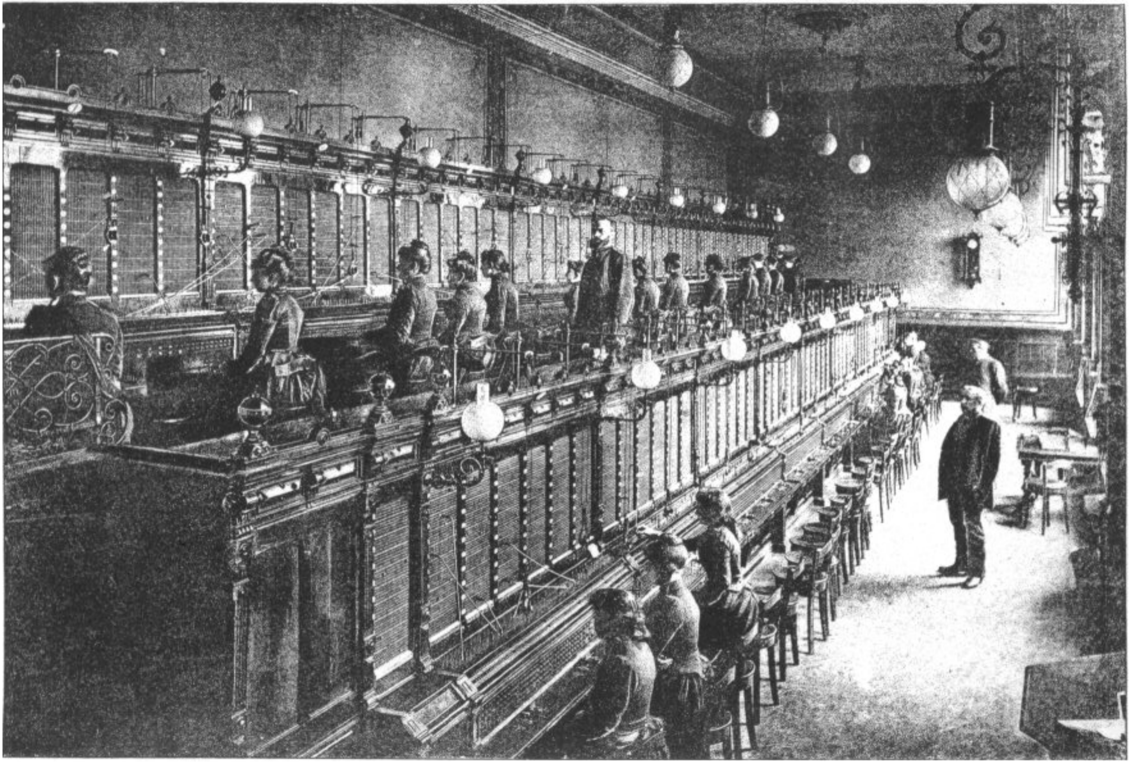

E & F N Spon, London & New York

THE BERLIN TELEPHONE EXCHANGE.

TELEPHONES

THEIR CONSTRUCTION AND FITTING

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

BY

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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.

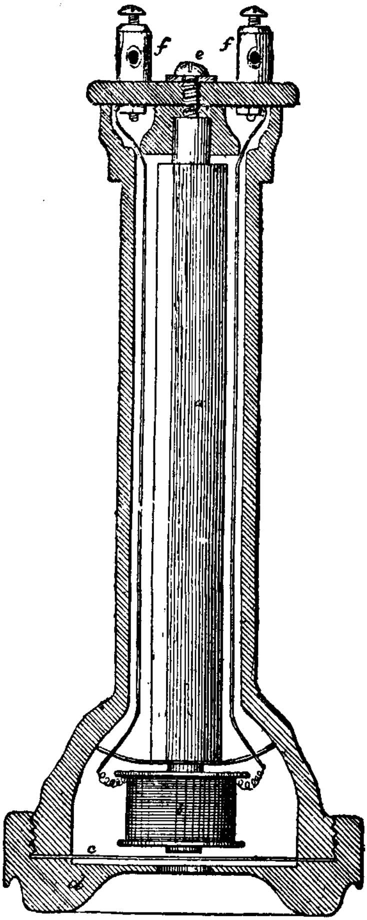
As most forms of receivers can be used also as transmitters, and are in fact for short lines often preferable to a microphone on account of their simplicity, receivers will be described first.

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,

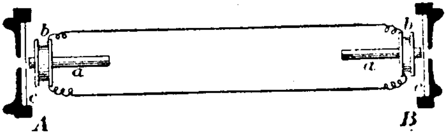
Fig. 1.



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.

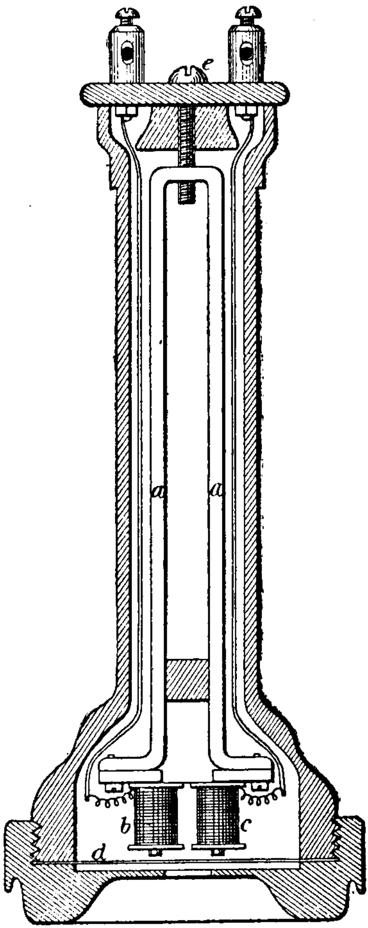


Two Receivers connected.

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 obbins are screwed to the magnet ends, thus forming soft ·on polar extensions of the magnet, the lower ends of the

Fig. 3.



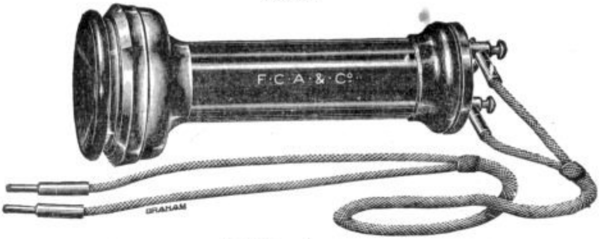
Double-pole Bell Receiver.

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.



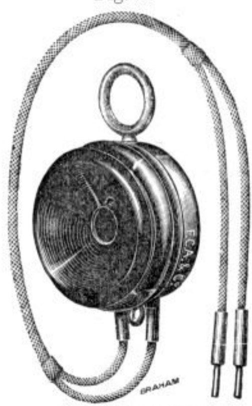
Bell Receivers.

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.

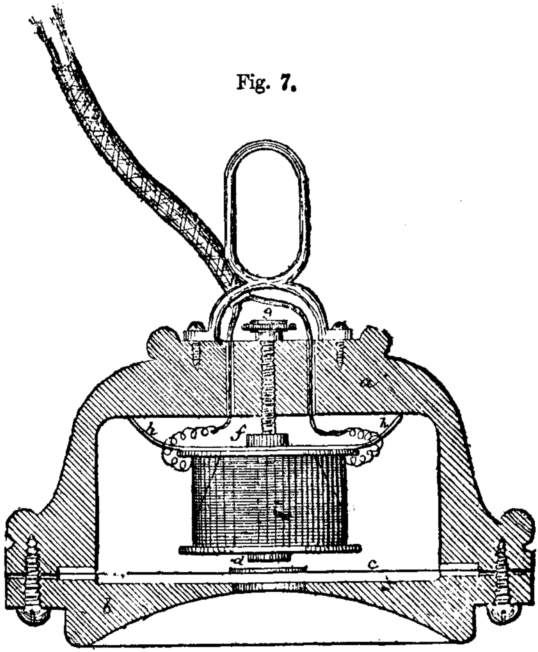
Fig. 7 shows, full size, partly in section, a form of the membrane receiver. It consists, as will be seen, of a boxwood, mahogany, or ebonite case *a*, fitted with a lid *b*, the lid being fastened to it by the screws shown. Between the lid and the case is the diaphragm *c*, which may be of gold-beater's 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.

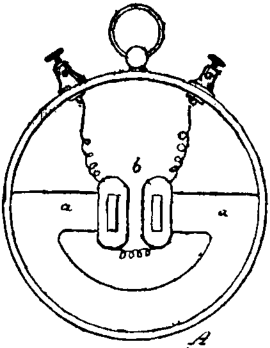
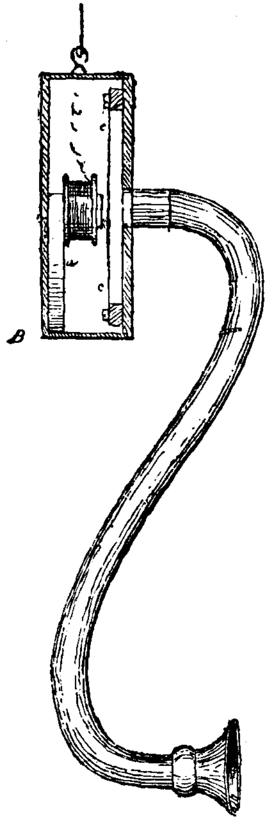


Fig. 9.



Gower Receiver.

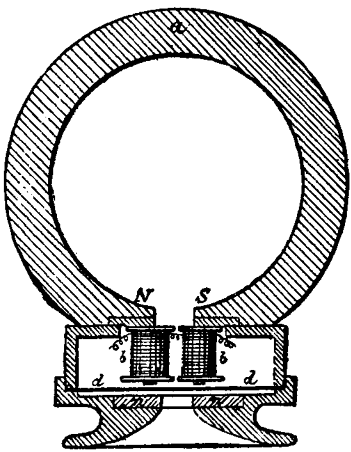
will be seen, is semicircular in form, and has at each pole two bobbins of wire, the soft iron cores of which form extensions of the two poles. The diaphragm *c*, which is generally of tinned iron, and somewhat larger than in the Bell, is carried by the front of the case, being fastened on to a brass 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.

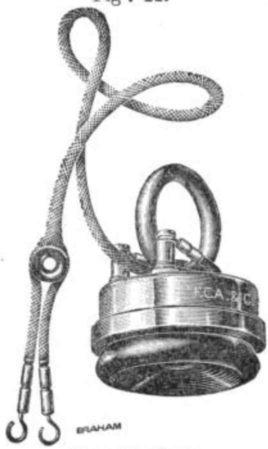


Ader Receiver.

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.

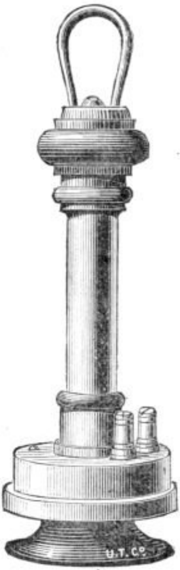
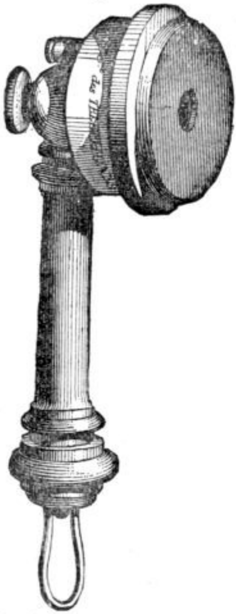


Fig. 13.



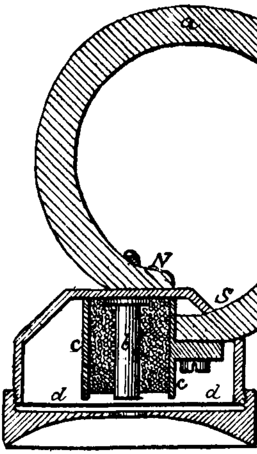
Bell-pattern Ader Receivers.

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.



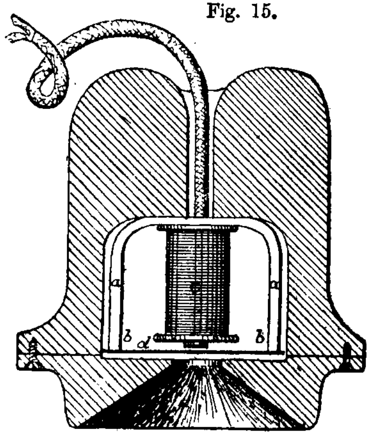
D'Arsonval Receiver.

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.



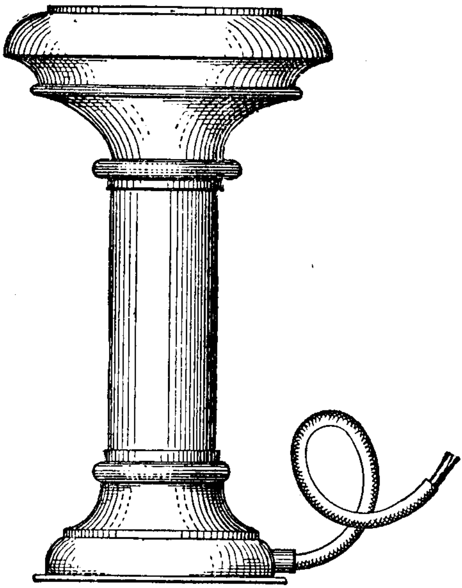
Hickley Receiver.

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 enter 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.

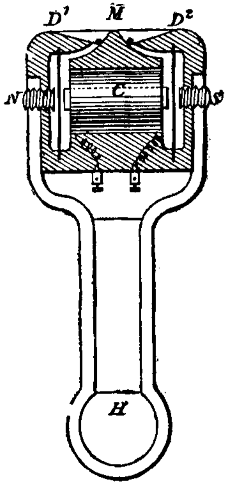
Spoon-shape Receiver.

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 esistance 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.

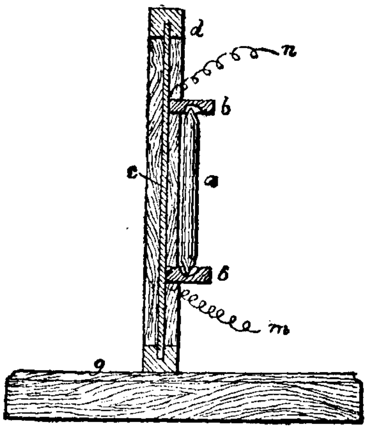
TRANSMITTERS.

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.

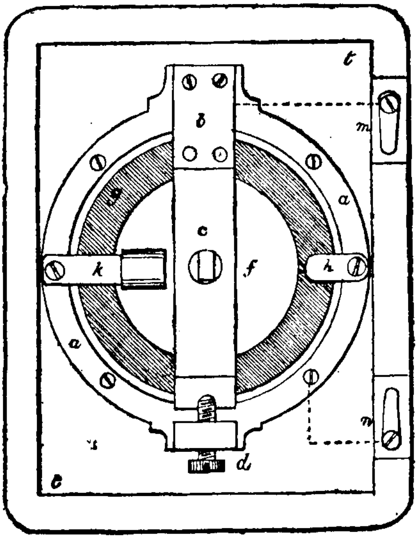
Microphone transmitters can be classed under three distinct headings, viz., the "platinum and carbon," the "carbon pencil," and the "granulated carbon" form. The first of these undoubtedly gives the most perfect and natural articulation, the second are the best for simple, reliable and all-round transmitters, 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.



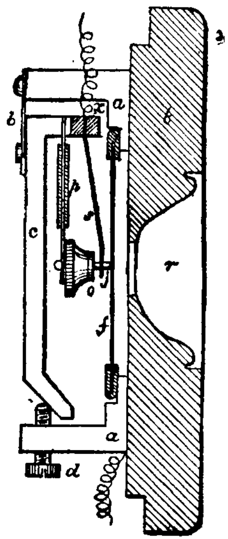
Blake Transmitter.

lever *e*. 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



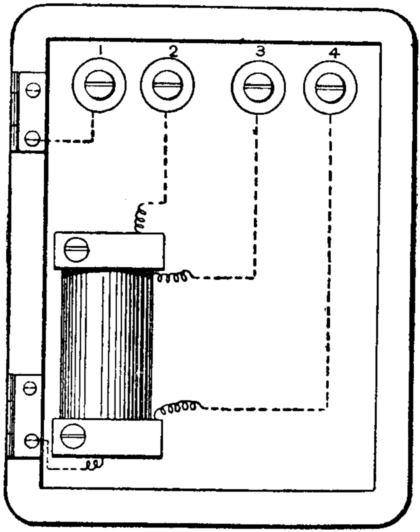
Blake Transmitter.

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.



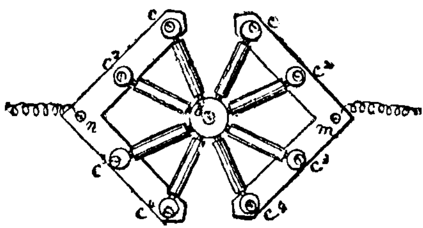
Case of Blake Transmitter.

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.

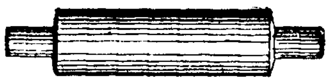


THE GOWER TRANSMITTER.

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.



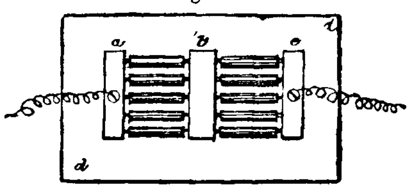
Carbon pencil of Microphone.

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 re-unites 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

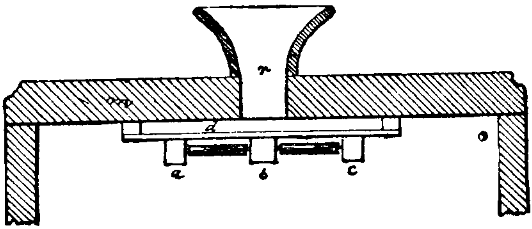
Fig. 26.



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.



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.

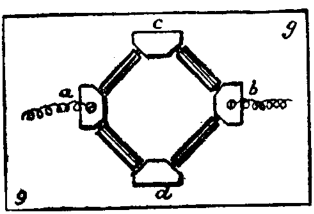
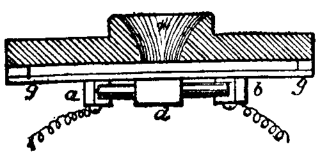


Fig. 29.

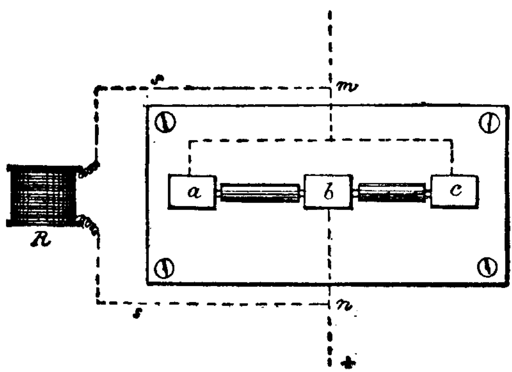


Figs. 28 and 29 show this transmitter in plan and in section. The diaphragm is a thin deal board *g*, as in the transmitter just described, on which are mounted the four carbon blocks *a*, *b*, *c*, *d*, these blocks being connected together by the carbon pencils shown. The connections are made to the 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.

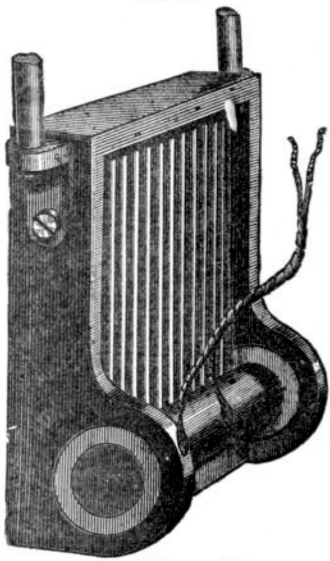
The microphone was arranged in a wooden case with mouthpiece, as in the Ader and Crossley transmitters, and in actual practice gave fair results. In the later forms of this microphone, however, the shunt has been discarded owing to its reducing the sensitiveness of the instrument too much.

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.



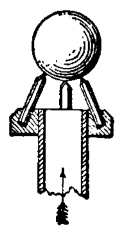
Swinton's Transmitter.

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.

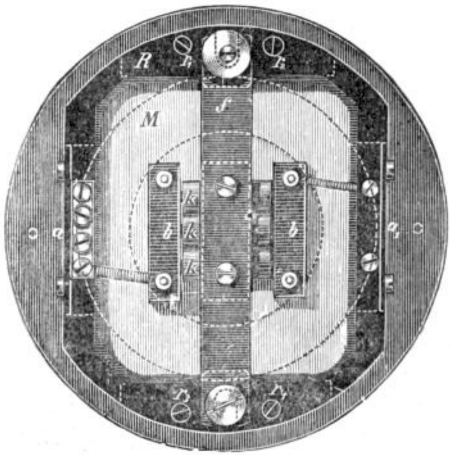
Both inventors, however, or rather the companies working their patents, were restrained from using these instruments by the National Telephone Company, who obtained an injunction against them.

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.

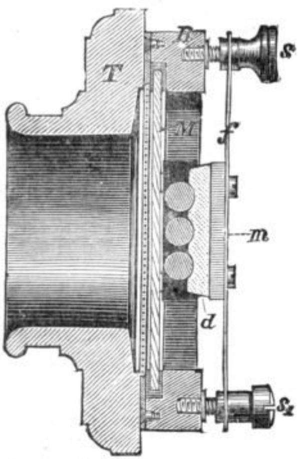
Granulated Carbon Transmitters.

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.

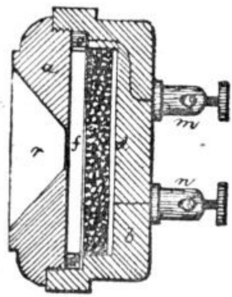
Fig. 35 shows in section Hunnings' transmitter, which consists, as will be seen from the figure, of a wooden case *b*, fitted with a lid *a*, that screws on and off, and in the front of which is cut the mouthpiece *r*. In the back of the inside of the case is fastened the platinum or carbon plate *d*, 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.

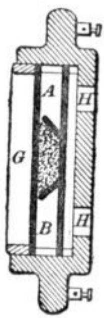
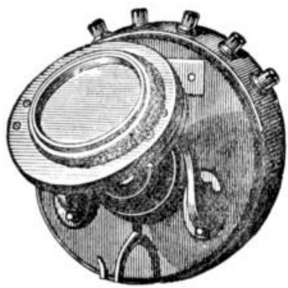


Fig. 37.



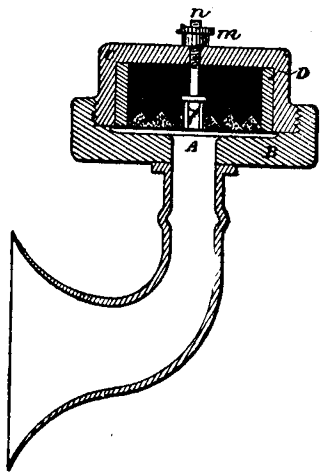
Berthon Transmitter.

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.

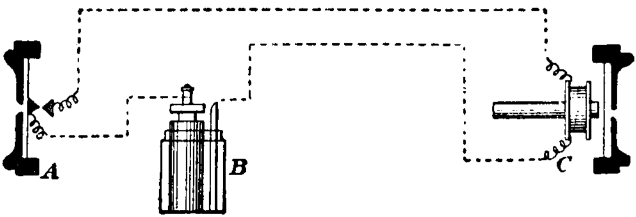
TRANSMITTER INDUCTION COILS.

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

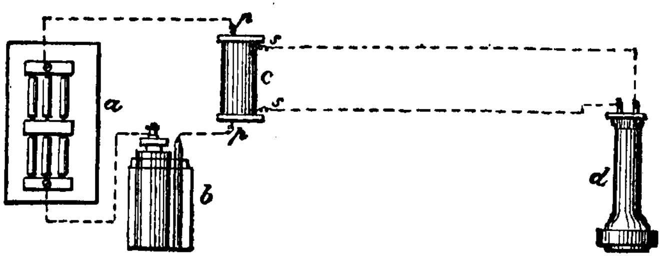
Fig. 39.



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.

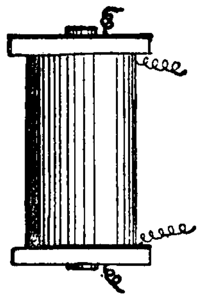


Microphone with Induction Coil.

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 1¼ 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

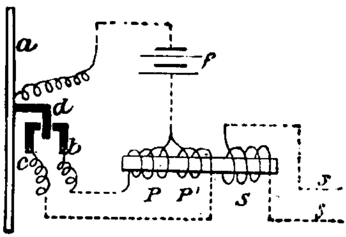


Microphone Induction Coil.

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.

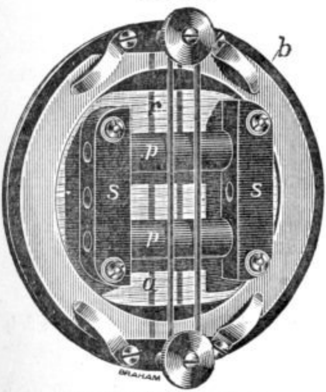
4th. Blake's special form of adjusting lever.

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 abovementioned 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.

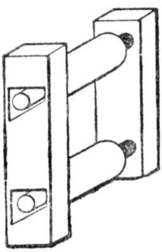
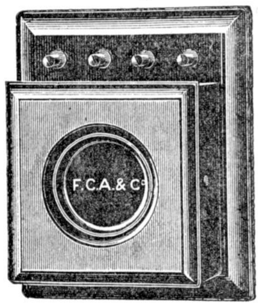


Fig. 45.



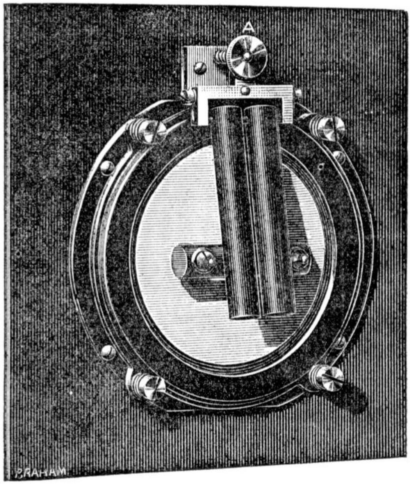
Two-pencil Microphone.

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 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.

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