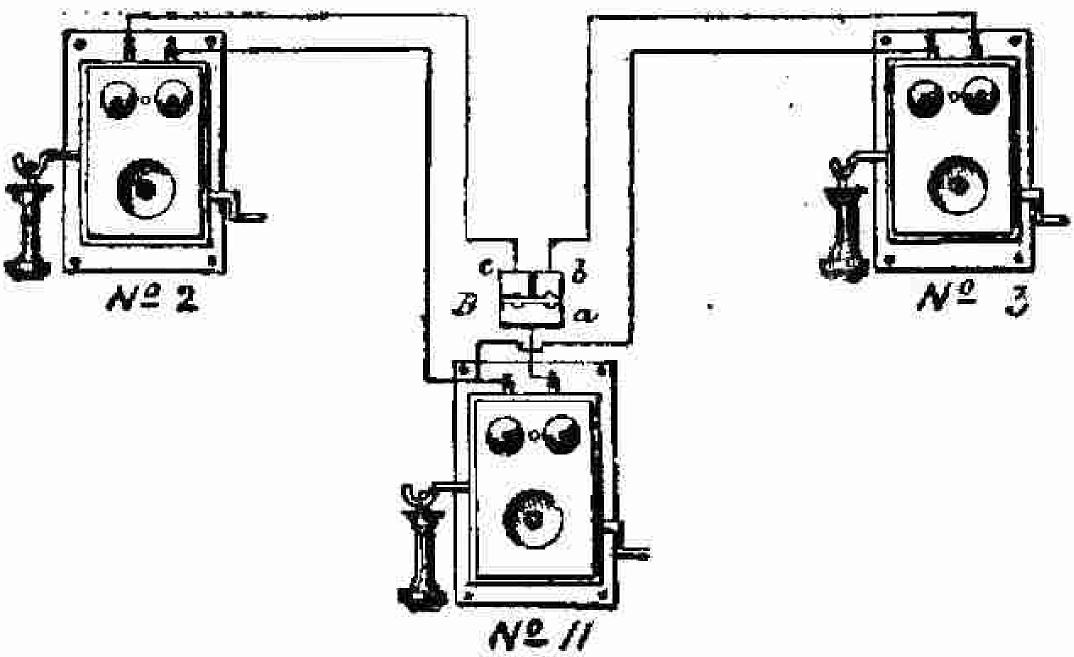


Three Stations in Series.

bell type, then a relay should be used for each instrument; otherwise there will be difficulty in getting the bells to ring nicely, unless they are of the form (described on p. 112) which govern their vibrations, not by breaking the circuit, but by shunting their coils.

Three Telephone Stations, One of which is able to communicate with the other Two as desired.—Fig. 175 shows an arrangement suitable for such places where it is desired for one station to be able to communicate with the other two, but not *vice versâ.* As, for instance, where the head of the firm wishes to be able to communicate with the clerks' office, stores, or other part of a building, without allowing himself to be communicated with unless he desires. In order to accomplish this, a two-way plug, switch B, is required. This switch is fixed within easy reach of the person who uses instrument No. 1, and to the top blocks *b* and *c* are respectively attached the two line-wires from the instruments No. 2 and No. 3. The bottom block *a*

Fig. 175.

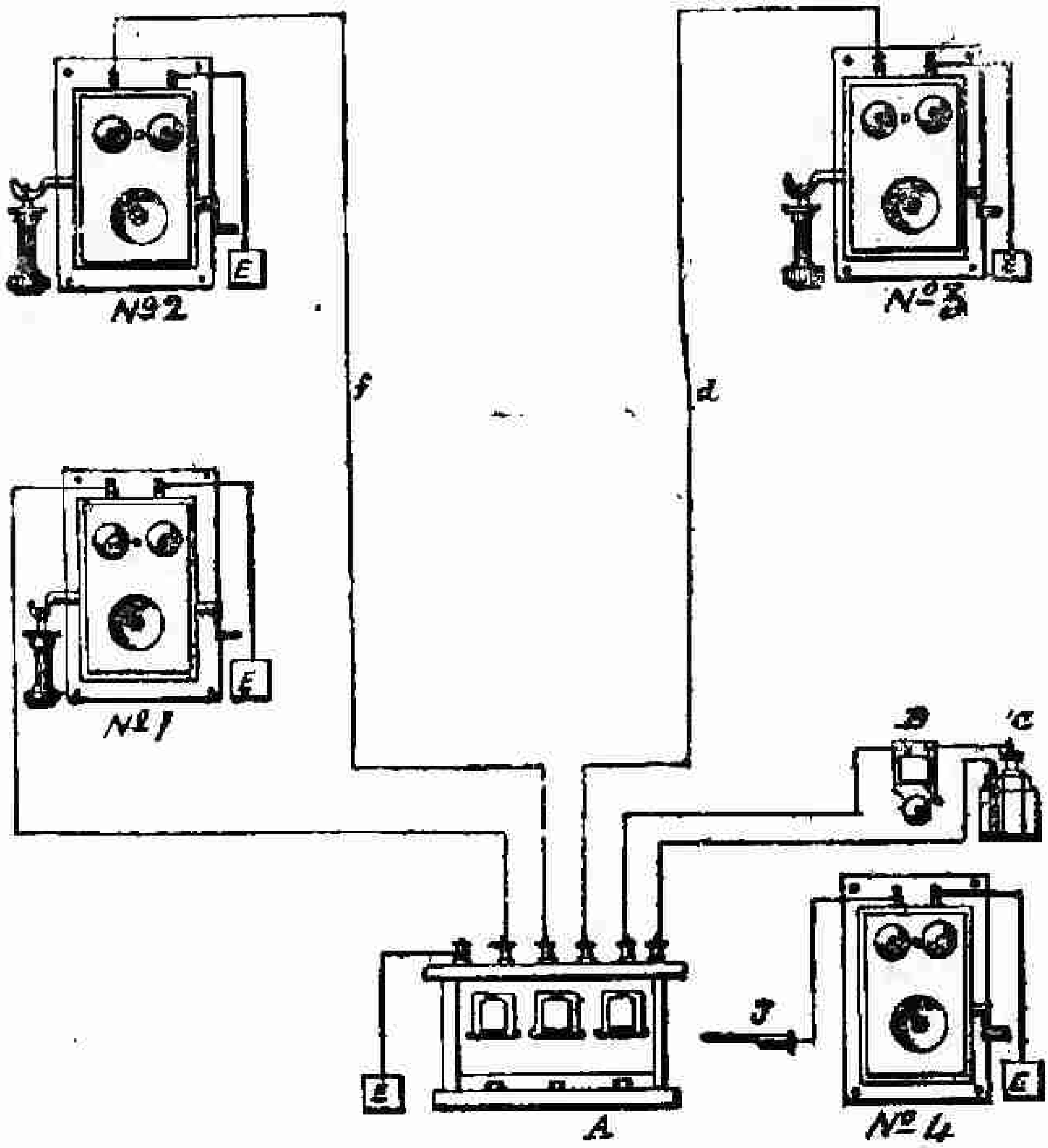


One Station connected to Two others.

is connected to instrument No. 1, and the return wires from all the instruments are joined together. Each of the brass blocks *a*, *b*, and *c* are fixed to a non-conducting base, and insulated from one another by an air space. When the brass plug is put in either of the two holes, the top plate above that hole is connected to the bottom plate. Thus, it will be understood that if the brass plug is inserted in the left-hand hole of the switch, No. 1 instrument will be connected to No. 2, and, if placed in the right-hand hole, to No. 3. When withdrawn altogether, communication is cut off from both instruments. A large number of stations can, of course, be connected into the system by employing a larger switch. Once the application and method of working the plug switch is understood, it will be seen that it is capable of great extensions, and, in fact, forms the simplest and most ready means of connecting-up instruments to meet special requirements.

Several Telephone Stations connected to One Central Exchange.—Figs. 176 and 177 show how several stations are connected up to a central one by means of a switch-board designed for that purpose. Fig. 176 shows the connections for boards of the form shown in Figs. 112 and 113, but Fig. 177 for the W. E. Co.'s patterns. In Fig. 176, No. 4 station is used as the "exchange," and contains, besides the instrument No. 4, the annunciator switch-board A, local bell B, and local battery C. The annunciator switch-board A is shown in detail in Figs. 112 and 113, thus allowing the connections to be followed right through. For the purpose of following the circuit right through, let us suppose that station No. 2 wishes to communicate with station No. 3. The person at station No. 2 first turns the handle of his generator, or if the instrument has a battery switch-bell, presses the ringing key, thus sending the current to station No. 4. This causes the shutter of No. 2 drop to fall, closing the local circuit, and causing the bell B to ring, the circuits being as follows:—Left-hand terminal of No. 2 instrument, line-wire *f*, No. 2 terminal of annunciator, drop No. 2, spring s^2, plate *b*, terminal E and earth, and from there back to instrument No. 2. The shutter of the annunciator falling, closes the local circuit which runs from the carbon pole of the battery C, to bell B, terminal B of annunciator, shutter, terminal B^1, and thence to zinc pole of the battery. This causes the bell B to ring, calling the attention of the person at that station, who then pushes the "plug" J underneath the spring s^2, thus putting his instrument in connection with that at No. 2 station. He then rings back and inquires of No. 2 which station he requires. Having obtained this information, he connects across the slipper spring s^2 of No. 2 annunciator with that s^3 of No. 3 by means of a piece of flexible cord with a "plug" at each end, thus putting No. 2 station in connection with No. 3. The circuit now runs from the left-hand terminal of instrument No. 2 to line-wire f, terminal No. 2 of annunciator, annunciator drop No. 2, spring s^2, "plug" spring s^3, drop No. 3, terminal No. 3, line-wire d, instrument No. 3 and earth, and from earth back to instrument No. 2.

Fig. 176.



Three Stations connected to One Central Exchange.

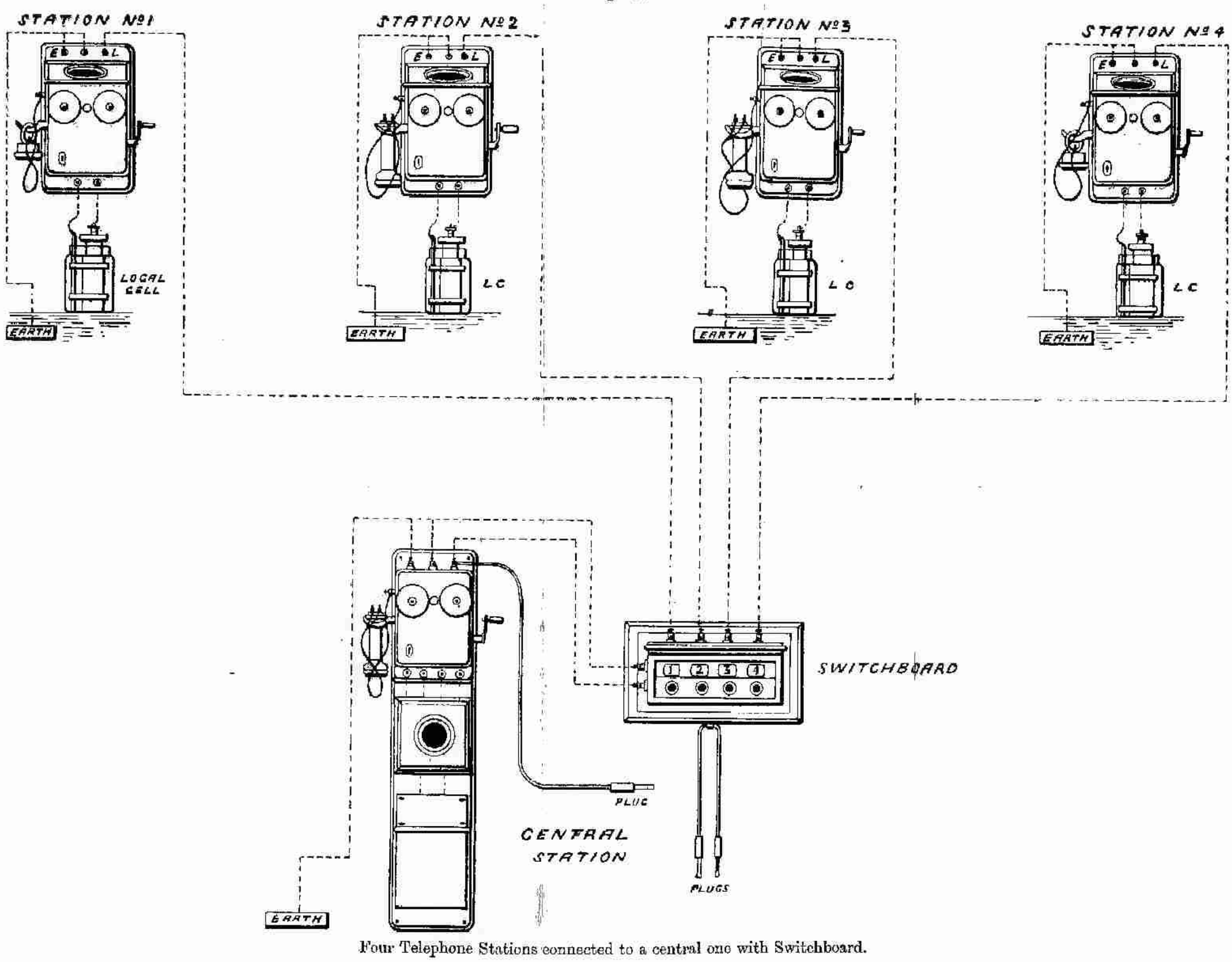
When No. 2 and No. 3 stations have finished talking, they press the ringing key or turn the handle of the generator, as the case may be, which causes the annunciator shutter to fall, thus informing the operator at No. 4 station that they have finished talking, who then pulls out the connecting plugs.

In Fig. 177, the form of switch-board used differs somewhat from that just described. First, there is no local bell circuit, all the calls being received on the instrument bell; and second, when two subscribers are connected through only one of the annunciator drops is in circuit. Suppose No. 1 station wishes to speak to No. 4, the ringing current from No. 1 station passes through No. 1 drop of the switch-board direct to earth, but, on the shutter falling, is diverted through the bell on the central station instrument. The operator at the central station, hearing the bell, inserts the plug connected to his instrument in No. 1 spring jack, and, on learning the number required, immediately plugs the two stations through by means of the two plugs seen hanging below the switch-board. One of these plugs has, it will be seen, an insulated sleeve, so that when two stations are connected through only one of the drops is left in circuit for the "ring-off" signal.

Four Telephone Stations, One of which has an Indicator and Switch, and is able to communicate with the other Three as desired.— Fig. 178 shows an arrangement very useful for connecting different parts of large buildings, such as asylums, &c. In the superintendent's office, or other part of the building which it is intended to make the chief station, is placed one of the instruments (No. 4), an indicator, bell,* and special switch. The other stations are connected to the switch and indicator as shown, either an earth or metallic return being used. When the switch is in its normal position, the circuits from telephones Nos. 1, 2, and 3 run directly through the switch, and respective indicator drops and bell to "earth." If a call is received (let us suppose from instrument No. 3), then person at No. 4 instrument moves the lever of his switch to No. 3 point, which transfers No. 3 line from the indicator to No. 1 instrument. No. 1 can thus converse with No. 3, and should any of the other stations ring up No. 1 (while so talking), these calls

* This bell should be a low resistance one.

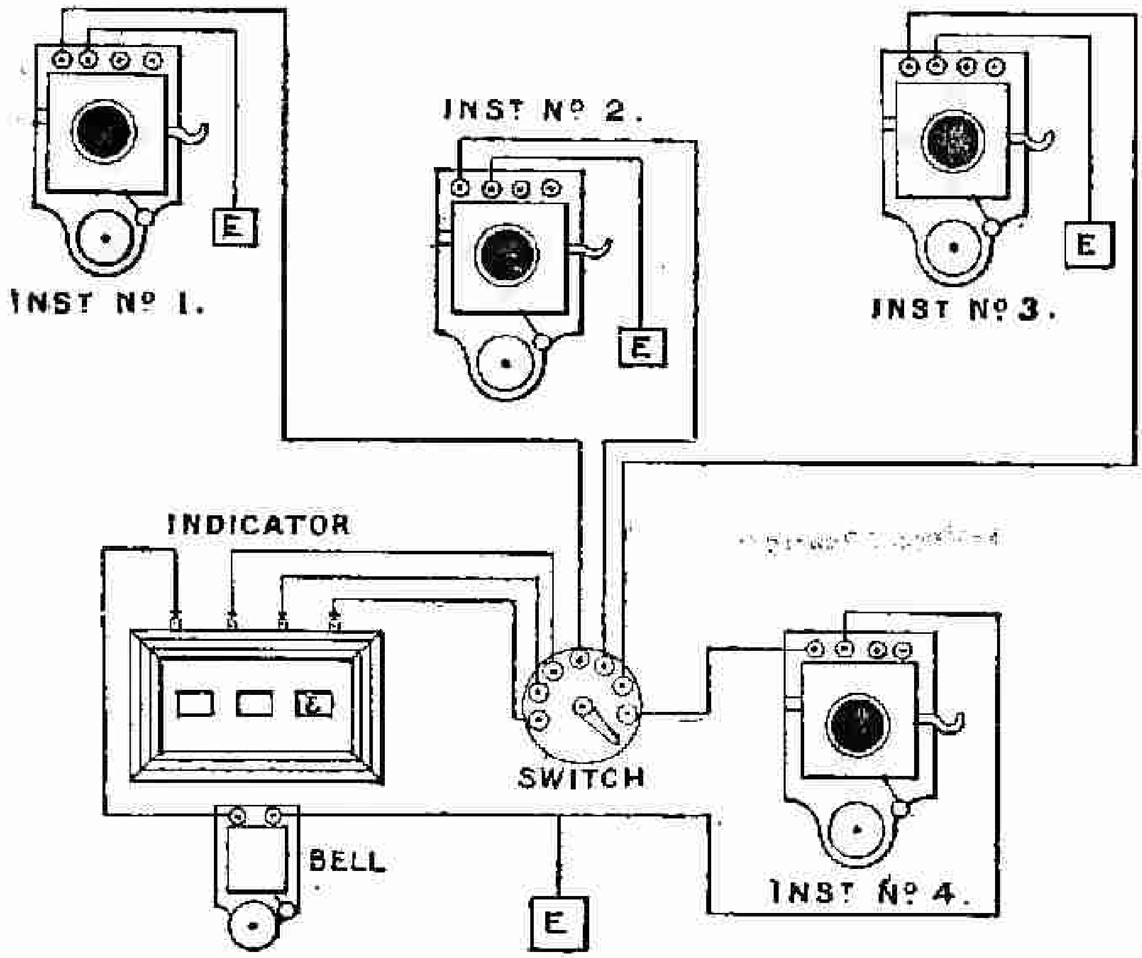
Fig. 177.



Four Telephone Stations connected to a central one with Switchboard.

are received on the indicator and bell, and the number of the station ringing can at once be seen from the number of the vane that falls. Either a mechanical replacement or pen-

Fig. 178.*

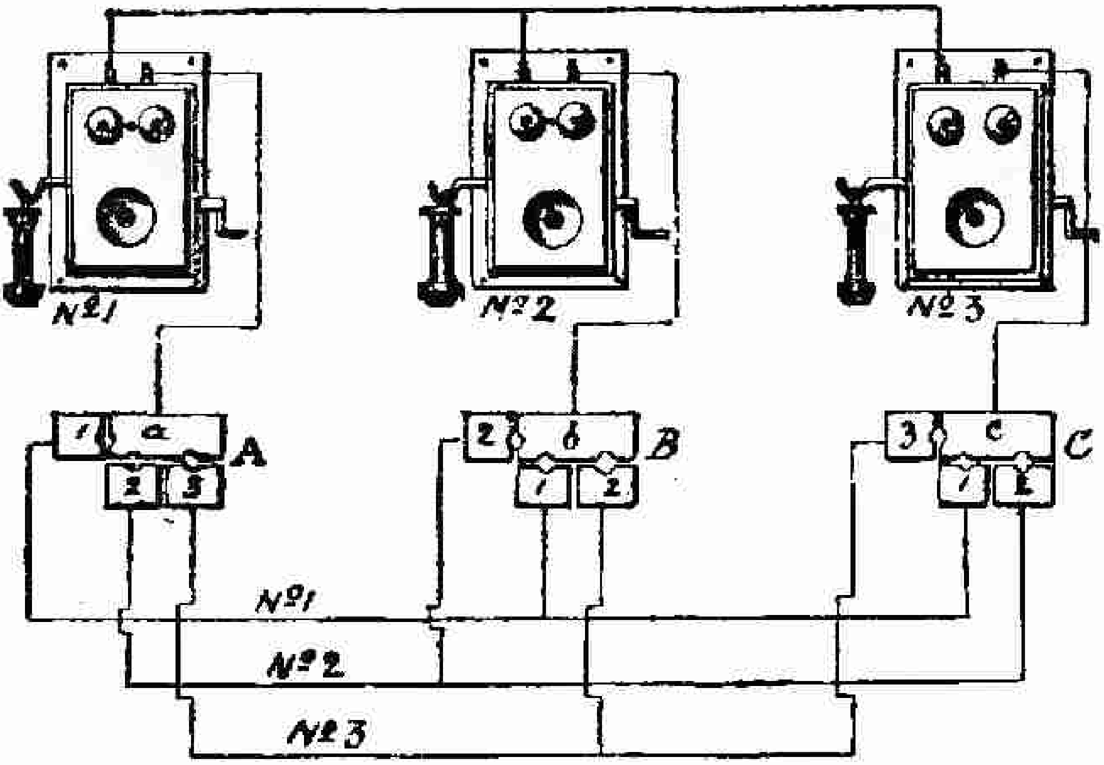


Three Stations connected to a Central one with Indicator.

dulum indicator can be used for telephones arranged thus, the pendulum form being perhaps preferable, as they require no resetting.

Three Telephone Stations, arranged on the Intercommunication System.—Fig. 179 shows a method of arranging telephones on the "intercommunication" system—a system or method of connecting telephones that allows of any one station being put into communication with any other on that system by the operator himself. On comparing Fig. 176, which is an "exchange" system, with Fig. 178, the difference between the two systems will be seen. In the "exchange" system it is necessary for all the other stations to communicate first with the central station before they can be put into communication with one another; but in the "intercommunication" system, the operator at each station can, by inserting a plug or moving a

Fig. 179.

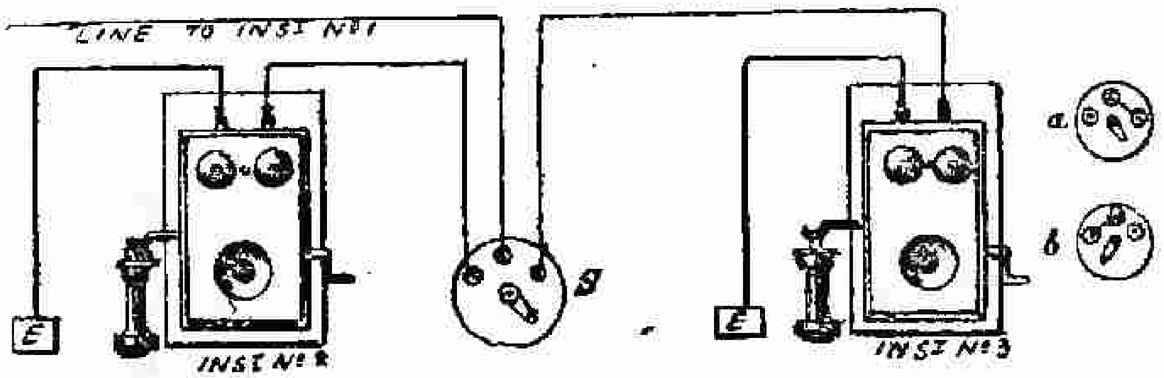


Intercommunication System.

switch, place his instrument in connection with any other on that system. The method by which this is effected in Fig. 179 is by means of special plug switches. The instruments are marked No. 1, No. 2, No. 3, and the line-wires to each instrument are also likewise numbered. The plug switches to each instrument are marked A, B, C respectively. In their normal position, the brass plugs of each switch are always in the holes connecting the brass blocks 1 and *a*, 2 and *b*, 3 and *c* together. Now, we will suppose No. 1 wishes to communicate with No. 3; to do this, he takes the brass plug from between the blocks 1 and *a* of the switch A and places it between *a* and 3; he is then in connection with No. 3, and after ringing him up, can carry on conversation with him. When No. 1 has finished talking, he withdraws the brass plug from between the blocks *a* and 3 and inserts it back into its original position between the blocks *a* and 1. A similar action takes place when any of the other stations wish to communicate, the only precaution to be taken being to see that the brass plug is returned to its original position when conversation is finished. It will be seen that any number of stations can be connected up on this system, the number of wires between each station being $n + 1$, where n equals the number of stations. This system is especially adapted for communication in hotels and other large buildings, though, when the distance between each station is very great, the expense becomes high owing to the number of wires required. For long distances the exchange system is the most suitable, and an automatic switch-board might be used, a form of switch-board that does away with the necessity of an operator to make the connections at the central exchange, as this is done by the subscribers themselves by means of contact discs so arranged as to work synchronously.

Three Telephone Stations with Three-point Switch.—Fig. 180 shows one use of the three-point switch, there being three

Fig. 180.

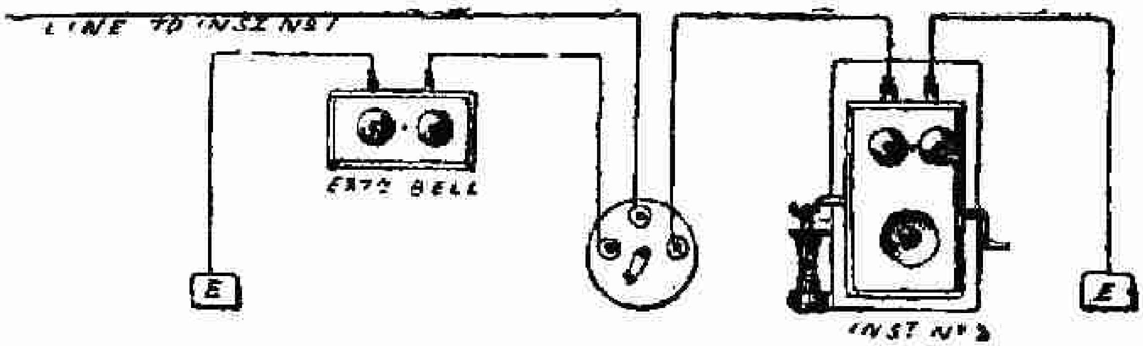


Three Stations connected as in Fig. 175, but with Three-point Switch.

telephone stations, one of which can communicate with either of the other two by means of the switch. The wire at the top runs to instrument No. 1, and is connected to the middle terminal of the switch S. The left-hand terminal is connected to instrument No. 2, and the right-hand one to instrument No. 3, an earth return being used for all the instruments. The switch S would be fixed close to instrument No. 2 or No. 3. When the handle of the switch is to the left, No. 1 instrument is connected to No. 2, but when moved to the right No. 1 is connected to No. 3. This arrangement is very convenient where there are two offices at one end of a line, and it is desired to be able to communicate from either of them. Thus, when the person leaves the one office he moves over the switch, which he again moves back when he returns. For a medical man also this is very useful, enabling him to have one instrument in his consulting room and the other in his bedroom. In this case of course the wire to No. 1 instrument would be an exchange line. The small diagrams *a* and *b* show which terminals of the switch are connected together when the handle is in the two different positions.

Two Telephone Stations with an Extension Bell.—Fig. 181 is an arrangement similar to that just described, there being

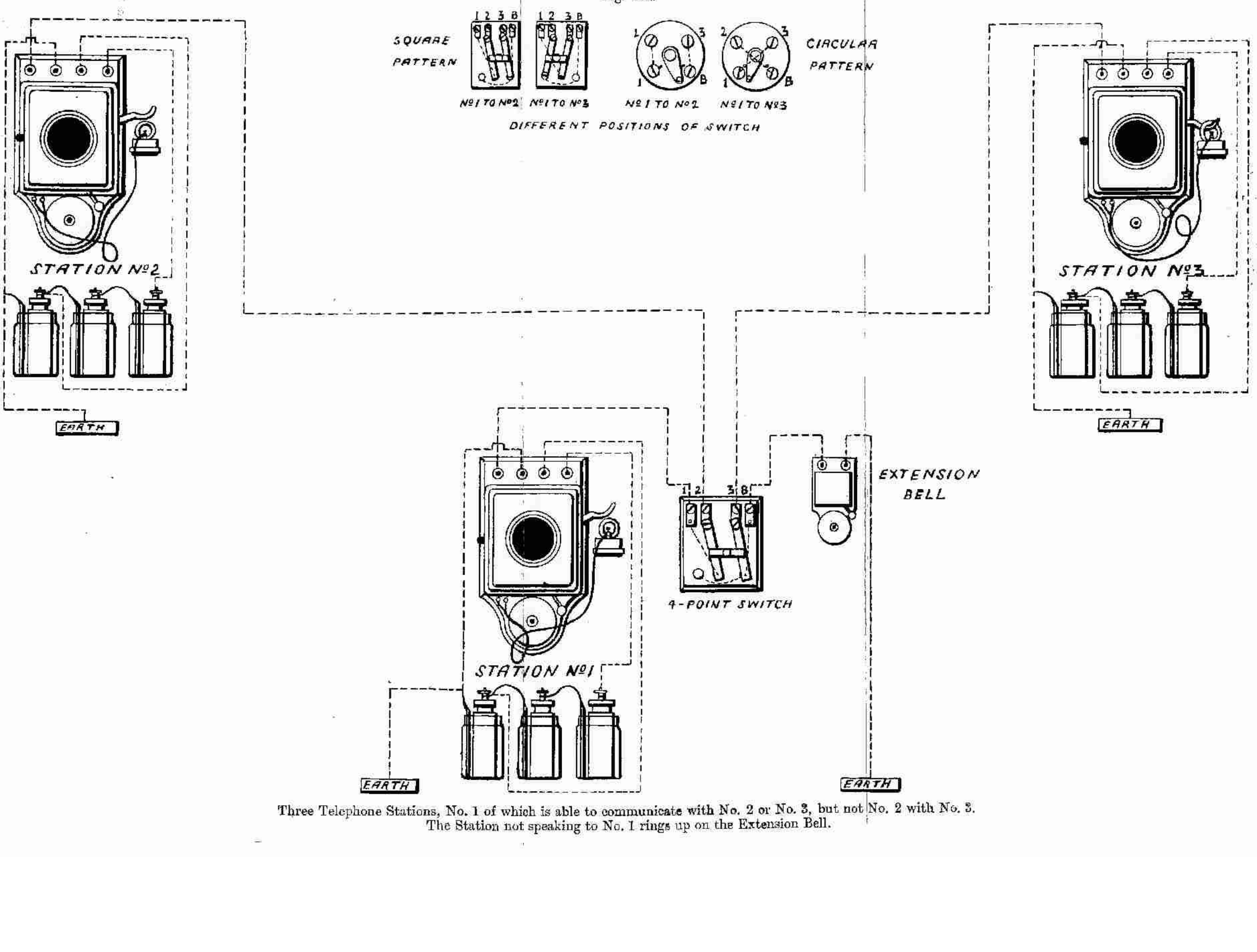
Fig. 181.



Connections for adding an Extension Bell.

what is called an "extension bell," instead of the third instrument. This enables the bell to be placed at such a place where it might not be convenient to fix the telephone, so that the signals can be better heard. It is convenient also where the

Fig. 182.



Three Telephone Stations, No. 1 of which is able to communicate with No. 2 or No. 3, but not No. 2 with No. 3. The Station not speaking to No. 1 rings up on the Extension Bell.

person who uses the instrument wishes at times to leave his office for another part of the building where the bell would be fixed. When the handle of the switch (which is a three-point one, as shown in Fig. 91) is to the left, the extension bell is connected to instrument No. 1; but when to the right, No. 1 is connected to No. 2. The handle of the switch must be put to the right during conversation, but returned to the left when finished. The extension bell shown is a magneto one, but the connections are similar for the battery form.

Three Telephone Stations, with Extension Bell at One Station and a Four-point Switch.—Fig. 182 shows how three telephone stations can be arranged by means of a four-point switch, so that No. 1 can speak with No. 2 or No. 3; but No. 2 and No. 3 cannot communicate with one another, an extension bell being used so that the station not in connection with No. 1 can give notice of their desire to communicate.

In the key diagrams at the top of the figure the connections of both the square and circular pattern switches are shown. These switches will be found described and illustrated on page 120. It will be seen, on referring to Fig. 182, that when the handle of the switch is to the right, No. 1 instrument is connected to No. 2, and instrument No. 3 is in connection with the extension bell. When the handle is to the left, No. 1 instrument is connected to No. 3, and No. 2 instrument is on the extension bell. Both the switch and extension bell would be in the same room as instrument No. 1, and the normal position of the switch would be that shown in the figure—that is, instrument No. 2 connected to No. 1, and instrument No. 3 on the extension bell. If instrument No. 3 wishes to communicate with No. 1, he rings the extension bell, and the person at station No. 1 puts over the switch. This arrangement is sometimes used in connection with a public exchange system, in order to prevent the subscriber making an illicit use of his instruments. Thus it will be seen that if No. 2 instrument is the exchange, the subscriber is enabled to communicate from

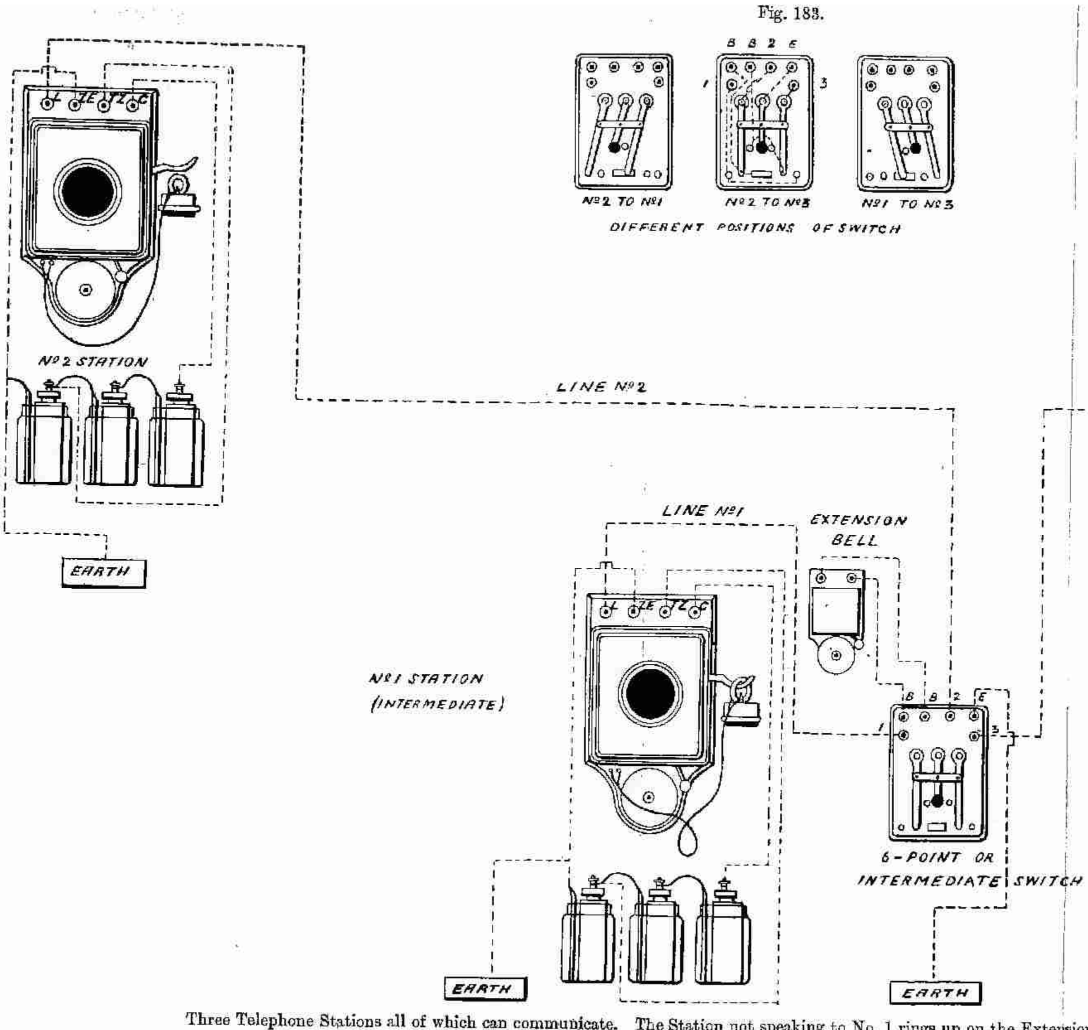
No. 1 instrument with the exchange, and can use No. 1 and No. 3 as a private line, but not speak from No. 3 to the exchange, which he would not be entitled to do unless he previously arranged to that effect with the Company.

The form of instruments shown both in this and the following diagram will be found described and illustrated on page 78.

Three Telephone Stations with a Six-point Switch and Extension Bell at the Intermediate Station.—Fig. 183 shows a very favourite way of connecting up three telephone stations so that all can communicate. An extension bell and six-point switch are required at the intermediate station, as shown in the figure. Of the six-point switch there are two kinds now in general use, viz., the square and the circular pattern, the former being that most often employed. The circular pattern is described and illustrated on page 121, and the square pattern on page 122, the difference being merely in the shape, as both effect the same operations. The square pattern is shown in the diagram (Fig. 183), the terminals being marked 1 (line No. 1), B B (two terminals for extension bell), 2 (line No. 2), E (earth), 3 (line No. 3), respectively. On page 121 the terminals of the circular pattern are marked 1, 2, 3, 4, 5, 6, passing from left to right, these being 1 (one terminal of extension bell), 2 (line No. 2), 3 (earth), 4 (line No. 1), 5 (line No. 3), and 6 (other terminal of extension bell).

Of the three telephone stations, one may be the exchange, or they may be wholly private lines. As shown in Fig. 183, the stations are represented as being all private ones and No. 2 is speaking to No. 3, the switch being in the central position. When the handle of the switch is to the left-hand side, No. 2 station is in connection with No. 1, while No. 3 station is connected to the extension bell, the left-hand terminal of which is put to "earth." If the switch handle is moved over to the right-hand side, No. 1 station is connected to No. 3, and station

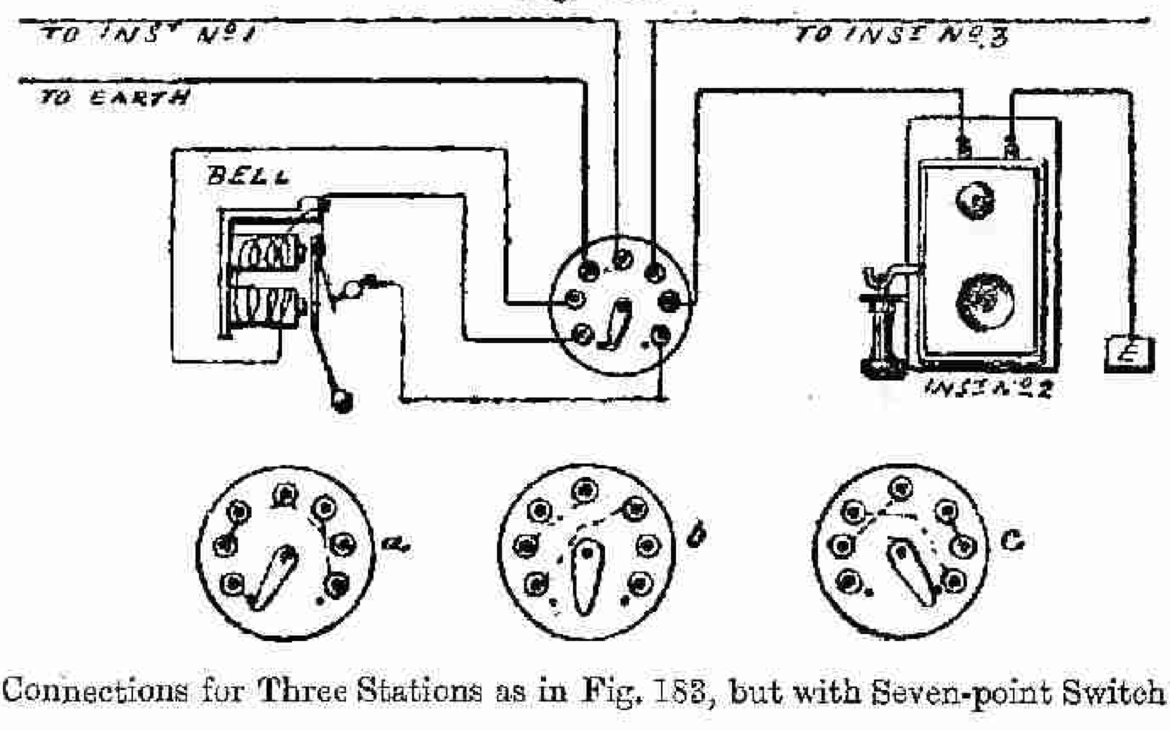
Fig. 183.



Three Telephone Stations all of which can communicate. The Station not speaking to No. 1 rings up on the Extension Bell, by means of which Bell also Nos. 2 and 3, when connected together, can call the attention of No. 1.

No. 2 is unconnected with the extension bell, the right-hand terminal of which is put to "earth." When the handle of the switch is in the centre instrument, No. 2 is connected to No. 3, and instrument No. 1 is cut out of the circuit, the extension bell being looped in so that No. 1 station can be signalled to disconnect. As an illustration of the use of this arrangement when No. 2 instrument is an exchange line, we will take the case of a large suite of offices. No. 1 instrument with the switch and extension bell would then be placed in the clerk's office, and No. 3 in that of the principal. All calls are then received and answered by the clerk, who, if it is important, places the handle of the switch over to the right, and asks the principal if he will speak with the person calling. Should he wish to do so, the clerk moves the handle of the switch to the central position, and the clerk's office is cut out. When the conversation is finished, the clerk's office is signalled to put back the switch into its normal position, which is that shown in the figure.

Fig. 184.



Connections for Three Stations as in Fig. 183, but with Seven-point Switch.

Three Telephone Stations with Seven-point Switch and Extension Bell, which is converted from Vibrating into Single

Stroke.—Fig. 184 shows how three stations are connected up, using a battery extension bell, which is converted from vibrating into single-stroke, when the intermediate station is cut out, so as to avoid a possible break of the circuit when speaking through the contact-breaker of the extension bell. The arrangement, it will be noticed, is very similar to the one just described. A seven-point switch, however, is used, the key diagrams of which are shown in *a*, *b*, and *c*. A wire is taken from the frame of bell, so that when the switch is in the central position, and the intermediate station is cut out, the bell becomes a single stroke; but when the handle of the switch is to the left or right, the bell is a vibrating one. This prevents the conversation being interrupted when station No. 1 is speaking to station No. 3 by any one accidentally touching the hammer of the bell, which would cause the spring to break contact with the contact-screw, and thus break the circuit.

CHAPTER X.

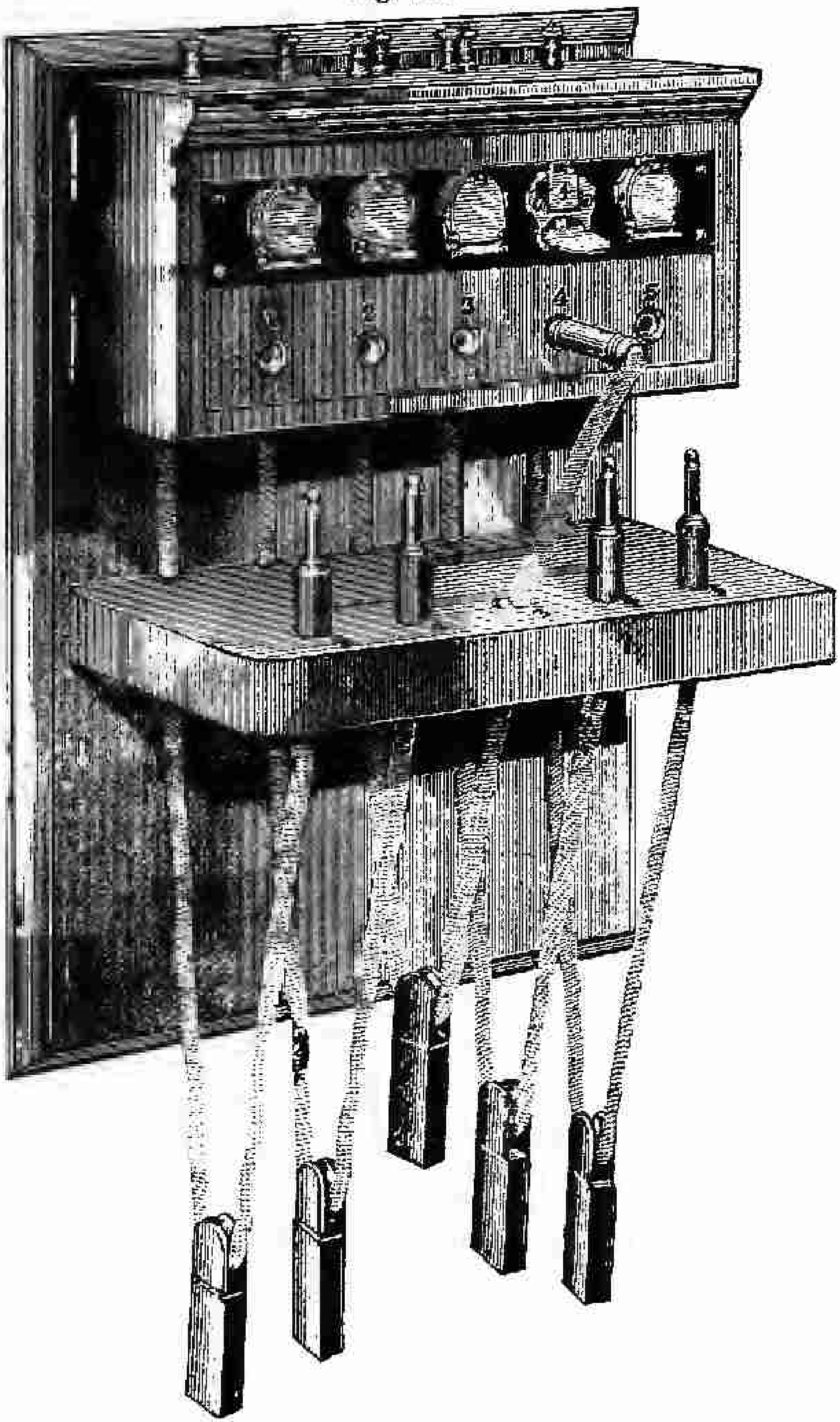
PRIVATE EXCHANGE SYSTEMS FOR HOTELS AND OTHER LARGE BUILDINGS.

As a means of establishing a ready method of communicating between the different departments of large buildings, the telephone is admirably adapted, and it is the intention in this chapter to describe one or two systems of telephonic communication suitable for hotels, large business houses, asylums, &c., which enable the stations in the different portions of the building to communicate the one with the other surely and with absolute despatch. For stations up to six in number the "intercommunication system," as shown in Fig. 178, is undoubtedly the most convenient, and the one that allows of the "calling" being most quickly put into communication with the "wanted" station. It requires a large amount of wiring, however, so that for buildings with more than six or seven stations some other system is best employed, especially if the stations are far apart.

In all buildings where there are more than twelve stations there is no doubt that the most satisfactory method is to make one of the stations the central exchange, to which all the lines are brought and from which all the desired connections can be made. The station selected for the central exchange should be that one to which calls will be most often sent, as this will considerably reduce the switching.

A convenient switch-board for private exchanges, up to about 50 or 60 stations, is the single-cord form, a five-station one, on which system, made by the Telegraph Manufacturing Company, is shown in Fig. 185. It differs from the ordinary exchange system, as shown in Fig. 176, merely in the form and arrange-

Fig. 185.



Single-cord Switch-board.

ment of the exchange switch-board, in which one or two modifications are introduced. By referring to Fig. 176 it will be seen that when one station rings up, the operator at the exchange, after ascertaining the number, has two "plugs" to insert—one for the "calling," and the other for the "wanted" station. This, although it only requires one or two double plugs, necessitates two operations and a consequent loss of time. With the single-cord switch-board there are an equal number of connecting plugs and plug-cords as there are annunciator drops or subscribers' lines, and on the operator at the exchange receiving the number required, she at once inserts the plug of the "calling" in the "wanted" station spring-jack, and the two stations are "through."

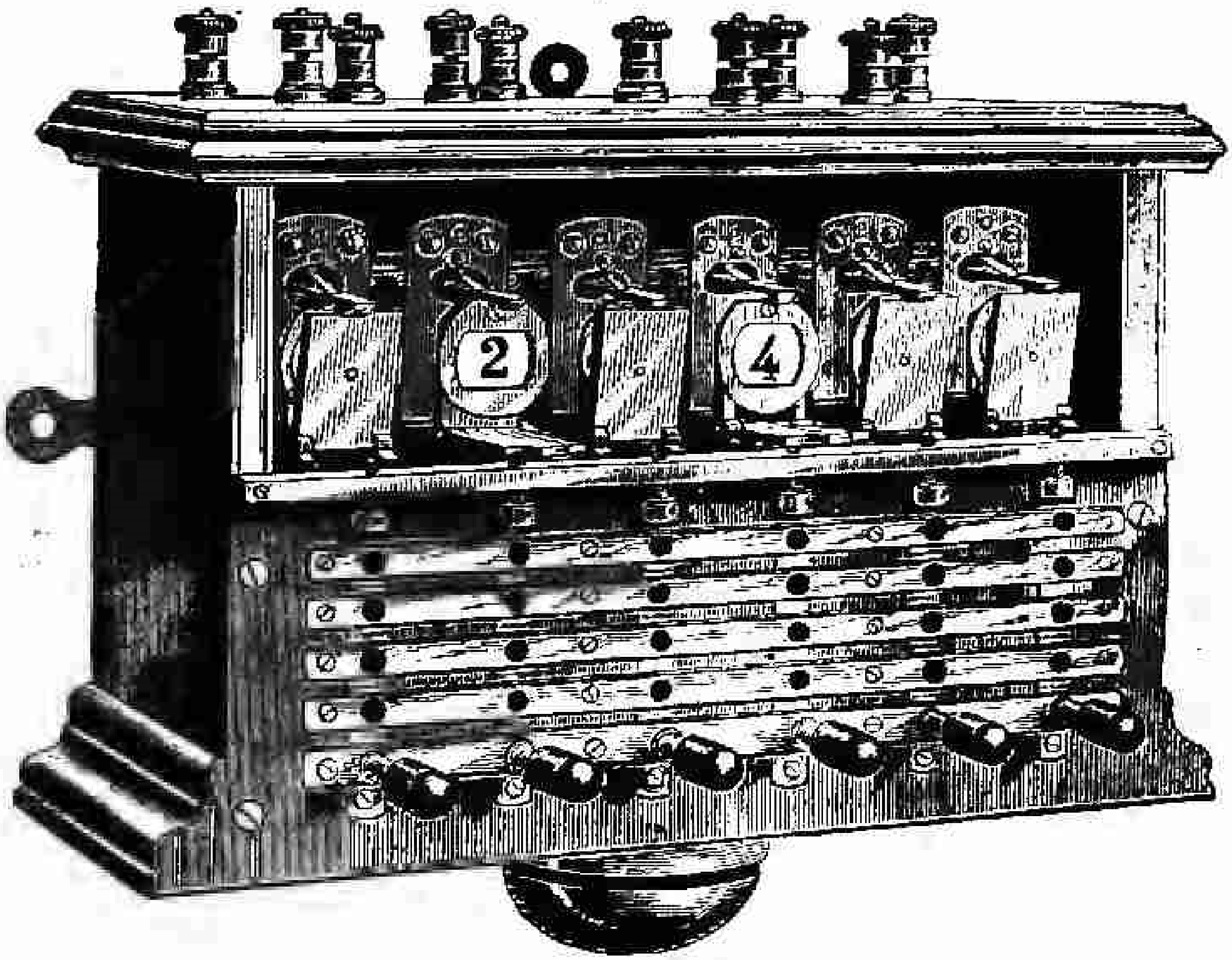
Referring to Fig. 185, it will be seen there are five annunciator drops at the top of the board, below this a similar number of spring-jacks, and at the bottom and supported on a small projection the connecting plugs. The plug-cords have a weighted pulley attached, so that when released they fall back into the convenient upright position shown.

The mode of operating is as follows:—Suppose No. 2 station rings, No. 2 annunciator falls and the operator inserts her plug in No. 2 spring-jack. She then ascertains what number is required, which, let us say, is No. 5, and the operator on hearing this inserts No. 2 plug in No. 5 jack, presses her ringing key (thus ringing the bells at both No. 2 and No. 5 station), and the two stations are in communication. It will be seen from this that the connections and disconnections are made in a very short time, allowing a better service, while at the same time the operator's work is considerably reduced.

Moreover, should one plug-cord fail the other is available; for instance, if Nos. 2 and 5 wish to communicate, either No. 2 plug can be inserted in No. 5 jack, or No. 5 plug in No. 2 jack; in both cases Nos. 2 and 5 would be connected together.

Another form of switch-board, much used for small private exchanges, is shown in Fig. 186, this form of board being also very suitable for stations arranged on the intercommunication system, in which case there is a switch-board at each station. Beneath the annunciator drops are, it will be seen from the

Fig. 186.



Bar Switch-board.

figure, five horizontal strips of metal, which are crossed at the back by six vertical ones, one from each drop. All these metal bars are perfectly insulated from one another, and are bored with a hole at each point where they cross. Thus it will be seen that by inserting a metal plug in any of the holes the corresponding horizontal and vertical bars are connected, and by inserting the plug in the correct hole any one station can be connected to any other.

The Société Générale des Téléphones System.

This system, which is somewhat extensively used for hotels, &c., on the Continent, is one of the few in which absolute secrecy between the stations in communication is obtained.

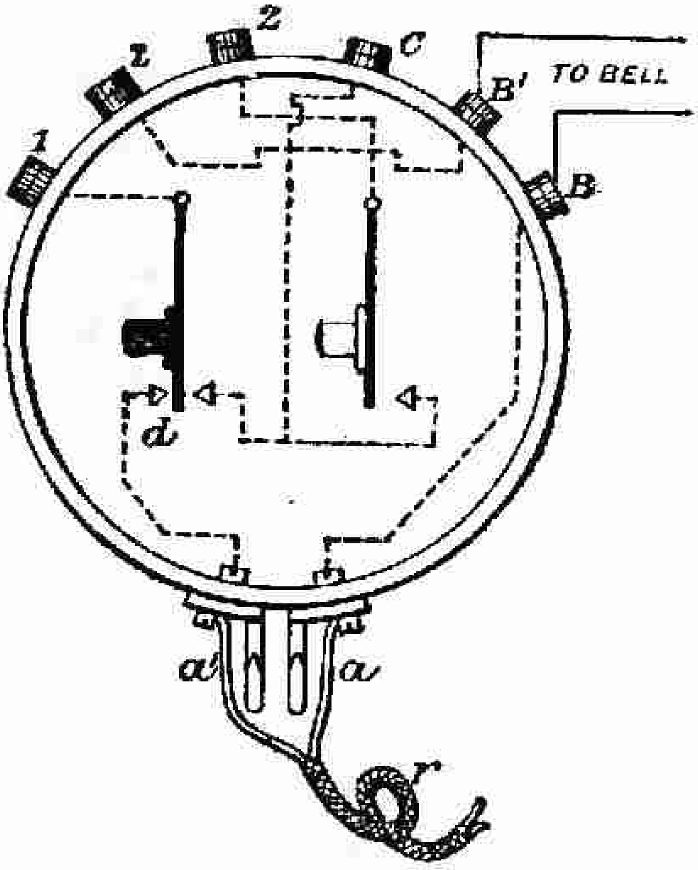
One of the most common objections urged against the exchange system of communication is that you can never be sure that part or even the whole of the conversation is not overheard either by the operator at the exchange, or in the intercommunication system by some inquisitive person at any of the other stations. For it will be seen, by referring to Fig. 176 and Fig. 178, that the operator at the exchange can, by sliding in the plug, place his instrument in circuit with the other two, and this without either of the speakers being aware of it. Similarly, on the intercommunication system, any one at either of the remaining stations can, by inserting the plug or moving the handle of the intercommunication switch, throw his instrument into circuit with any of the others. Thus the speaker is afraid to trust to the telephone matters of importance, and must either go to or summon the person to his presence, a proceeding likely very often to cause considerable inconvenience. In the system about to be described, however, there are none of these objections, and each station can, moreover, when put through, signal to the other station direct, as well as to the central station.

In Fig. 189 are shown four stations connected on this system, though any number can of course be similarly arranged. In the figure, Nos. 1, 2, 3, and 4 are the instruments at the different stations, A the switch-board at the central or switch-room, B the local bell, and D the battery, which can be located anywhere in the building, but should be preferably near the switch-board.

The telephone instrument is shown, with its inside connection, in Fig. 187, and the switch-board in Fig. 188.

The telephone instrument, it will be seen from Figs. 187 and 189, is of a similar form to that shown in Fig. 60, p. 75, except that it has two ringing buttons, a black and a white one. The telephone is not shown in Fig. 187, but hangs

Fig. 187.



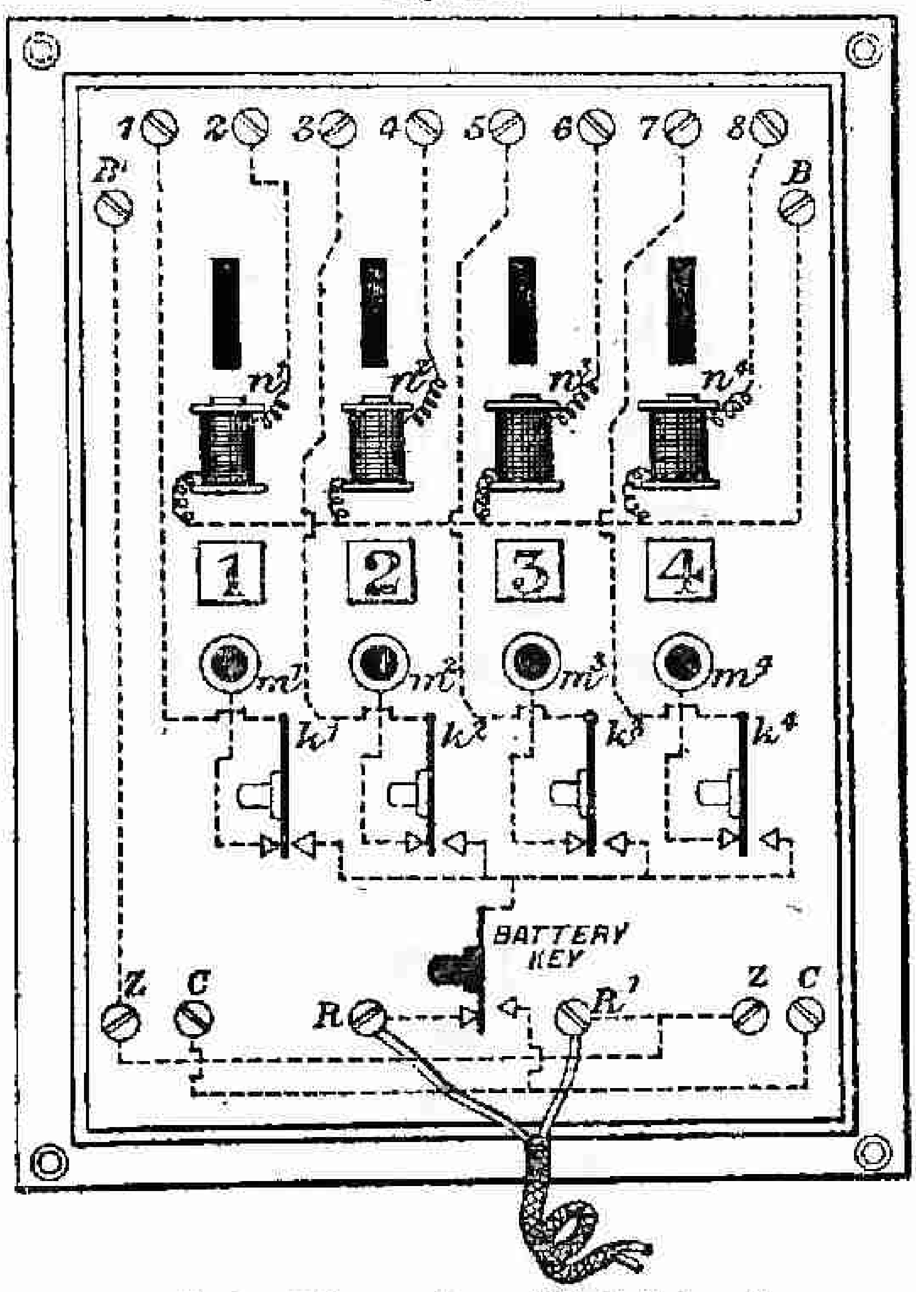
Internal Connections of Instrument.

when not in use on the two switch-hooks *a* and *a'* at the bottom. A separate bell is required with each instrument, though in some forms a buzzer is placed inside the wooden case.

The switch-board (Fig. 188) consists of a polished wood case, in which are contained the annunciator drops n^1, n^2, n^3, and n^4, the connecting plugs m^1, m^2, m^3, and m^4, the ringing keys k^1, k^2, k^3, and k^4, with white buttons, and the battery key at the bottom with a black button. At the top of the board are the terminals 1, 2, 3, 4, 5, 6, &c., for the wires from the different stations, just below these the terminals B and B' for the local bell, and at the bottom the battery terminals C and Z.

Referring now to Fig. 189, it will be noticed that only one battery is used for the whole number of stations, and that four wires run from each instrument, two of these being joined into the battery wires C and Z, which run from the

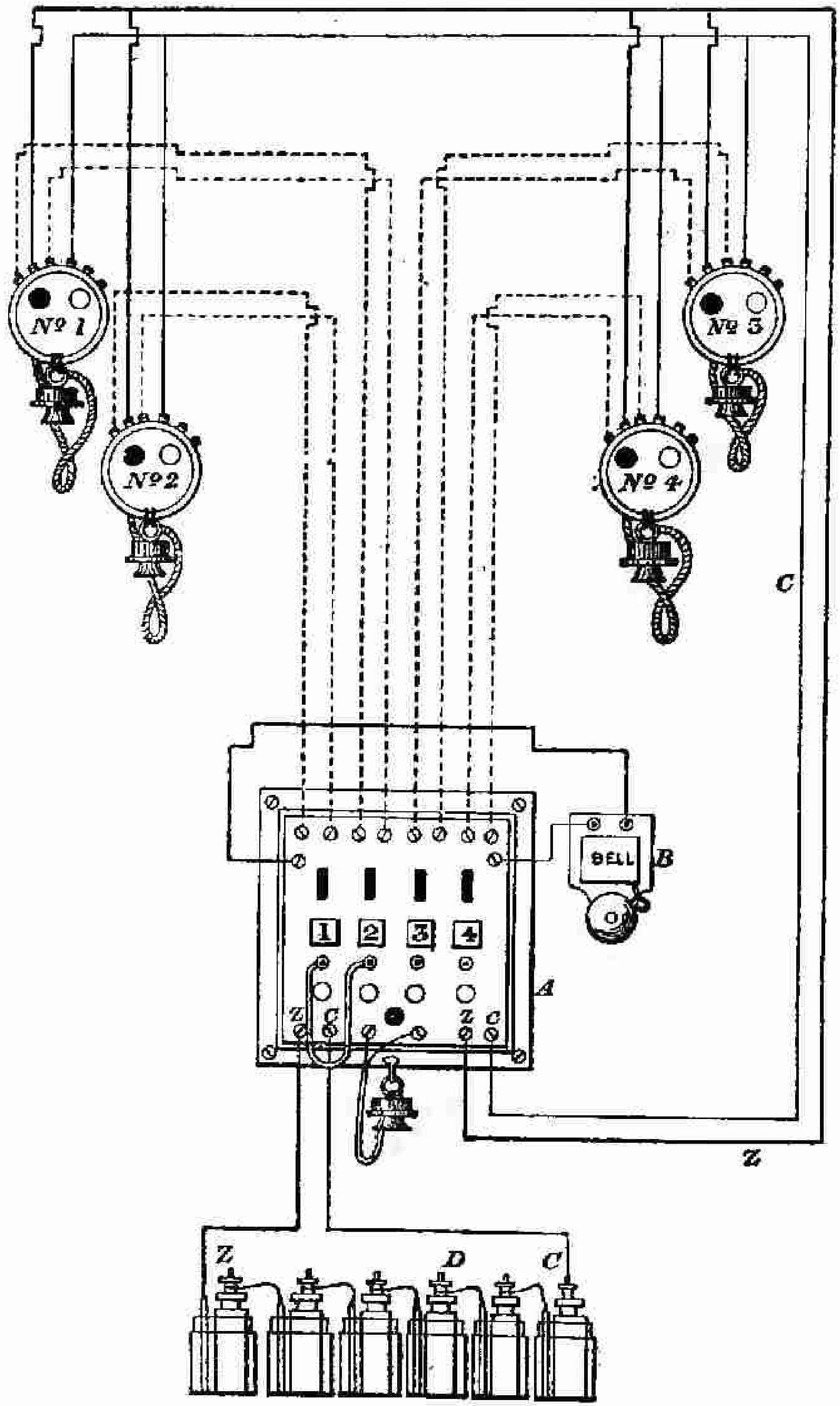
Fig. 188.



Internal Connections of Switch-board.

switch-board to the farthest station, picking up the others *en route*. By this means only one battery is required, and the cost of the extra wire is trifling to what would be that of the extra batteries. The two line-wires from each instrument, it will be noticed, are dotted, the one being thicker than the

Fig. 189.



Private Exchange System.

other to enable the connections to be better followed. The Z battery wire is also shown darker than the C wire.

The method of working is as follows :—We will presume No. 1 wishes to communicate with No. 2. The operator at station No. 1 then presses the white button of his instrument, which causes the bell at the central station to ring, and the annunciator No. 1 of the switch-board to drop, the circuit being as follows :—Starting from the pole C of the battery D (Fig. 189) terminal of switch-board, battery wire C, terminal C of instrument No. 1, bottom contact of white ringing key, key-spring, terminal 2 of instrument, line-wire, terminal 2 of switch-board (Fig. 188), annunciator drop n^1, terminal B, local bell, terminal B′, and thence to zinc pole of the battery.

The operator at the central station now presses the battery key (black button) of the switch-board, and also the ringing key k^1, which causes the bell at station No. 1 to ring in reply, the circuit being as follows :—Pole C of battery, bottom contact of battery key, key-spring, bottom contact of key k^1, terminal 1 of switch - board, line - wire, terminal 1 of instrument No. 1, key-spring of black button ringing key, top contact of key, switch-hook a, across to switch-hook a', by means of the metal supporting ring of the telephone, to terminal B, bell (not shown in figures), terminal B′, and from there back to zinc pole of the battery.

The person at No. 1 station, and also the one at the central station, now take the telephones off the hooks and conversation can be carried on, the person at the central station still keeping key k^1 pressed in, but releasing the battery key. The "speaking" circuit is now, starting from the telephone at the central station :—Telephone coil, terminal R of switch-board, top contact of battery key, key-spring, bottom contact of key k^1, key-spring, terminal 1 of instrument No. 1, key-spring of black button ringing key, top contact d, switch-hook a, through the telephone (now off the hook) to switch-hook a, terminal B, bell, terminal B′, Z wire, terminal R^1 of switch-board, and back to bobbin of telephone.

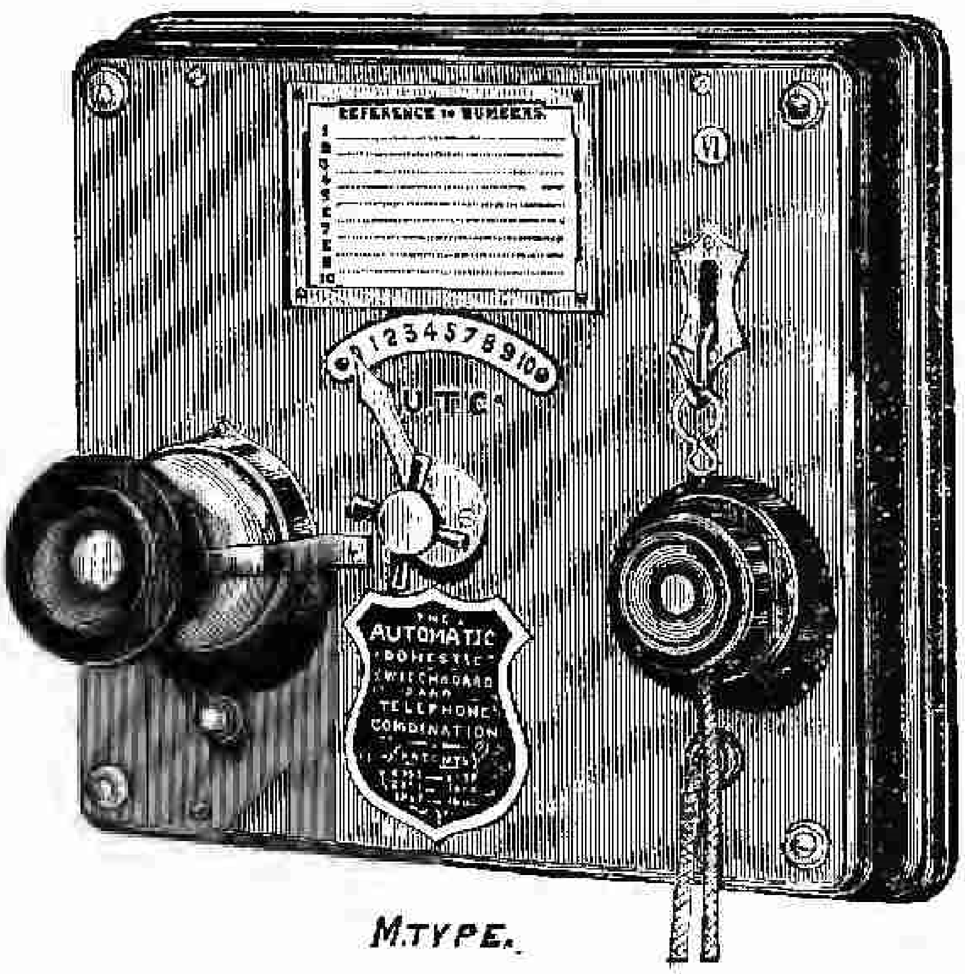
The person at station No. 1 now informs the central station that he wishes to speak to No. 2. The operator at the central station then takes the jack cord and places one end of the jack cord in plughole m^1 and the other in m^2, thus connecting terminals 1 and 9 of the switch-board together, and therefore instruments No. 1 and No. 2. The two stations being now in connection, the persons at either station can ring one another, *without affecting the central station*, by pressing the *black* button, and can also ring the central station by pressing the *white* button; moreover, should the person at the central station attempt to listen, both the person at station No. 1 and also No. 2 are made aware of it, by the conversation immediately being interrupted. For in order to listen he must put his instrument into circuit, to do which he will have to press either key k^1 or k^2, and to press either of these keys will at once break the connection between instruments No. 1 and No. 2, see Fig. 188.

THE CONSOLIDATED SYSTEM.

Fig. 190 shows a form of switch-board so designed that the index hand and also the arm of the switch automatically return to zero when the receiver is replaced on the switch-hook. An objection to the ordinary intercommunication system is that it is necessary, for the persons at both stations, after having finished, to turn the handles of their switches to zero, otherwise they cannot be rung up; and it is evident that as this returning is dependent exclusively on the memory of the operator, it is liable to be sometimes omitted. This objection is entirely obviated in this switch, and also in the system next to be described.

Referring to Fig. 190, the switch is in the centre of the board, and the index must be moved to the number required. When finished speaking the receiver is hung up on the hook, which in moving down releases a catch, and the index flies back to 0.

Fig. 190.



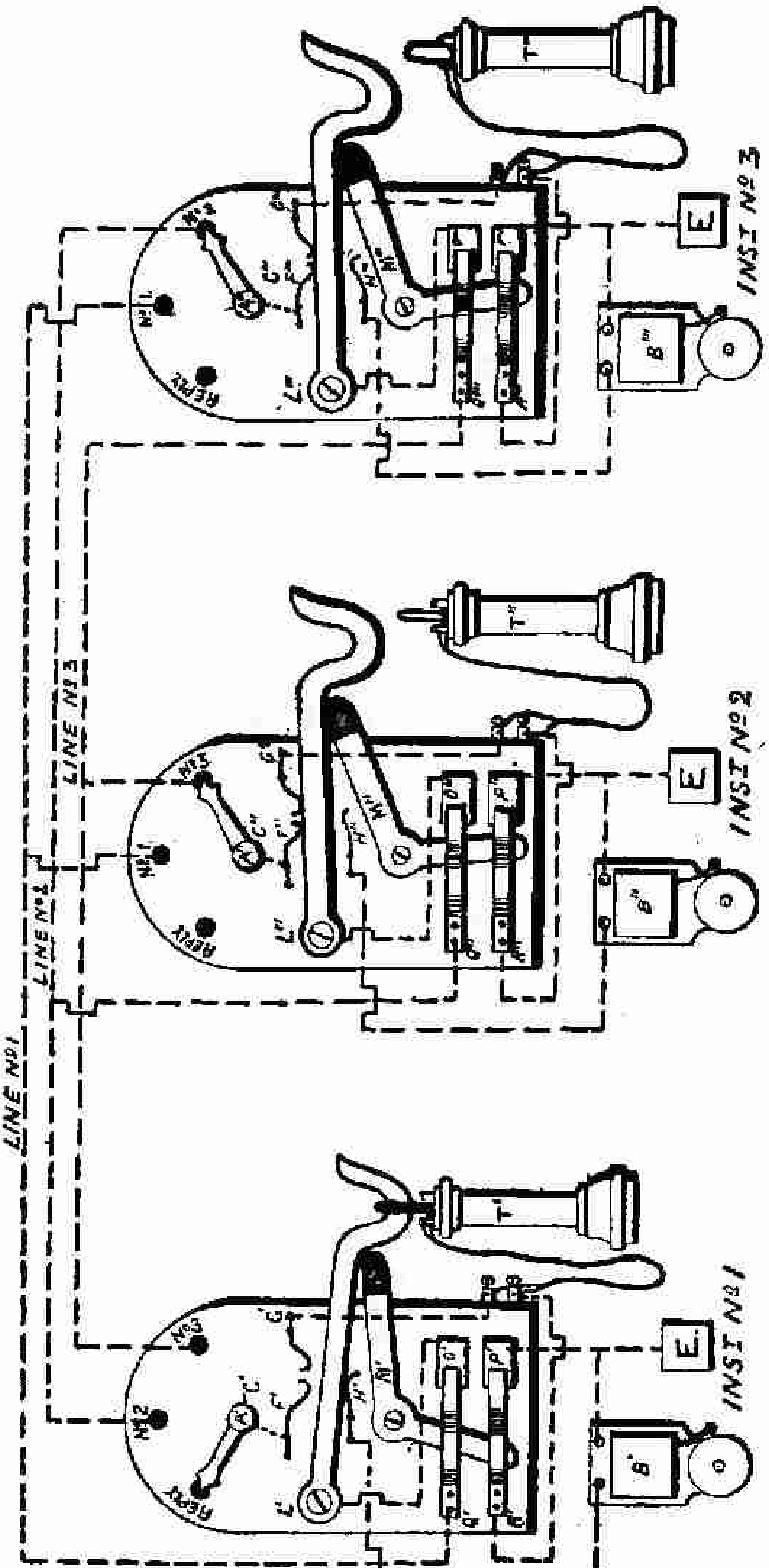
Switch-board with automatically returning Index.

The "Secret Circuit" Intercommunication System.

Another objection to the ordinary intercommunication system is that any person at any station on the system can, by placing the arm of his switch to either of the numbers that are talking, overhear the whole of the conversation, and this without either of the stations being aware of it. A neat and ingenious intercommunication switch that entirely does away with both this objection and the previously mentioned one of the necessity of returning the arm of the switch to zero, has recently been devised by Mr. Thomas B. Sloper.

Briefly stated, the principle of the system is this:—When secrecy is not required, the line-wire and earth return are used similar to the ordinary intercommunication system, but by

Fig. 191.



The "Secret Circuit" Intercommunication System.

moving a knob underneath the telephone hook all "earth" is cut off, and the two line-wires of the two stations that are speaking used as "line" and "return."

Three instruments arranged on this intercommunication system with secret-circuit switches are shown in Fig 191. The switches are usually made up in combination sets, with microphone, bell, &c., but this illustration shows the connections without a microphone. Station 1 is shown, ready to receive a call. L is the lever on which the receiver is hung when not in use. H is a spring connected through the bell to earth. This spring H makes contact with L only when the receiver is hung up. G is a spring connected to one terminal of the telephone, and F is another spring in connection with the switch arm C. F, G, and the lever L are all insulated from each other when the receiver is hung on the hook L, but the latter is drawn up by a spring in the usual manner after the receiver is removed, thus making contact with both G and F. The line is connected to a spring Q, which is in contact with O and the lever L. The telephone is in connection with spring R, and to "earth" through P. The ringing contact is situated between F and C, and is the same as illustrated in Fig. 192.

The switch arm C may be left on either contact, and it will not interfere with the working of the system (which would be the case with other systems), but upon *receipt* of a call it should be directed to "reply," which disconnects it from all the lines, and conversation can then be carried on, the earth being used for return. Should the message be of a private nature, the called station moves his switch arm C to the number of the station he is talking to, and both stations raise their lower levers M, which puts the secret circuit into operation, when no other station can overhear or disturb. In Fig 191, stations 2 and 3 are shown connected as a "secret circuit," the course being from telephone T″ through springs G″ and F″ to No. 3 line, then through Q‴, M‴ and spring R‴ to telephone T‴ through G‴, F‴, and C‴ to line No. 2, then through Q″, M″

and R″ back to telephone T″. The act of replacing the receiver *automatically* puts the connections in their normal position, so that it is impossible to leave an instrument in such a position that a call cannot be received.

Figs. 192 and 193 show the intercommunication switch *without* secret lever, Fig. 192 being a section of Fig. 193. In the centre of the wood case A revolves the spindle P, carrying the index C, which points to the numbers at H. The spring B is connected to one pole of the battery, and F is connected to the spring F in Fig. 191. S is a spring used to keep the spindle T towards the front of the switch, this spindle being free to revolve and pressed inwards. D is a disc which is

Fig. 192.

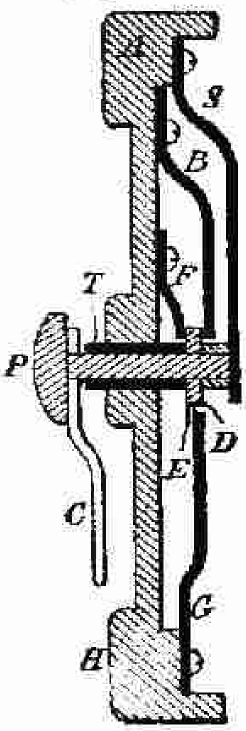
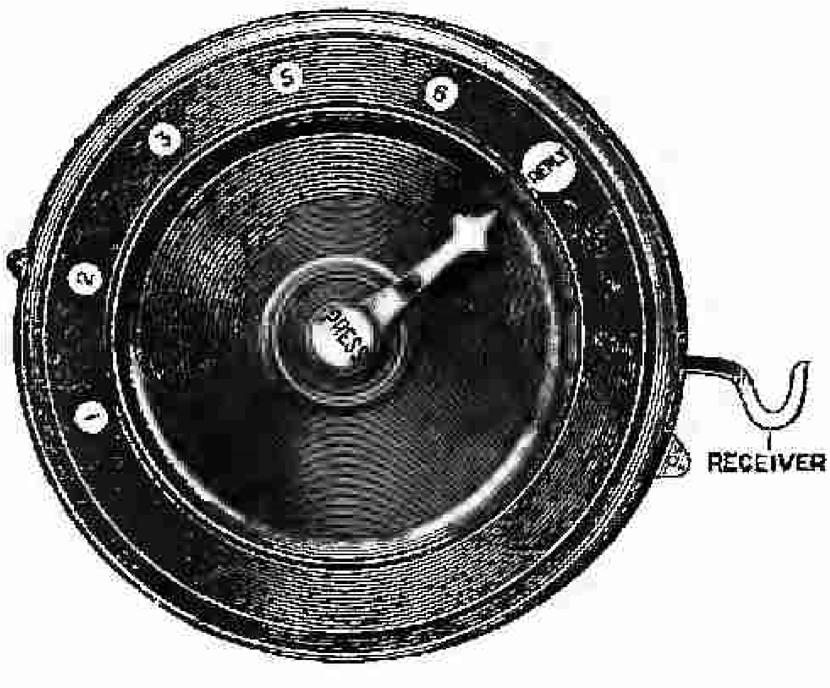


Fig. 193.



Sloper Intercommunication Switch.

fixed to the spindle T, and has a projection E, which makes a contact with the spring G, or any other spring that the index C is pointed to. The index being directed to the line required, the centre of the switch P (which is marked "Press") is pressed inwards, which causes the disc D to break contact with F and to make contact with the battery spring B, which sends a current to the line the projection E is in contact with, and so rings the distant bell.

CHAPTER XI.

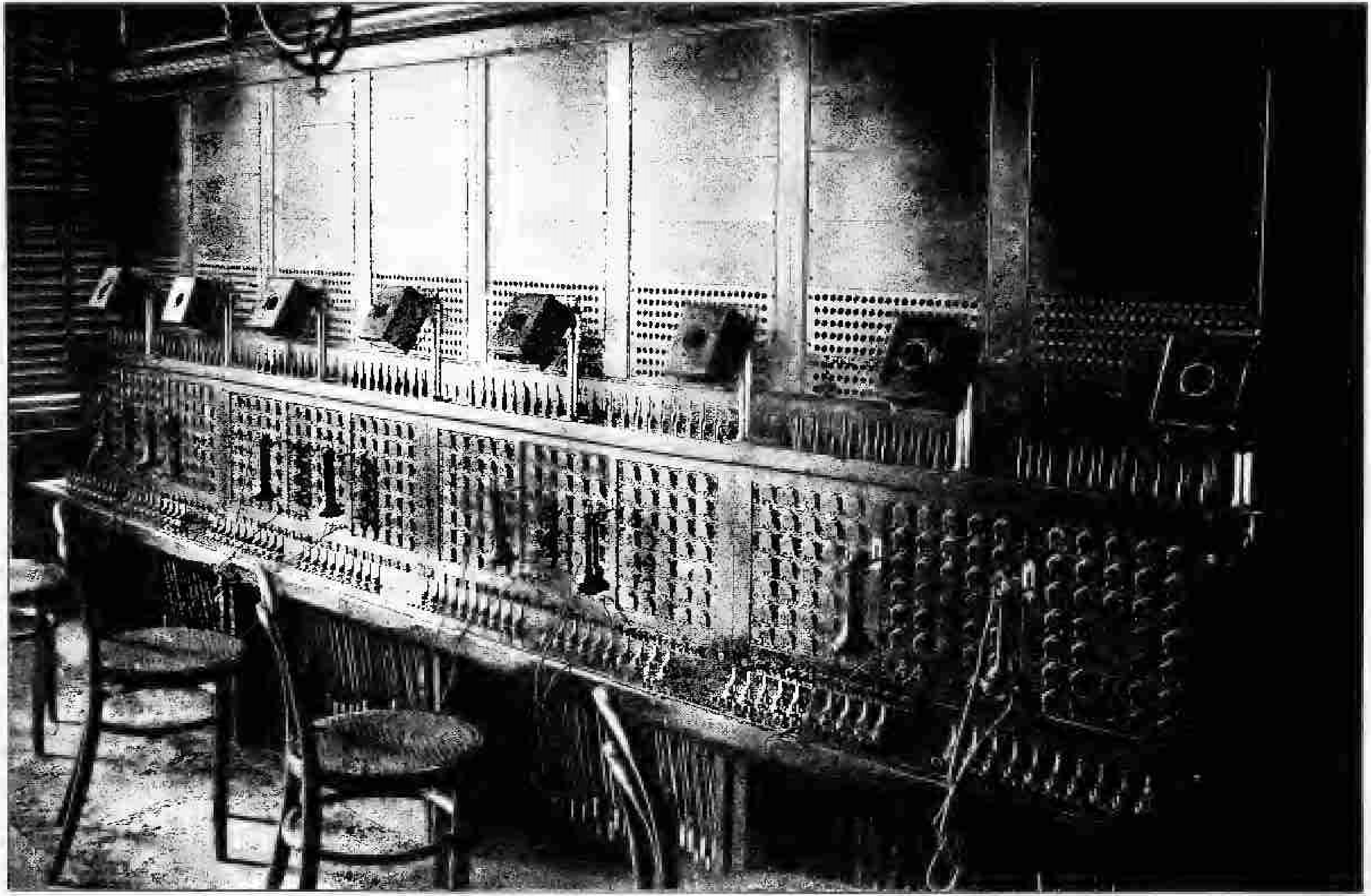
PUBLIC EXCHANGE SYSTEMS.

Of the various exchange systems now in use, the more prominent are those of the Western Electric Company, the British Post Office, the Société Générale des Téléphones in France, and the Law system and its modifications. In an exchange system wires are run from each subscriber to a central office, in which are erected special switch-boards whereby any one subscriber can be connected to any other on that exchange. Sometimes, instead of the wires being taken to one exchange, the town is divided into sections, with an exchange in each section to which the nearest subscribers are connected, the different exchanges being also connected.

In connecting the subscribers to the central exchange or switch-room either single wires with "earth return" are used or else double wires and no "earth," this latter being the best method (as it eliminates all inductive noises) and the one that no doubt will be chiefly employed in future. In some systems a combination of both methods is used, the two wires and earth return being employed for signalling, and the metallic circuit for speaking.

To attract the attention of the operators at the exchange there are two methods in general use, first, and this is the more usual way, by means of an indicator in circuit with the subscriber's line, and second, by the employment of a separate wire, known as the call or service wire, on which the operators listen continually. The switch-boards used at the exchanges are, for a small exchange, the ordinary standard pattern, and for a large exchange, or where there is a heavy service, multiple ones.

Until quite recently the erection of public exchanges in this country was divided between the National Telephone Company and the Government, the former owning by far the greater proportion. With the expiration of the patents, however, competition has arisen, which will, it is to be hoped, bring about a greatly improved service and a general reduction of rates. The company rent the instruments to the subscribers, who pay an annual sum (varying from 10*l.* to 20*l.*) for their use, the company running all the necessary wires, &c., and keeping same in repair free of charge. The system employed by the National Telephone Company is mainly that of single wires with "earth" return and Western Electric multiple switch-boards, except in the small exchanges, where standard boards, either double or single cord, are used. The wires from the subscribers to the exchange are run overhead, and the subscribers are provided with magneto switch-bell instruments of the form shown in Fig. 70. The different towns in each district are rapidly being connected one to the other, so that a subscriber in one town can speak with another in a town 50 or 60 miles away. For instance, London is in telephonic communication with Brighton, Birmingham, and Manchester, as well as Paris; while the neighbouring towns around these first three centres are also connected, so that in a few seconds one subscriber can be switched on to another in any of these towns. These lines connecting the different towns or different exchanges in a town are called "trunk" lines, to distinguish them from the subscribers' lines. Complete metallic circuits are always employed for trunk lines to get rid of inductive noises, and as a further prevention the wires are run on some twist system after the manner shown in Figs. 158 and 159. The exchange system



E & F. N. Spon, London & New York

THE WESTERN ELECTRIC CO.'S MULTIPLE SWITCHBOARD.

most widely used is that of the Western Electric Company, a description of which will now be given.

The Western Electric Company's Multiple System.

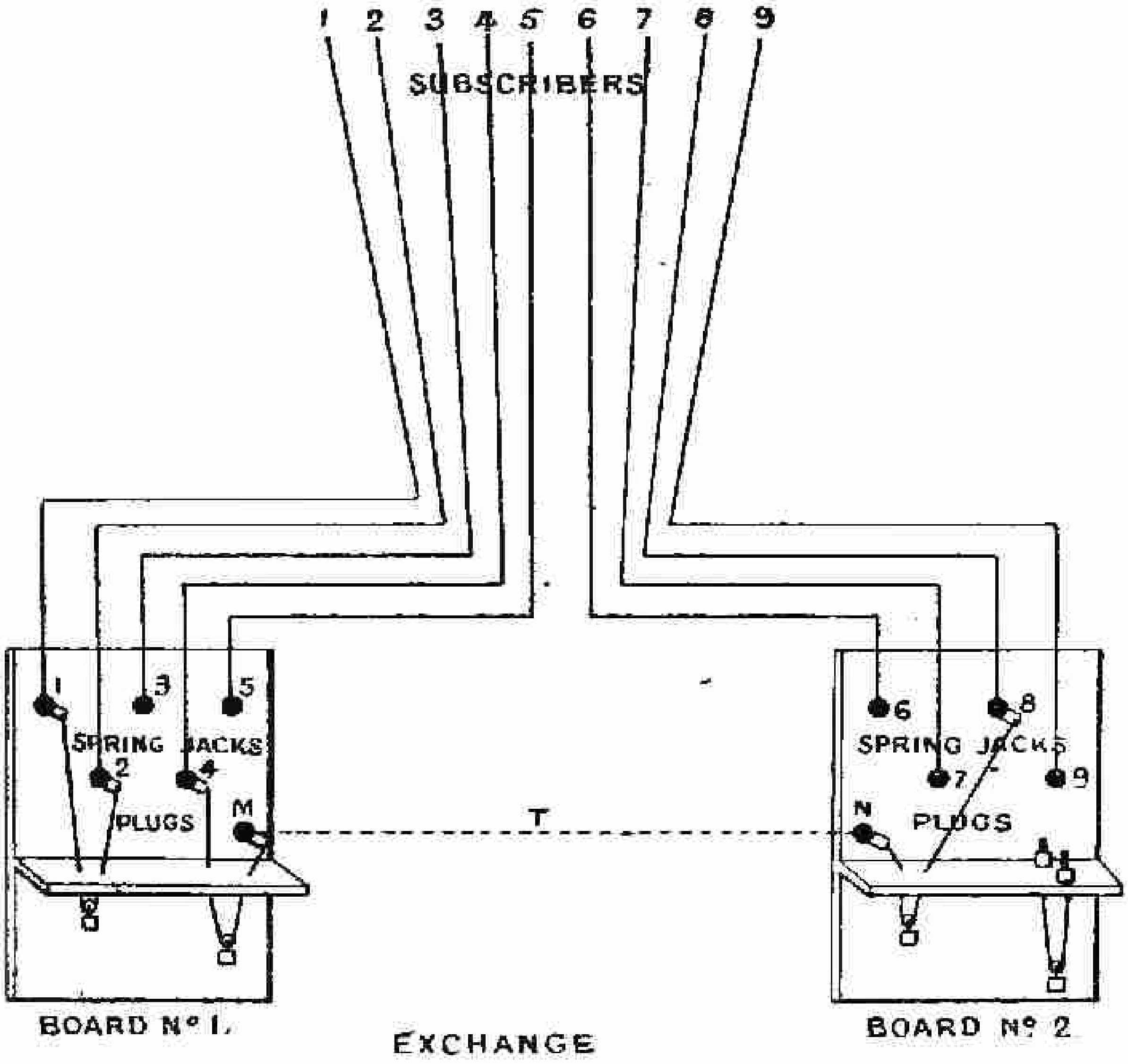
This system is specially adapted for coping with very large numbers of subscribers, and as the number increases, so fresh sections can easily be added to the board. It can be employed with either single or double wires, though in this country, as used by the National Telephone Company, single wires and earth returns are almost always used.

The frontispiece shows a part of the Berlin exchange, which is fitted throughout on the Western Electric Company's system, and Fig. 194 shows a portion of the multiple switch board (also made by the same company) at the National Telephone Company's Brighton exchange, with which exchange the writer was formerly connected. The Berlin board differs slightly from the Brighton one, the former being a single and the latter a double cord.

Before the invention of multiple switch-boards, public telephone exchanges in this country were worked similar to the method shown in Fig. 176, all the subscribers' lines being terminated at a large board, having an annunciator and spring-jack for each line. One or two of the operators sat at tables provided with instruments by means of which they answered the calls of the subscribers, and on learning the numbers required called them out to other operators at the board, who then made the necessary connections. This method answered very well when there were only a few subscribers, but as the number increased, the noise and confusion arising from such a mode of operating necessitated other means being adopted.

The first improvement was to allot to each operator fifty or one hundred lines which terminated at her board, and to which number she had to attend, answering the calls of the subscribers and making all the necessary connections. This arrangement is illustrated in Fig. 195, which shows nine subscribers connected to the central exchange to two standard boards, five to one board, and four to the other, the boards for simplicity being shown diagrammatically and without drop or operators' instruments.

Fig. 195.



Standard Switch-board.

It will be seen that No. 4 on Board 1 is connected to No. 8 on Board 2, connection being made by means of the separate spring-jacks M and N, and the wire T.

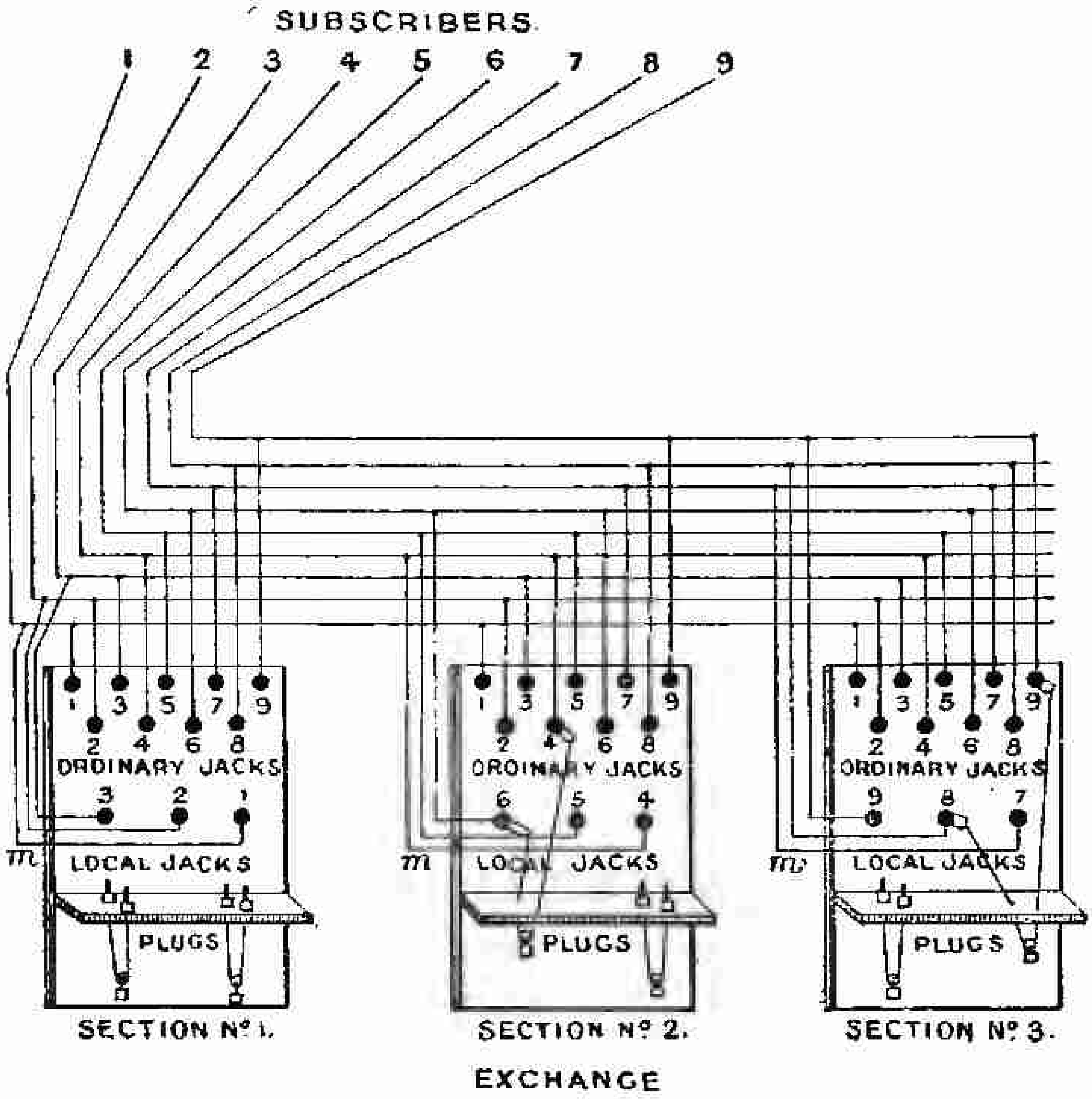
The great disadvantage in this method is that any subscriber not on one operator's board had to be asked for from another, and connection made between the two boards by means of a special wire, an arrangement that means considerable loss of time; and it was not until the introduction of the multiple switch-board that a quick and comparatively silent service was obtained.

The principle of the multiple switch-board will best be understood by referring to Fig. 196, which shows nine subscribers connected up to the central exchange on this system; though it must be borne in mind that this figure does not show the actual method of connecting up the spring-jacks. The board is divided into sections, and a certain number of subscribers' lines (generally about 200) are allotted to each section, these lines being terminated in the diagram at the local spring-jacks. In addition to this the line of *every* subscriber whose wire runs into the exchange passes at the back of *all* the sections and is connected to the "ordinary" spring-jacks as shown in Fig. 196. Thus the operator at each section can connect any one of the subscribers allotted to her to any other subscriber on the exchange without moving from her place.

In Fig. 196 the nine subscribers are allotted three to each section. Section No. 1 takes wires 1, 2, and 3, section No. 2 wires 3, 4, and 5, and section No. 3 wires 7, 8, and 9, these wires being marked with the letter *m* to distinguish them from the wires running to the ordinary jacks. In section No. 2 it will be noticed No. 6 subscriber is connected to No. 4, and in section 3 No. 8 subscriber to No. 9.

We will now proceed to a more detailed description of the multiple switch-board, which derives its name from the fact that the points at which connection can be made to any one line are *multiplied*. Referring to the Brighton board, shown in Fig. 194, it will be seen that it is divided into sections or tables, only two of which sections are shown. Strictly speaking, the build of this board differs slightly from the usual pattern, being put together in half instead of whole sections, which half sections can be seen by the joins in the woodwork. This, however, does not affect the general construction or working of the board. Each section is divided into four panels, and in the panels of each section are fixed the ordinary spring-jacks, the circular openings of which only are visible, these jacks being arranged in five rows of 20 in each panel, making

Fig. 196.



Multiple Switch-board.

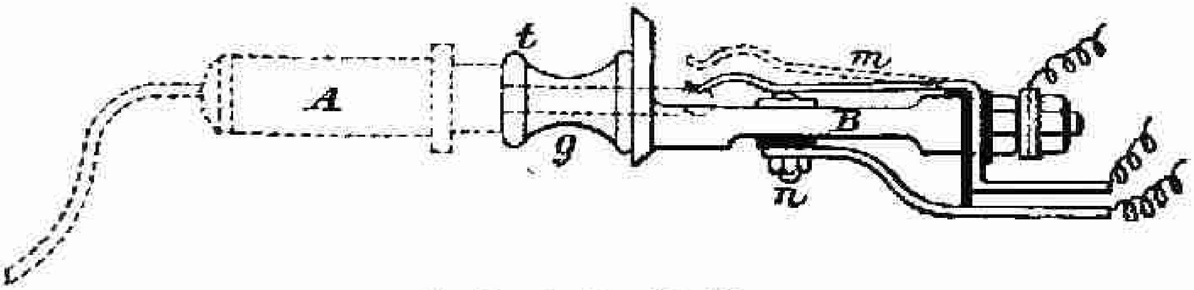
400 altogether. Beneath these jacks are the 200 local spring-jacks, to which are connected the wires of those subscribers that terminate in that section. Immediately below the local jacks and on a ledge about 6 inches wide can be seen 40 pairs of connecting plugs, the cords of which pass down behind the

board and are visible underneath. These cords are weighted with pulley weights, which cause the plugs to stand in a vertical position and prevent the cords from twisting. Underneath the plugs will be seen in each section of the board 200 annunciator drops, one for each subscriber's line that terminates in that section, and immediately below these 40 smaller annunciators, one of which is in circuit with each pair of plugs. These 40 annunciators are called the "clearing-out" or "ring-off" drops. On a projecting ledge below these drops are 40 switches, in front of which are 80 ringing keys, two to each switch, these switches and ringing keys being also in circuit with the plugs. When the lever of a switch is depressed it puts the operator's instrument in connection with that pair of cords corresponding to the lever depressed. The operator's receivers can be seen hanging up by the annunciators, and the transmitters (Blake's) are supported by brass standards from the ledge carrying the plugs.

It will be noticed that there is ample room above the ordinary spring-jacks for more to be added, and as the number of subscribers increases a strip of the woodwork is taken out of each panel, and 200 additional spring-jacks added to each section. Another section is also added at the end of the board to take the terminating wires of these new subscribers, so that the length of the board continually increases, and this fact should be kept in view when selecting a room for exchange purposes. The size of the space for the ordinary spring-jacks determines the ultimate number of subscribers the board will carry, or, what is called its "ultimate capacity." The ultimate capacity of the Brighton board is 2000 subscribers.

An enlarged view of the spring-jack with the connecting plug in place is shown in Fig. 197, the plug being indicated by the dotted lines. The jack consists of the metal body B, to which is attached the spring *m* and pin *n*, both of which are perfectly insulated from the metal body. A hole is bored in the shank *g*, of the jack, through which passes the point of the plug when inserted for the purpose of making a connection. In its normal position the spring *m* presses firmly against and makes contact with the pin *n*, but when the plug A is

Fig. 197.

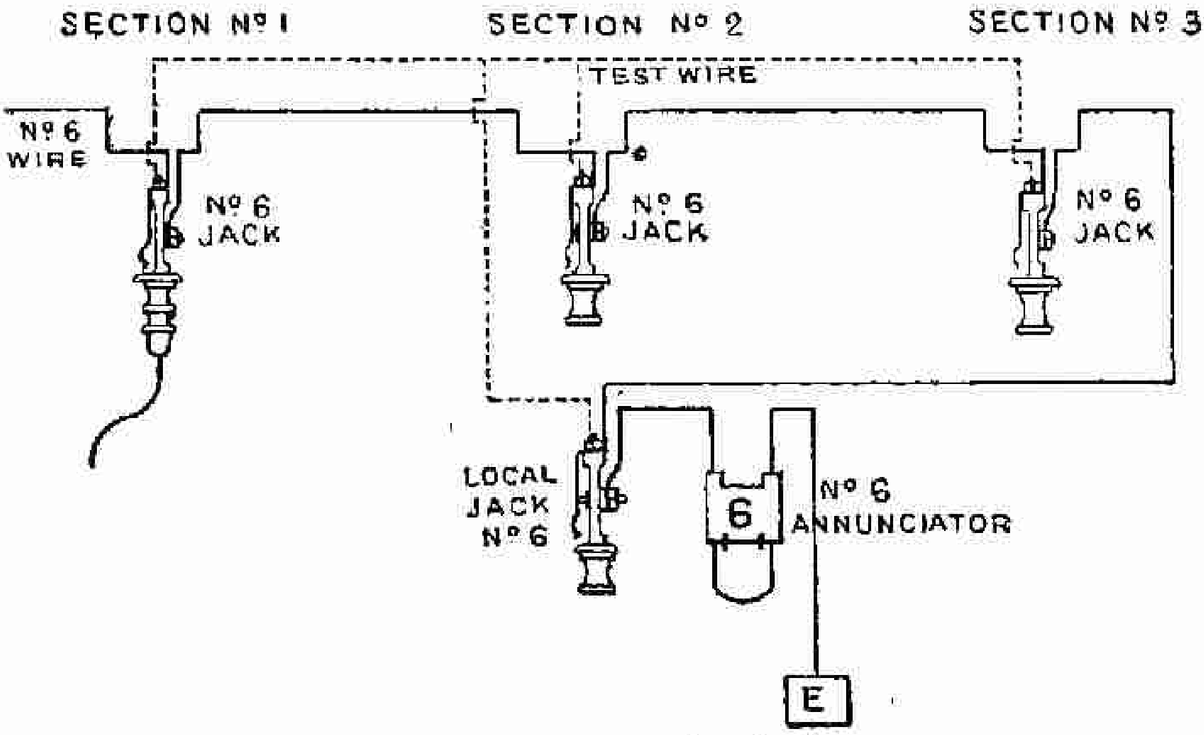


Spring-jack with Plug.

inserted it is moved into the position shown by the dotted lines. This causes the spring to make contact with the end of the plug and break contact with the pin *n*, the spring *m* also making connection with the metal body of the jack through the point of the plug. The jack is inserted in the woodwork of the switch-board till the flange *t* comes flush with the surface, leaving only the opening exposed as in Fig. 194.

The connections of the spring-jacks on different sections of the board will best be understood by referring to Fig. 198, where the wire of No. 6 (see Fig. 196) subscriber can be followed through the spring-jacks of three sections of the board. The wire of No. 6 subscriber passes first though the ordinary jack No. 6 of section No. 1, next to ordinary jack No. 6 of section 2, then to ordinary jack No. 6 of section 3, and lastly to local spring-jack and annunciator, No. 6 in section 2, and thence to "earth." No. 6 being one of the wires allotted to section No. 2. If the operator at any of the sections has a subscriber who wishes to speak to No. 6, she inserts the plug on one end of the connecting cord into the local jack of the "calling" subscriber and the other into spring-jack No. 6. The effect of this is to raise the spring *m* (see section 1, Fig. 198) off the contact *n* and connect it to the plug, and the two subscribers are through, the spring *m* also being connected to the metal body of the jack as before described.

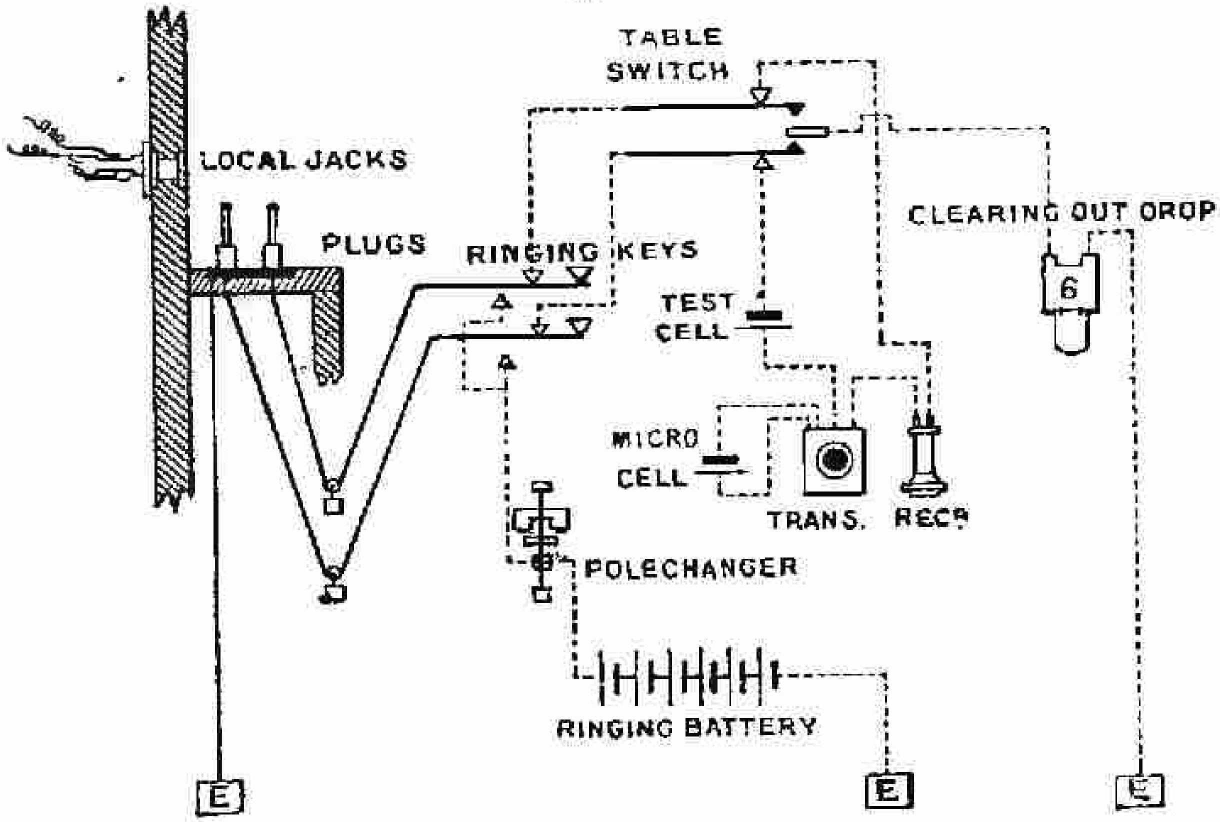
Fig. 198.



Connections of Spring-jacks.

This brings us to one of the most ingenious points of the board, that is the "engaged test." It is obvious that as there are numerous places in the switch-room where a line may be connected, some means of readily ascertaining whether the "wanted" line is already in use becomes indispensable. The way in which this is done in the Western Electric Company's board is simple, ingenious, and efficient. On referring to Fig. 198 it will be seen that all the spring-jacks on every section of the board are connected by a separate insulated wire as shown by the dotted lines, and this wire is called the "test wire." So long as all the spring-jacks of the one number are without a plug in them this wire is perfectly insulated, but on inserting a plug (as shown in section, 1 Fig. 198) the test wire, it will be seen, gets "earthed" through the subscriber's line. In the line circuit of the operator's instrument is an extra cell called the test cell (see Fig. 199), so arranged that if the operator touches the metal body of the "wanted" line spring-jack with the end of the cord to which she has previously connected her instrument by pressing down one of the switches, a "click" will be heard in her receiver

Fig. 199.



Connections of Plugs in Multiple Switch-board.

should the line be engaged. This click is caused by the test cell getting a complete circuit in one direction through the "calling" subscriber's, and in the other through the "wanted" subscriber's instrument, by way of the metal frame of the spring-jack and test wire.

The clearing-out drops, ringing keys, &c., are in circuit between the two plugs of each connecting cord as in Fig. 199, which shows how the different parts are generally connected up in the multiple board. The table switch has two positions. In its normal position, the top and bottom springs make contact with the centre plate, but when the lever is moved, the springs make contact as in the figure. With the switch in the position shown, it will be seen, the circuit runs from one plug to the other through the ringing keys, switch, and operator's instrument, but with the switch in the other position, both plugs are connected to earth through the clearing-out drop.* The back ends of the plugs when they are not in use make contact with metal plates in connection with "earth."

The method of operating the board is as follows:—Let us suppose subscriber No. 75 wishes to speak to No. 120. Subscriber No. 75 turns the handle of his generator and drops the shutter of No. 75 annunciator at the exchange. The operator (in whose section No. 75 happens to be) at once inserts one of the plugs in No. 75 local jack, and pressing down the switch corresponding to the number of the connecting cord she is using takes off the receiver and asks the number required, in this case No. 120. She then takes the plug on the other end of the cord, and touches it momentarily on the hole of No. 120 subscriber's spring-jack, thus getting connection on to the metal body of the jack. Should she hear a click she knows the line is in use, and informs No. 75 that the line is at present engaged. If no sound is heard on touching the spring-jack she at once pushes the plug home, and pressing down one of the ringing keys rings the bell of subscriber No. 120, and the two subscribers are through. The operator listens until she hears the conversation commence, when she pulls over the switch lever and cuts off her instrument from those two subscribers. When the conversation is finished, the subscribers turn the handles of their generators, thus dropping the shutter of the "clearing-out" drop corresponding to the connecting cord in use, and the operator at once withdraws the two plugs.

It will be seen from Fig. 199, that when either of the ringing keys is pressed a current is sent to that subscriber's line to

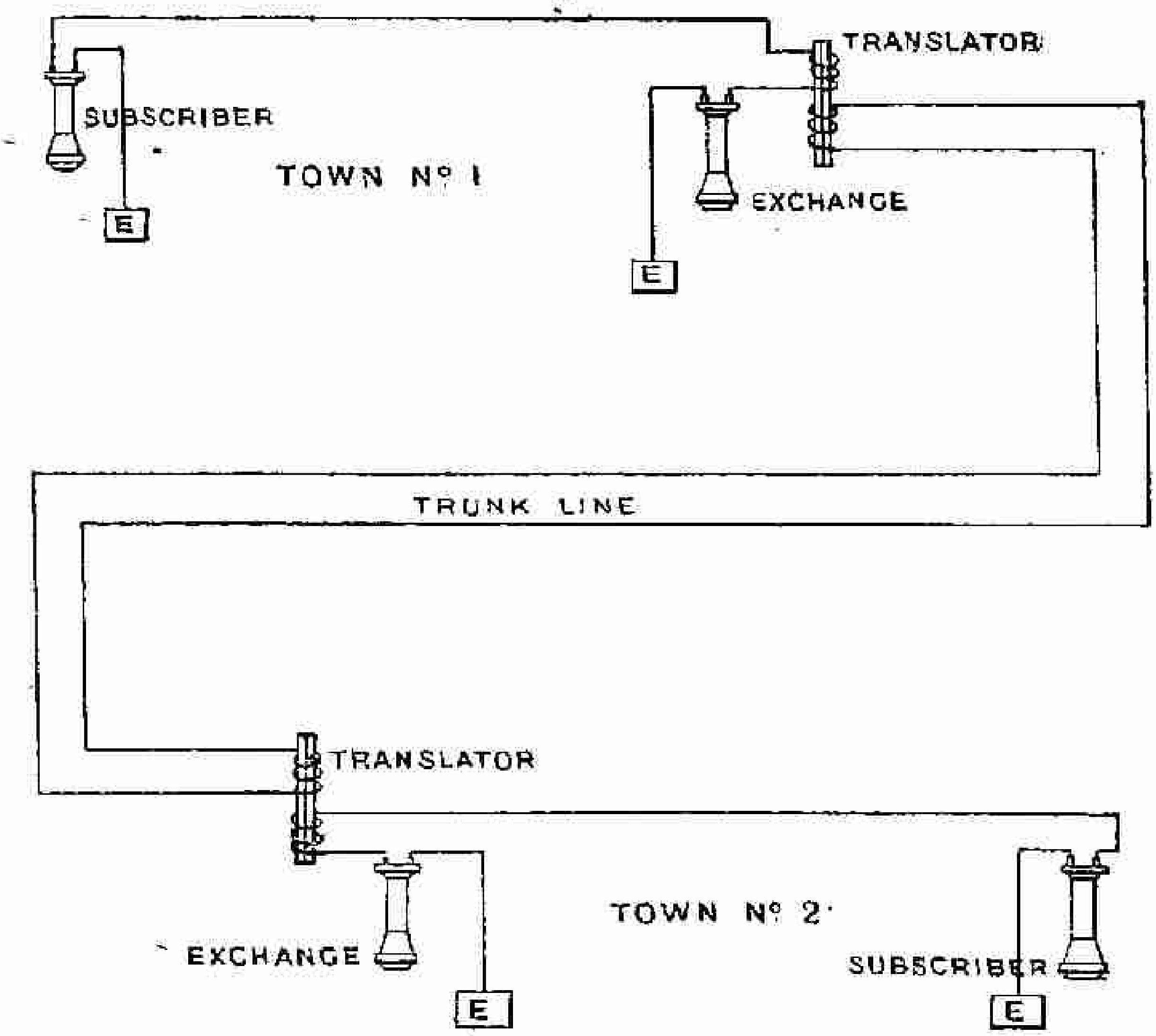
* The clearing-out drop when connected as in Fig. 199 is in a branch circuit to "earth," the drop being of a special form called a "retardation drop." In the older forms of boards the clearing-out drop is in series with the two plugs.

which the plug happens to be connected. This ringing current is furnished either by a magneto generator kept running continuously by a water motor, or by a battery of ten or twelve gravity cells in conjunction with a *pole-changer.* A pole-changer is a piece of apparatus so arranged that the current from the battery as it passes through it is sent first in one direction and then the other, one moment the positive pole of the battery being to "line" and then the negative. The unidirection current of the battery is thus transformed into an alternating one suitable for ringing the magneto bells of the subscribers.

For the trunk lines between the different towns, double wires without "earth" are, as was before mentioned, always employed, chiefly because were an "earth" return used on these long lines, the noise arising from induction from neighbouring wires would quite overpower the speech. On the London and Brighton trunk line, for instance, the line runs for about 50 miles in close proximity to the telegraph wires on the railway, and when a trial was made of a single wire with earth return, the inductive noises were very loud, a rapid "click, click" being the predominating sounds. Double wires, however, run on some cross-over system, as shown in Fig. 158 completely do away with the trouble from induction, as the effect on the "line" wire is neutralised by that on the "return." A difficulty that presented itself first connecting up the different towns was how to connect the subscribers' lines to the trunk wires without putting "earth" on to the trunk wires and thus destroy their freedom from induction. For instance, the subscribers in London and Brighton have single exchange wires with earth returns, while the trunk line is a complete metallic circuit, and it is evident that to connect the subscribers direct to the trunk line is to at once put it to "earth." This difficulty is overcome by employing at each end of the trunk line a *translator*, the connections being as shown in Fig. 200

The translator consists of an induction coil, the two circuits of which are wound with an equal number of turns, and have about the same resistance. The one circuit is connected to the trunk wires, and the other to the subscriber's line as shown, the currents in the one coil being reproduced in the other by induction, with of course a slight loss. Thus the trunk line, it

Fig. 200.



Trunk Wires between Towns.

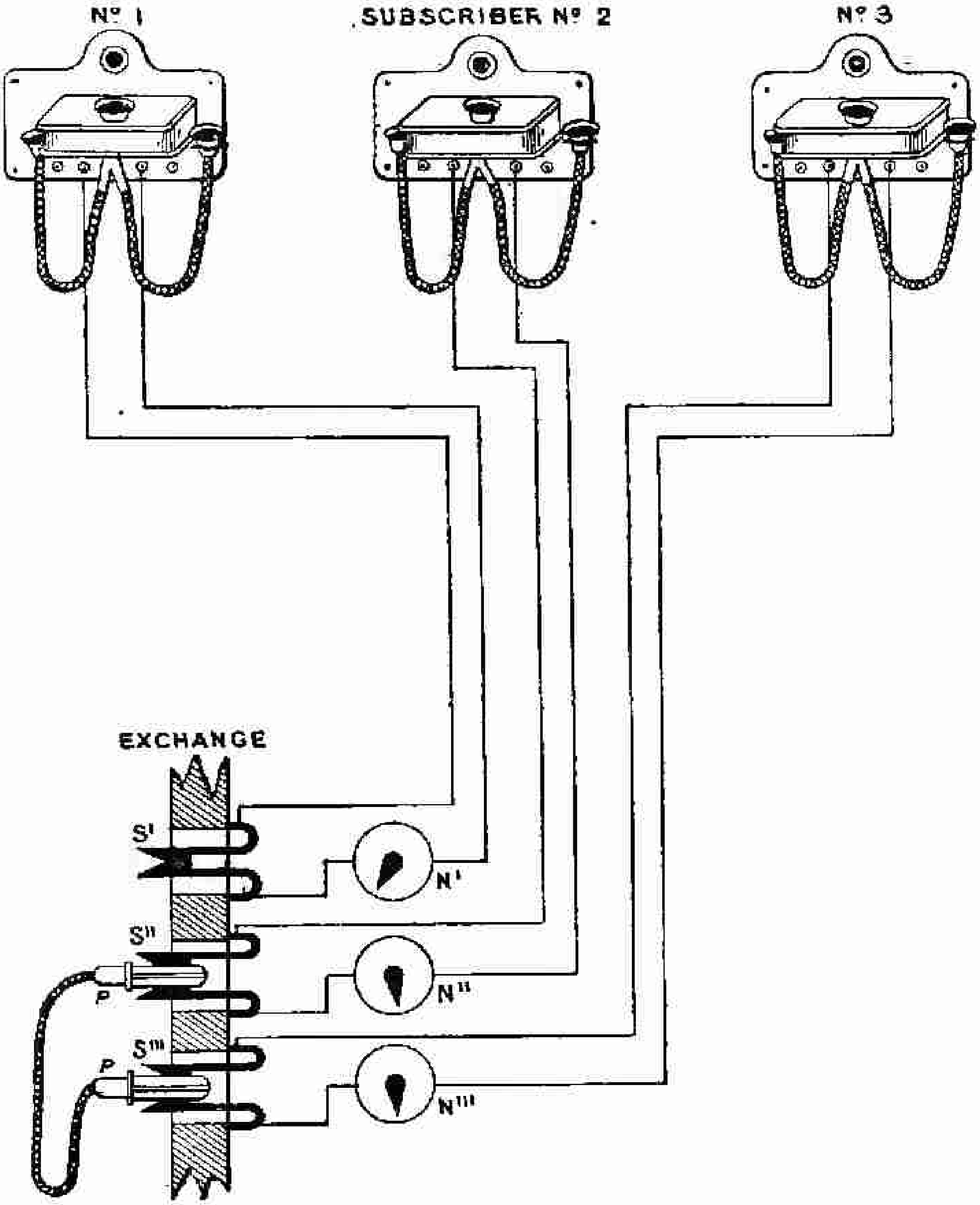
will be seen, consists of a complete loop and is not affected by the earth return of the subscribers while the subscribers' lines do not require to be altered in the least. In some of the later forms of translators the efficiency of conversion between the two coils is so good that the subscribers are enabled to ring as well as speak through them.

The British Post Office System.

This system, which is in successful operation in Newcastle, Sunderland, and numerous other towns, has several novel features, the most prominent of which is the employment of a permanent current that retains the shutter of the annunciator at the exchange in position, and keeps the needle of a special indicator deflected. This current is utilised in conjunction with the annunciator and indicator, 1st, to enable the different subscribers to call the exchange; 2nd, for the "ring-off" signal; and 3rd, it forms a permanent indication of the condition of each subscriber's line. Metallic circuits are used exclusively, and the instruments employed are the Gower-Bell (as described on page 82) with Daniell batteries for ringing. The system will best be understood by referring to Fig. 201, which shows diagrammatically three stations and a portion of the switch-board at the exchange. The two lines of each subscriber terminate at the spring-jacks S′, S″, and S‴, in the switch-board, and the indicators N′, N″, and N‴, with an annunciator (not shown in the figure), are included in each circuit. The indicators consist of a pivoted needle that is deflected by a current, and the annunciators are so arranged that the shutter is only held up so long as a current is passing through it. Normally the two spring-jacks are in contact with each other as shown by those of line No. 1, but when the operator wishes to join any two subscribers together, he slides in the special connecting plugs P and P′, thus separating the two springs which make contact with the top and bottom plates of the plug respectively.

The method of working is as follows:—A Daniell battery is placed at each subscriber's instrument and the switch-hooks so arranged that so long as the hearing tubes are hung up the batteries are in circuit, and a current passes continually from the subscribers' instruments through the annunciator, spring-jacks, and indicators at the exchange, deflecting the needles of the indicators N. When any station wishes to call the exchange, all that it is necessary to do is to lift up the hearing

Fig. 201.



British Post Office System.

tubes, which cuts off the permanent current, thus causing the shutter of the annunciator to drop, and the needle of the indicator to go back to its central position. The operator then plugs in his instrument and ascertains the number required, on hearing which he calls the wanted station and puts the two stations through as shown in Fig. 201, where No. 2 is talking to No. 3 while No. 1 is inactive. This calling of a subscriber is effected by sending a powerful current from the exchange, which actuates the relay in the subscriber's instrument, and rings his bell, the armature of the relay being kept off by a stiff spring so as not to be affected by the permanent current. No. 2 and No. 3 stations being talking the tubes of the instruments are off their hooks and the permanent current cut off, which state of affairs is disclosed to the operator at the exchange by the needle of the indicator not being deflected. When the two stations have finished they replace the hearing tubes, switching on the permanent current, and the operator seeing the needles deflect, at once withdraws the connecting plugs from the spring-jacks. The connecting plugs are flat-shaped, and so arranged that they can only be placed in the spring-jacks the right way, that is, top plate to top spring, and also so connected up that when two plugs are put in, as P and P′, the top spring S″ is connected to the bottom one S‴, and the bottom spring S″ to the top one S‴, otherwise the permanent currents of the two instruments would, when the two subscribers hang up their tubes, oppose one another.

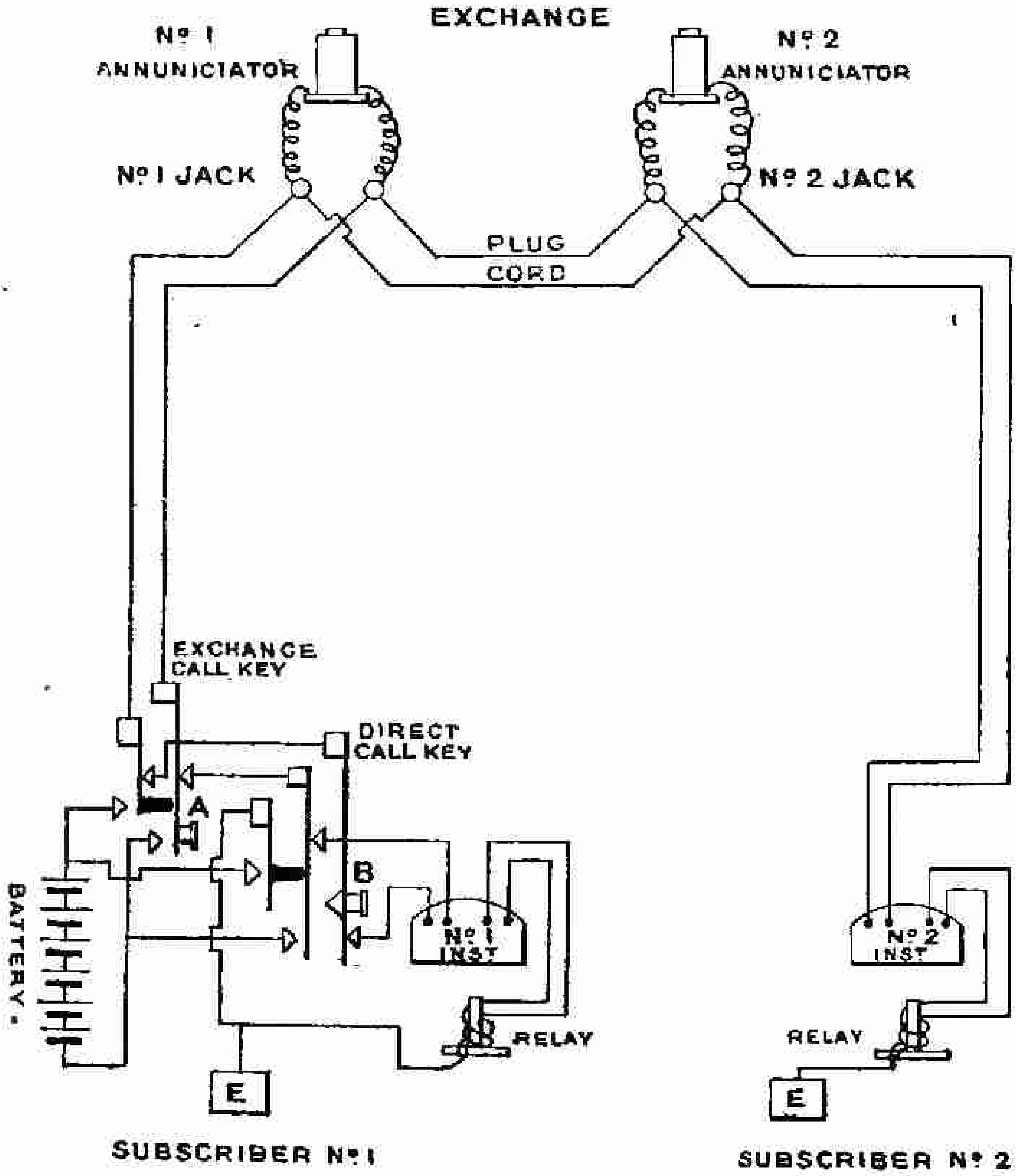
This system is an excellent one for small exchanges, and one that is capable of giving great satisfaction to the subscribers, though the expense of keeping up so many Daniell cells makes it somewhat costly to maintain.

The French System.

In the exchange system used in Paris, like in the one just described, metallic circuit and battery switch-bells are used. All the wires are placed underground, being made up into convenient cables and run in the excellent and capacious sewers for which the city is noted. Special hooks are fastened into the roofs of the sewers on which hooks the cables are hung. Each subscriber's instrument is provided with two ringing buttons, with the one of which he calls the exchange and with the other he can (when put through at the exchange) signal *direct* to any other subscriber, similar to the private exchange system shown in Figs. 188 and 189. In signalling and talking to the exchange, or when talking to any other subscriber, the metallic circuit is used, but when one subscriber signals to another by means of the direct call key the two wires are connected together so as to form one, and an earth return is used.

The manner in which this is effected is shown in Fig. 202, which shows diagrammatically two subscribers' instruments with their annunciators and jacks at the exchange. Only the ringing keys of No. 1 subscriber's instrument are shown, and the jack at the exchange is illustrated as two separate holes for the sake of clearness. In reality the two contacts are combined in one hole, the plugs having two insulated parts that make contact with them in the ordinary manner. The method of operating is as follows:—No. 1 subscriber, to call the exchange, presses the button A of his exchange call key, which puts the top spring to one pole of the battery, and the bottom one to the other. This sends a current through the metallic circuit and drops the shutter of the annunciator at the exchange. The operator at exchange then inquires the number wanted, and on learning this plugs No. 1 and No. 2 through as shown in the figure. Nos. 1 and 2 can now signal direct to one another without affecting the exchange. For if No. 1 presses the button B of his direct call key he depresses the three springs, putting one pole of his battery to "earth" and the other to *both* of his lines, the current passing through the two lines as one, through the exchange, and to earth through the relay of No. 2 subscriber's instrument, thus ringing his bell. The annunciators at the exchange are, it will be seen, in a shunt circuit to the jacks (when two subscribers are connected through), and their resistance is so proportioned that the subscribers after having finished can, by pressing their

Fig. 202.



The French System.

exchange keys, drop the shutters of both their annunciators as a "ring-off" signal. When no plugs are in, each subscriber's annunciator forms part of his metallic circuit.

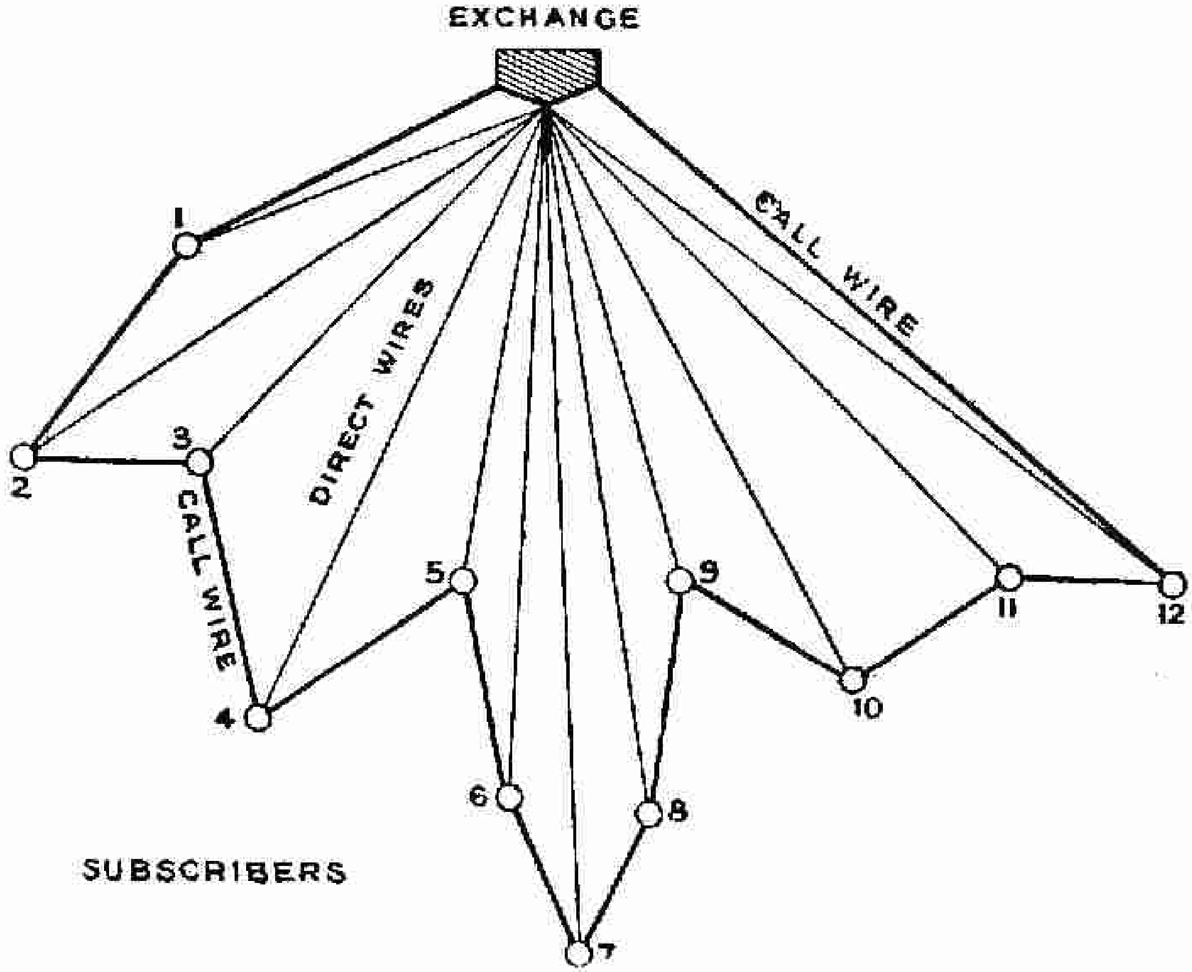
This being able to signal direct from one subscriber to another without affecting the exchange is a great convenience, since one knows that any delay after having been informed by the exchange that you are "through" can only be occasioned by want of attention on the part of the other subscriber. The speaking between two subscribers is of course on the metallic circuit, all earth being cut off by the ringing keys and the switch-hooks.

THE LAW SYSTEM.

This system was devised by Mr. F. Shaw, of the Law Telegraph Company, New York, the object of the inventor being to simplify the exchange apparatus, and by enabling the subscribers to put themselves at once into communication with the operator at the exchange to secure a more rapid service. This is effected by providing in addition to the subscriber's direct wire to the exchange a "call" or "service" wire, which after leaving the exchange passes from one subscriber to another, thus joining them all in series as in Fig. 203. Twelve subscribers are shown connected to the central exchange, and are numbered 1, 2, 3, 4, 5, 6, &c., the call wire being indicated by the heavy black line and the direct wires by the thin lines.

The method of operating is as follows:—At the exchange the operator sits with a special form of telephone clasped to her head, this telephone being in circuit with the call wire on which she listens continually for calls. Every subscriber is provided with a special switch, by means of which he can connect his instrument to his own direct exchange line or loop it into the call wire. Each subscriber, therefore, when he wants to speak to another, moves his switch so that his instrument is looped in the call wire, and on taking off his receiver finds himself in direct communication with the operator at the exchange. He then makes known his requirements by saying (presuming No. 20 wishes to speak to No. 75) "20 to 75," which numbers the operator repeats to show that she has heard, and having rung the bell of No. 75 by sending a current from the exchange, immediately plugs the direct wires of Nos. 20 and 75 through. No. 20 then moves back his switch, putting his instrument on to his direct exchange wire, and speaks with No. 75. At the close of the conversation one of the subscribers switches his instrument on

Fig. 203.



The Law System.

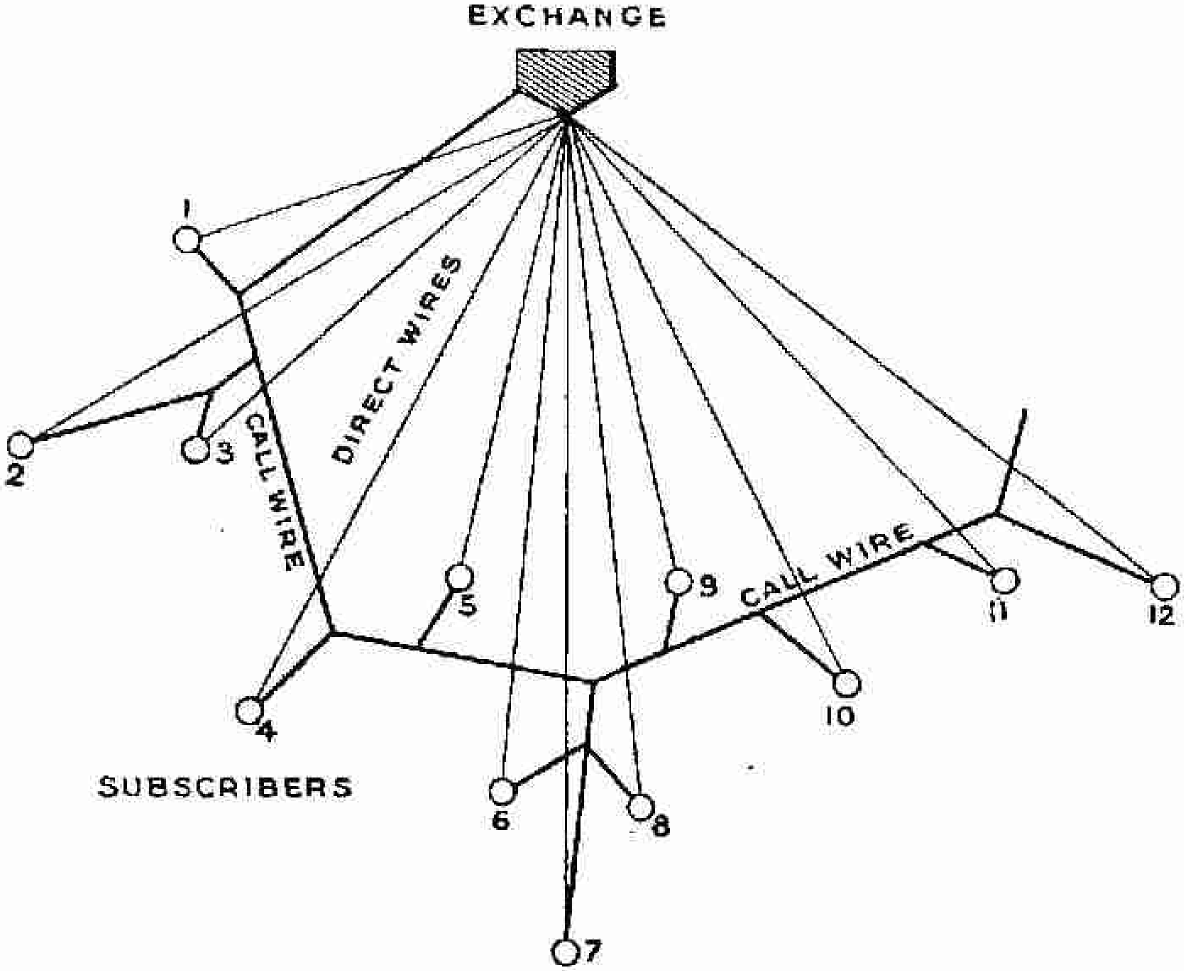
to the service wire, and says, "No. 20 off" or "No. 75 off," as the case may be, on hearing which the operator at once withdraws the plugs and disconnects Nos. 20 and 75 lines.

A call wire is provided to every 100 or 120 subscribers, to which number one operator can even at the busiest times easily attend, and without confusion arising as might be supposed. It will be seen that the employment of a call wire, besides allowing the subscribers to be at once put into communication with the operator at the exchange on taking off their receivers, also does away with the necessity for annunciators, and consequently considerably cheapens the system.

THE MANN SYSTEM.

The system just described has one great defect, and this is the way in which the call wire is arranged. All the subscribers are connected in series, and it is obvious that a break anywhere

Fig. 204.



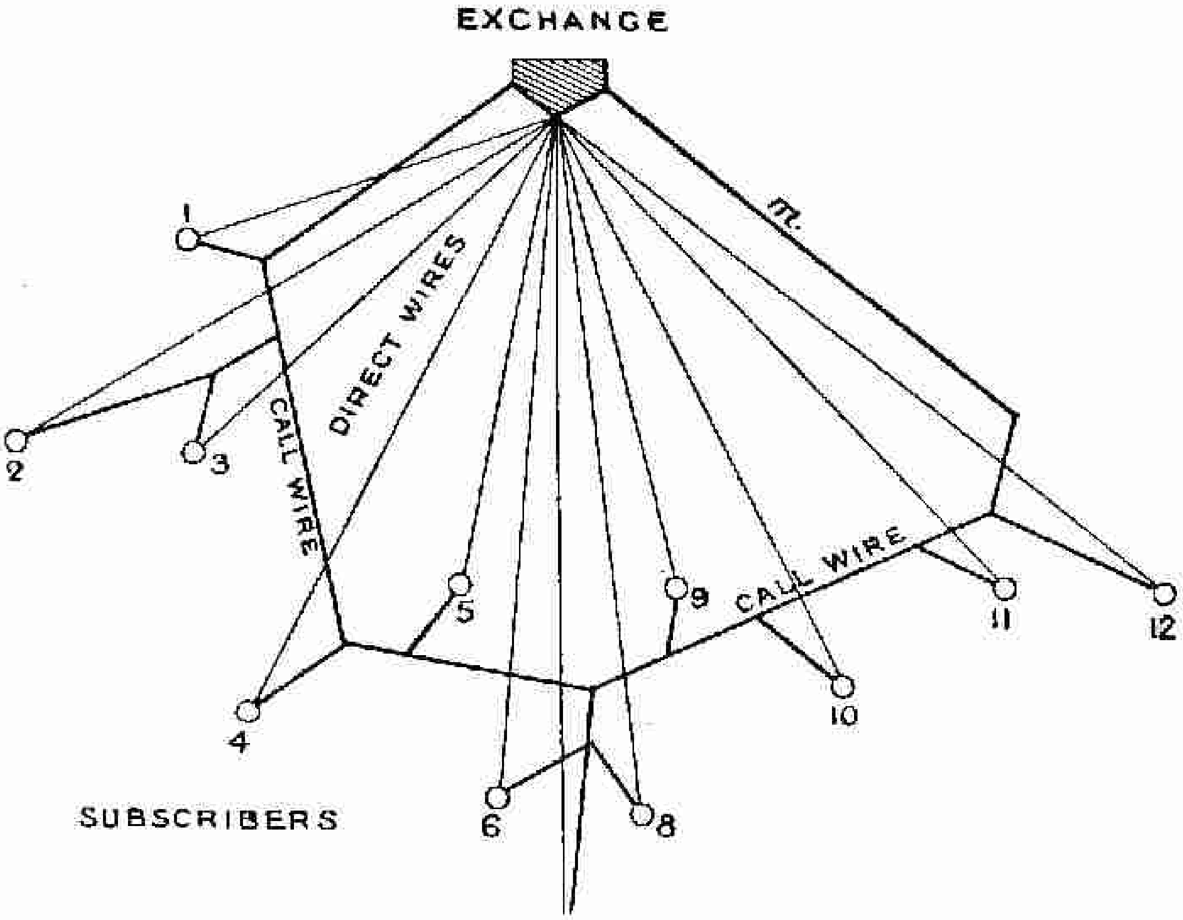
Mann's Method of arranging the Call Wire.

in the call wire, or an imperfect contact in any of the switches, at once cuts off every subscriber, since it destroys the continuity of the circuit. To do away with this objection Mr. J. J. Mann devised a different method of arranging the call wire, which method is shown in Fig. 204, and was first put into practical operation by the National Telephone Company, who adopted it for their Dundee exchange.

In the Mann system the call wire runs out from the exchange, and branches are taken off to each subscriber at the most convenient points, this call wire being "earthed" at the exchange and also at each subscriber's instrument. The effect of this, it will be seen, is to place the different subscribers in parallel on the call wire and thus independent of one another. Each subscriber is provided with a special switch, which in its normal position joins his instrument to his direct exchange wire, but when the lever is depressed connects his instrument to the call wire. In Fig. 204 the call wire is shown by the dark lines, and the direct exchange wires by the dotted ones, as in the previous figure. The method of operating is the same as that described for the Law system on the previous page. The only fault that can *completely* cut off *all* the subscribers in the Mann system is, it will be seen, a break in the first span of the call wire as it leaves the exchange, a point at which it can be most quickly repaired, though a "full earth" on the wire would result in considerably reducing the loudness of the speech until removed. The other faults likely to affect the call wire, such as bad earth at the subscriber's instrument, or a disconnection further along the wire, would only affect that particular subscriber, or in the case of a break in the call wire, those subscribers beyond the break.

A further improvement in the call wire, whereby it becomes impossible for a single break in the wire to cut off any of the subscribers, was introduced by Mr. J. D. Miller. This consists in returning the free end of the call wire to the exchange as shown in Fig. 205, the returned portion of the wire being marked *m*. By thus returning the call wire to the exchange, it will be seen that if a break occurs at any point, its only effect is to divide the wire into two portions, part of the subscribers being on one portion, and the remainder on the other. A break at two places must occur to seriously interrupt the service of the call wire, and then only those subscribers between the two breaks are cut off. As two breaks are very unlikely to occur simultaneously great reliance can be placed on a call wire thus arranged, so much so that indicators on the main or direct

Fig. 205.



Miller's Improvement in the Call Wire.

wires, as are often employed in the ordinary Mann system to enable the subscribers to attract the attention of the exchange, should the call wire break down, can be dispensed with.

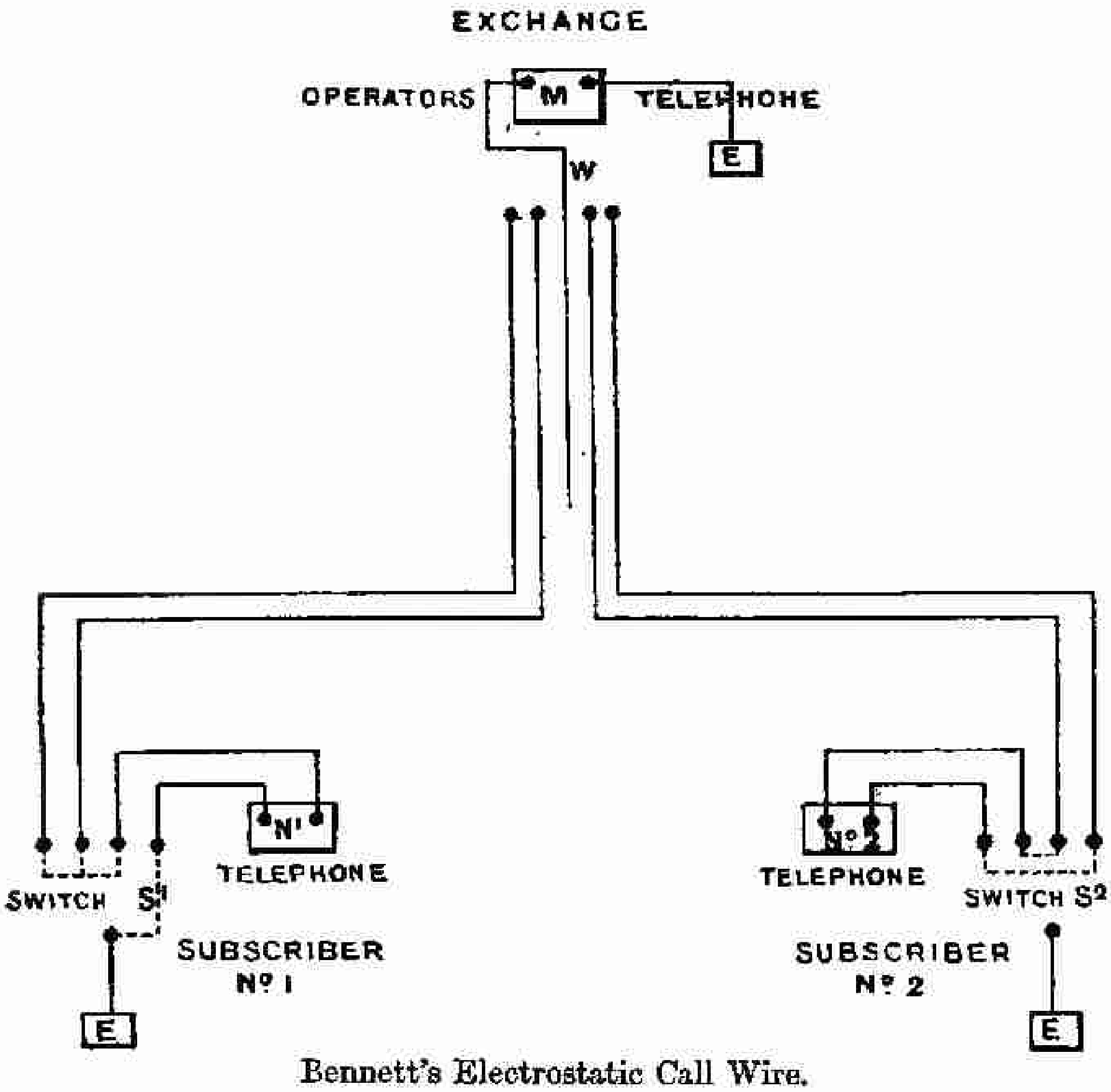
Bennett's Electrostatic Call Wire.

The necessity of taking to every subscriber another wire in addition to his ordinary wire is a great objection to all call-wire systems, and the expense of so doing an important item in the total cost of the system. It occurred to Mr. A. R. Bennett.

while laying down the Mutual Exchange at Manchester, that it might be possible to convey the service messages between the exchange and subscribers by means of electrostatic induction between the subscribers' wire and a special wire run out some distance from the exchange.

On experimenting, such a method was found to be perfectly

Fig. 206.



Bennett's Electrostatic Call Wire.

feasible, and has been adopted in connection with the Mutual Telephone Company's exchange in Manchester, the arrangement of the circuits being similar to Fig. 206.

Metallic circuits are used, and the wires at the exchange end are made up into cables of 36 or 72 circuits, an insulated wire being placed in the centre of the cable, to which the operator's instrument at the exchange is connected. In Fig. 205, M is the operator's telephone, and N^1 and N^2 those of subscribers No. 1 and No. 2, each subscriber being provided with a special switch, S^1 and S^2. The terminals only of these switches are shown, but the two different operations performed by the lever of the switch are shown in S^1 and S^2. When the lever is in its normal position the terminals are connected as shown in S^2, but when depressed they are joined as in S^1, the first position being that when speaking with another subscriber, and the latter when using the call wire. When the lever of the switch is depressed, as in S^1, it will be seen one terminal of the subscriber's instrument is put to "earth" and the other joined to the two ends of his metallic circuit, these two wires practically forming one side of a condenser, the other being formed by the insulated wire W, in the centre of the cable. The operator at the exchange (who listens continually at the instrument M) on learning the number required, immediately plugs through the two wires of the two subscribers, who thus speak on a metallic circuit without fear of being troubled by inductive noises, or of being overheard by the operators at the exchange.

The "ringing up" of the "wanted" subscriber is done by the "calling" one, who turns the handle of his generator, causing the bell of the "wanted" subscriber to ring, the position of both the switches S^1 and S^2 being as in S^2.

CHAPTER XII.

TESTING FOR AND REMOVING FAULTS.

In telephonic, as well as in all other systems of electric communication, certain defects will from time to time develop themselves, however well the apparatus may have been constructed and erected. These are called "faults," and the methods of locating and removing these will form the subject of this chapter. Communication between two telephone stations can be interrupted by faults arising in the "ringing" circuit, or the "speaking" circuit, or in the circuit common to both. Thus, in the telephone stations A and B, A may be able to ring up B, yet B may not be able to ring up A, though both can hear clearly; or the ringing may be good in both directions, and the speaking interrupted from one end, but in whichever circuit the fault occurs the effect is the same—viz. to render both instruments useless for practical purposes until it is remedied. The rapid detection of faults in telephone instruments requires a thorough knowledge of their construction, combined with no small amount of skill and experience. The various telephone companies keep men called "inspectors," whose sole duty is to locate and remove faults as they arise on the subscribers' lines or instruments, and on the skill and quickness of these men depends much of the efficiency of the system. A good telephone inspector can generally, after a minute or two's testing of one of the instruments with a short length of wire, during which time he momentarily connects one terminal or part of the instrument with another, point out almost the exact position of the fault.

When removing faults from a telephone line, the proper way is to alter or repair nothing till you are absolutely sure where the fault is. This maxim cannot be too firmly impressed on all telephone fitters, as an immense amount of trouble will be saved by strictly adhering to it. The slovenly and careless fitter who jumps at conclusions, and forthwith attacks a certain part of the apparatus because an idea strikes him that the fault lies there, is one who should leave telephone fitting alone, as his hasty action will, in nine cases out of ten, only lead him into fresh difficulties. He will pull to pieces the transmitter when the fault was perhaps the battery run dry, report a break in the line when the trouble is a faulty generator, or dissect the receiver when the automatic switch was the offending part of the apparatus. Be careful, therefore, to make a thorough inspection of the whole apparatus, and carefully test each circuit before attempting to alter or repair. Adjust only a little at the time, and if a piece of apparatus is working well be wise enough to let it alone.

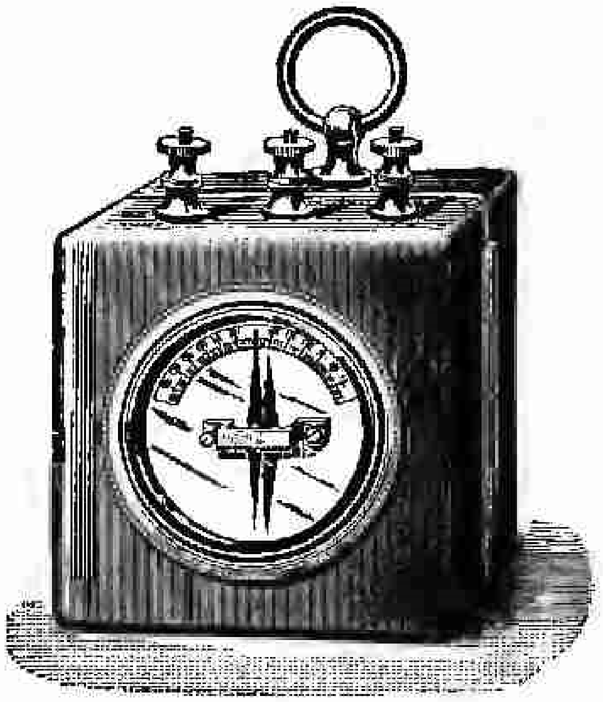
Searching for a Fault.

When searching for a fault make first a careful inspection as follows:—First examine the battery, replacing any zincs that may be unduly eaten away, and see that each cell has plenty of solution in it. Scrape off any crystals that may have collected on the carbon, zinc, or glass jar. If necessary, wash out the jars and recharge. Try all the connecting screws to see that none are loose, and scrape with a knife or clean with emery any that may have become corroded from contact with the solution. Follow up the wires from the battery to the instrument, repair them where damaged, and staple up if loose. Next inspect the switch-bell. Try all the connections to see that they are firmly screwed up, and see that the switch-hook works freely. Carefully note that good contact is made when the automatic arm is up, and also when down. Inspect the bell. If of the battery form, see that the contact post is firm and the platinum contacts clean. If of the magneto form, see that the bell is not out of adjustment, and test the automatic cut-out of the generator to see that it is working well. All rubbing contacts may have the minutest drop of oil placed on them with advantage, but the quantity must be very small indeed. Then inspect the transmitter: if of the Blake type, clean the carbon contact by drawing a clean piece of note-paper between the button and platinum point. If of the carbon pencil form see that no pencils are broken, and the connections are firm. Next inspect the receiver: see there is no dirt between the pole-piece and the diaphragm, that the diaphragm is not buckled, that the bobbin is tight on the pole-piece, and that the cord is sound. See that the two ends of the telephone cord are not frayed, and thus short-circuiting, if so—double back the ends well under the terminal screws. Metal tags are now almost always employed for connecting the cords, the wire being soldered to the tags, and the point of the tags passing under the terminal; this makes the best job. If the telephone cord is suspected of being broken, it should be removed and tested for continuity with a cell and galvanometer, a slight tension being put on the cord while tested, in order to cause the broken ends to part should there be a break. A broken receiver-cord is often difficult to detect, the cord appearing intact at one moment, while the next the continuity is broken.

If, after having been carefully over the instrument as directed above, the fault is not discovered, proceed to test for the particular fault that may be on; but look well first, and do not alter the least thing till you are quite sure what you intend doing.

Both for testing for "faults" and for ascertaining the condition of the battery, a small galvanometer, or a detector, as it is more commonly called, will be found a great convenience. The most usual form of detector, or linesman's galvanometer, is shown in Fig. 207. It consists of a polished mahogany case, in the front of which is cut a circular aperture, through which the scale of the detector is visible. This scale is marked on the front of a brass plate that forms the base plate of the needles and bobbin, or bobbins as the case may be. The instrument has two needles—the smaller

Fig. 207.



Detector Galvanometer.

one working inside the brass bobbins, its lower or N end being weighted for the purpose of bringing the needle to zero. The other needle, which is lighter and longer, is placed in front of the dial, and immediately indicates the passage of a current through the coils of the detector by being deflected over the scale either to the right or left according to the direction of the current. Both needles are carried by a common spindle, the front end of which is supported by the bar screwed on to the front of the dial, and the other by a bearing behind.

The instrument should be wound for quantity and intensity as it is called, the quantity or short coil consisting of a single layer of thick wire having a low resistance, generally some decimal of an ohm, and the intensity or long coil having a number of layers of fine wire with a resistance of 150 to 200 ohms. The ends of these coils are connected to the three terminals at the top of the case.*

The scale of the detector is graduated in degrees, although the graduations on the dial are not proportional to the current flowing. It is fairly accurate up to 20°, but as the needle moves further and further from parallelism with the coils, the

Fig. 208.

Linesman's Testing Set.

effect is less and less, until at right angles or 90° it is practically nil.

For outdoor work, such as when testing underground or overhead wires, a small portable box containing two or three Leclanché cells and a detector will be found very convenient. A form of the linesman's outfit is shown in Fig. 208.

* For a more detailed description of the detector the reader is referred to 'Electric Bell Construction,' where scale drawings will be found.

Faults in Transmitters.

One of the most common faults is :—

Buzzing or Rasping Noises in the Telephone.—This fault is generally local, and if the instrument is of the microphone class we must look in the microphone or local cell for the origin of it. A continuous humming noise is caused either—1st, by the transmitter (especially if of the Blake type) being too loosely adjusted; or, 2nd, by the local cell being too strong. To ascertain which of these is the case, touch the diaphragm with the finger, and if this stops the noise the adjustment is too loose, and screwing up the adjusting screw will cure it. Should the noise, however, continue, unless the transmitter is so tightly adjusted as to affect the transmission of speech, the local cell is too strong, and if there are more than one cell, one or two must be taken off. If there is only one cell, as is generally the case with transmitters of the Blake class, a resistance of two to three ohms should be inserted until the battery weakens. In the Blake transmitter rasping sounds are caused by the carbon buttons, where they touch the platinum points, being rough. If this is the case, the screws in the insulated block must be slackened, when the carbon button can be moved up or down a little, so as to bring the point to a new spot. Dust in between the springs of the contact in the local circuit will also often give rise to rasping sounds in the receiver, or the spring may not be pressing firmly against the contact stud. It should be remembered that when the spring only touches the contact lightly, the slightest jar or vibration causes it to act as a microphone, which could not happen if the contact were firm. If the contact has a rubbing action, as all the more modern forms have, see then that the spring makes firm contact, and put the slightest touch of sweet oil on the point. Never put oil on dotting contacts, as this will only make matters worse. Before attempting to remedy a fault of this character, it must be ascertained by testing whether the fault may not be at the distant end. To do this, join the "line" L and "earth" E terminals (see Figs 47 and 48) with a short piece of wire, and if the noises cease, the fault is probably at the other station.

The speaking of a Blake transmitter will often become impaired owing to the rubber ring *g*, or glove on the spring *k*, having become sticky. This can be remedied by placing a paper ring between the rubber and iron frame, or in the case of the spring *k*, between the glove and the diaphragm. In all cases of adjusting or repairing transmitters never pull springs back too far or turn adjusting screws more than a quarter of a turn at a time, as it must be borne in mind that transmitters are, in many respects, delicate instruments, and will not stand rough or clumsy handling. The carbon button of a Blake transmitter will frequently be found to have been slightly penetrated by the platinum point, causing the speaking to be impaired. When this is the case a new button will generally be required, though it may be possible to adjust as described on the previous page so that a fresh surface is obtained.

Carbon pencil transmitters are liable to have one or more pencils broken by impatient persons tapping on the diaphragm, and the speaking will also frequently fall off owing to dust and dirt having got into the bore holes. When this latter is the case the pencils must be taken out and the bore holes properly cleared. Bad connections from the microphone to the coil are also likely to arise in instruments where the connection from the lid to the body of the case is made through the hinges.

Transmitters of the Hunnings type are as a rule not subject to many faults, there being so little to get out of order. Bad connections to the platinum or carbon diaphragm and pierced diaphragms being the most common.

FAULTS IN RECEIVERS.

Perhaps the most common fault in receivers is a gradual falling off in the speaking owing to filings, dirt, and rust accumulating on the pole-pieces and damping the vibrations of the diaphragm. Particles of dust, &c., very often remain in the receiver cases after they leave the manufacturer's hands, and these will frequently shake down between the diaphragm and pole-piece, filling up the intervening space and interfering with its action. A very simple remedy for this is to cut a disc of tissue paper $\frac{1}{8}$ in. larger than the bell part of the receiver, and having a three-quarter hole in the centre. If this is gummed at the edges and the centre, and stuck on the end of the bobbin as centrally as possible, the edges can be pushed down into the bell part so as to prevent the paper touching the diaphragm. This forms a kind of screen that will prevent particles of dirt &c., passing down lower than the end of the bobbin, thus they cannot cause any trouble. A temporary remedy is to unscrew the lid, take off the diaphragm, and gently jar out as many of the filings, &c. as will come, the pole-pieces being afterwards carefully wiped with a clean piece of rag. Where rust is the cause the pole-pieces must be wiped to remove it, and a coat of *thin* varnish applied.

Diaphragms touching the pole-pieces is another frequent fault, and is caused either by the magnet having shifted or the diaphragm (owing to the continual pull of the magnet) having got bowed and approached the poles. This is a common fault with the "watch" receivers. Remedy, turn the diaphragm over, or, in receivers with adjusting screw, draw back the magnet a trifle.

Buckled diaphragms are caused generally by inquisitive persons unscrewing the cap and meddling with the diaphragm. It is always best to substitute a new one, a straightened one is never the same.

Fused coil.—This occasionally happens during thunderstorms and is caused apparently not by the direct action of the flash but by an induced discharge. The writer has had occasion to put new receivers to several lines which receivers ceased to act, in each case directly after the storm. New receivers must be substituted and the damaged ones unwound to the faulty part, or what is better, the bobbin entirely rewound.

It seems probable that the path of the discharge after reaching the switch hook is to the metal case and frame of the receiver, and thence by the bobbin of wire to earth, otherwise the receiver would not be in the circuit when hanging on the hook.

Faults in Switch-bells.

Battery switch bells are liable to several faults, bad contacts in the ringing key, bad contact between the automatic switch arm and its springs, bell out of adjustment, and broken connections being the most frequent.

When looking for faults in switch bells go carefully over the connections and inspect each part to see that it performs effectually the operations it is required to do. Very often the contact springs get worn or bent, and thus the automatic switch may fail to make contact when up and also when down. The spiral spring also that draws up the switch hook will sometimes get weak and not pull the arm far enough back.

Magneto switch bells, if they give any trouble, generally do so with the driving gear, more especially when friction gear is used. The small V-shaped pulley wears, and to make up for this the driving wheel is always adjustable towards it. If the wear is excessive a new pulley may be required. Cog-gearing is more reliable and scarcely ever gives trouble. Short circuits will sometimes occur owing to a film of metallic dust forming across the connections, this dust arising from the wear of the cog or friction gearing.

The gongs of bells may require adjustment from time to time, which can be done without opening the case.

The armature shunt or cut-out gives trouble sometimes, owing to the wear of the different parts, and in some forms from dust or dirty oil accumulating on the contacts.

In both battery and magneto switch-bells, an instrument will occasionally be found short-circuited owing to the lightning-arrester plates having got into contact, either from warping of the woodwork or from nails, tools, or pieces of metal having been laid or fallen on top of the instrument.

Battery Faults.

The most common of these is the battery run dry, either from the solution having evaporated, syphoned over from creeping of the salts, or leaked away from a cracked cell. Trouble will often arise from white lead forming at the lead cap, and when such is the case a new porous pot should be substituted for the defective one. The connections may also be corroded from some of the solution having got splashed on them. For directions as to inspecting or re-charging a battery see page 111.

Faults in the "Line."

These are of three kinds, either "*breaks*," "*contacts*," or "*earth*."

A *break* is a total disconnection somewhere in the circuit, caused generally by trees having fallen on the wire or from the wire having been blown down. A *contact* is two or more wires having got into connection, and an *earth* is the wire having got into direct communication with the ground.

All these faults present themselves in different degrees, thus we may have a "dead earth" or only a slight earth, or it may be an "intermittent" fault, that is, one that is present at one moment and disappears the next only to reappear again in a short time.

These "breaks," "contacts," and "earths," must be located by walking over the route of the wire, or tested for as described at the end of this chapter.

LOCATING FAULTS.

We will now pass on to a rather more difficult operation, that of locating the different faults as they appear. We shall treat of each fault in connection with the different kinds of instruments, but more especially those with microphone transmitters, and battery or magneto switch-bells.

The connections of the battery switch-bell form are shown in Figs. 47 and 48, and the terminals are labelled L, Z E, T Z, C, these being the "line," "zinc earth," "transmitter zinc," and "carbon" or "copper" terminals respectively. The connections of the magneto switch-bell form are shown in Figs. 51 and 52, there being the two terminals, E and L "earth" and "line," at the top of the instruments. In speaking of faults we shall refer to the station at which the operator is as the "home," and to the other as the "distant."

Bell at "Home" Station does not ring, Ringing at "Distant Station" good, and Speaking good in both directions.—It is evident that the fault may be either in the bell and its attendant apparatus at the home station, or in the ringing battery and its connections at the distant. To ascertain which of these is the case (presuming the instrument to be a microphone one with battery switch-bell), join terminals C and L, that is "copper" and "line" (see Fig. 47), with a short piece of wire, and if the bell rings then, the fault is most likely at the distant station. If your bell does not ring when terminals C and L are connected, the fault is probably in your own bell. Inspect the bell and see that the adjusting screw has not worked back; if so, screw it up, so that when the armature is held against the magnet-poles the contact spring just leaves the contact screw and no more. Should the bell appear in good order, see that the back spring of the ringing key makes firm contact with the front stop, which is connected to the bell, and if this is all right follow the wire back to see that it is not broken. Next see that the arm of the automatic switch makes proper contact with the bottom stop, and if not, adjust so that it does. If the bell rings all right when terminals C and L are connected, the fault is either caused by the battery at the distant end having got weak, or the spring of the ringing key does not make proper contact with the bottom stop when pressed. The battery may be too weak for ringing, yet the local cell for the transmitter may be strong enough to give satisfactory results on the microphone.

In the instruments having magneto switch-bells the fault may be in the bell at the home station, which may be out of adjustment, or, what is more likely, in the generator at the distant end. If your bell rings when the handle of your generator is turned, the fault is in the generator of the distant station; but if not, it is probably in your own instrument.

Inspect your bell, see that the adjustment is perfect, that the hammer moves freely, and that the gongs have not worked loose. If these appear all right, see that the wires from the bobbins are not touching the frame, and so cutting out the coils. If the fault appears to be at the distant station, inspect the generator there. See that the insulation of the armature has not broken down, and that the automatic cut-out works properly. Probably the spindle fails to break contact with the spring when the handle is turned, or if the armature shunt is of the "Post" form, the bob may not leave the contact.

Bell at Home Station rings, but cannot reply. Speaking good in both directions.—This is probably due to the battery at home station having got weak, or the bell at distant station is out of adjustment. Test as described for previous fault, repair any apparent bad places, and test again. If the instrument has a battery switch-bell, you can ascertain whether the bell at the far end is ringing thus:—Take receiver off the hook, and hold it to your ear; then with a short piece of wire join terminals C and L, and if the bell at the far end is ringing, a loud chattering noise, corresponding to the make-and-break of the circuit by the bell, will be heard in your receiver. With instruments having a magneto switch-bell, test as described for the previous fault.

Bell at Home Station does not ring, and no Call can be sent to Distant Station. Speaking good.—The fact that the speaking is good in both directions proves that the line is intact. Examine and test as described for the previous faults; but fault will most likely be found in the automatic switch of the instrument at the home station. Probably the bottom contact for bell circuit does not make good contact with switch-hook. Adjust and test again, when all will probably be found right. Should no fault be found in either of the instruments at the home or distant station, it is probable there may be a partial break or disconnection somewhere in the circuit. A transmitter will often speak through a high resistance contact or partial disconnection where a battery-bell would not ring, since a very small current is required to work the receiver, and the fault might be of too high a resistance to let sufficient pass for the bell, but quite enough for the receiver, the current for which is of a higher E.M.F. If the switch-bell is of the magneto form, it is probable that the generator, if a good one, would ring through any resistance that the transmitter would speak through.

Signalling good in both directions, but cannot make Distant Station hear.—The fault here is probably in the local circuit of the home-station instrument. Examine transmitter cell and test with galvanometer (thick wire coil), to see if it is in good condition. If this is so, inspect microphone, and also local circuit switch, which may not be making good contact. Should this be all right, the fault is probably in the primary of induction coil, which should be tested with galvanometer for continuity. Should all be found in good order at home station, inspect receiver at distant station, where iron filings or dust may probably have got between the pole-piece and the diaphragm.

Signalling good in both directions, but cannot hear at Home

Station.—This fault is similar to the one just described, and is probably due to some disarrangement in the local circuit in the instrument at distant station. Test as described for the previous fault. To ascertain whether the fault is at the home or distant station, join terminals L and E (that is "line" and "earth"), take receiver off the hook and holding it to your ear, gently tap with your finger the diaphragm of the transmitter, which should produce a loud sound in the receiver. If this is so, the fault is probably at the distant station; but if the tapping produces no noise, examine receiver, where the fault will most probably be found.

Signalling good in both directions, but cannot hear at either Station.—The fault in this case may be either in the primary or microphone circuit of both instruments, or in the primary circuit and receiver of one instrument. It would also be caused by a break in the secondary circuit of the coil and its connections at either station, or the automatic switch may be at fault. To ascertain at which station the fault is, join terminals L and E with a short length of wire, take receiver off the hook, and holding it to your ear, tap the diaphragm of the microphone. If this produces a loud sound in the receiver the fault is at the other station; but if no noise can be heard the fault is at your own station.

Proceed to locate the fault as follows: Take the receiver off the hook, and place to your ear. Next momentarily connect terminals C and L with a short length of wire, and if you get a sound at the moment of connecting, the trouble is in the microphone or primary of induction coil and its connections. If you get no sound, inspect the automatic switch, and see that it makes good connection with the top or telephone circuit contact. If you find no fault here, take away the receiver cord and replace it with two wires, and if you get a sound now the trouble is in the cord, which must be replaced by a new one. If the receiver still appears dumb, connect across the two ends of the secondary of the coil, and then join C and L as before. If you get a sound in the receiver now, the fault is in the secondary windings of the coil. If you get no sound, the fault is in the primary of coil or microphone and its connections. Having traced the fault to the primary or local circuit, we have now to find out the exact spot. To do this first inspect the local transmitter cell to see that it is in good condition, and also inspect the local contact breaker of automatic switch, and note that it makes good connection. These being all right, take your galvanometer (using the thick wire coils and still keeping the receiver off the hook), fasten one wire on to the terminal C, and with the other touch in succession different points of the local circuit, noting the deflection. Should at one place no deflection be obtained, the fault will be found between that point and the one last touched. Presuming there is a fault found in the local or primary circuit at one instrument, there must still be another in the secondary or receiver circuit to account for the speech not being received from the other end; unless, of course, there is a fault in local circuit of both instruments. When looking for faults in the local circuit of the Blake transmitter, it should be noted that the spring carrying the carbon button and the one with the platinum point do not touch one another except at the platinum point. It is advisable also to test with a galvanometer and battery to see that the iron frame and diaphragm are insulated from one another, as contact between these would prevent the microphone working properly. While testing a piece of paper must be placed between the carbon button and platinum point.

Partial Breakdown. Ringing and Speaking in both directions faint.—The most probable cause of this would be a partial break or high resistance connection in the circuit. Join terminals L and C to test your bell, and afterwards join terminals L and E, and take off receiver, tap diaphragm of transmitter while listening in receiver. If the sound is loud and your bell rings all right, the fault is at the other station or in the "line." Test similarly at other station, and if that instrument is in good order the line or earth-wires are at fault. If the bell did not ring when terminals C and L were joined, and the instrument seemed dumb when you joined terminals L and E, go carefully over the connections of the instrument, looking more particularly to all moving contacts. Dust or film of dirt in the contacts of automatic switch may be the cause of the trouble.

Total Breakdown. Cannot ring or speak in either direction.—The most probable cause of this is either a broken line or earth-wire. It would also be caused by "full earth" on the line-wire—i. e. the line-wire has got into direct communication with earth. Join terminals L and C to test the bell, and also terminals L and E, as described for the previous fault. If the instrument is in good order disconnect the "line" and "earth" (L and E) terminals, and test with the battery and galvanometer both wires in succession, using a temporary earth-wire for the purpose. If no deflection is obtained with the earth-wire the wire is probably broken or corroded at some point, and this must be found and repaired. If the fault is in the line-wire, this must be located by testing, as follows :—

Locating a "Break" in an Underground Wire. — When locating a break or disconnection in an underground wire where an "earth" return is used, the wire at one end of the line must be disconnected from the instrument while the other is left connected up. One end of the line thus makes earth though the other is perfectly insulated. Now taking the portable testing set, and starting from the end of the line that is put to earth, proceed to the most accessible point and dig up the wire. Next put one of the poles of the battery to earth, which can be done by driving an iron rod into the moist ground, and connect the other to one terminal of the detector, using the fine wire coils. A short length of wire must also be joined to the other terminal of the detector.

Now with a knife remove the covering of the wire (taking care not to nick the wire or remove more covering than is necessary to expose the copper), and touch the wire from the detector on the exposed place. If (when the wire is touched on) a movement of the detector needle is obtained the wire is intact between the place tested and the end of the line put to earth, but if no deflection is obtained the wire is broken in this part. Care must be taken to see that a good earth connection is made by the iron rod. If the circuit is complete so far proceed to the next convenient place; having first well insulated the bared place on the wire with rubber solution and tape. Here we go through the same operation, and if the circuit is complete proceed to the next, and so on until no deflection of the detector needle is obtained, when the break will be between this place and the one last tried at which detector showed a deflection. From this place we then work backwards till the fault is found. It must be borne in mind, however, that this test is no good if the insulation of the line is faulty, and it makes earth anywhere, which should be previously ascertained.

Locating a Leak to "Earth."—If the fault is a leak to earth instead of a break, disconnect the line wires from the instruments at both ends of the line before commencing to test. Then proceed to the most accessible point in the wire (preferably where there is known to be a joint), and having arranged the detector as described for the previous fault, cut the line wire, and touch one end of the wire from the detector first on one end of the line and then on the other; the part which gives a deflection being the faulty wire. Different places must then be tried in the faulty part till the fault is localised. Always make *perfectly sure*, however, before proceeding to pull your line-wires to pieces that the fault is really in the line-wires and not in either of the telephone instruments, as cutting and re-insulating the wires is not particularly beneficial to the insulation of the line.

INDEX.

K.

L.

M.

N.

O.

P.

R.

S.

T.

U.

V.

W.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.