tried the results did not prove encouraging. Indeed the variations of the resistance which can be produced in this way must be excess­ively small, unless the liquid has a very high specific resistance, the distance between the ends is very small, and the sides of the rods are prevented by an insulating covering from interfering with the results. Neither of these transmitters has any great merit as such, but they show that both Bell and Gray clearly recognized the principle on which successful transmission of the different forms of sound, including speech, could be accomplished.

The first successful microphone transmitter was Edison’s. An early form of it (fig. 10) somewhat resembles Bell’s hand tele­

phone in external form. A

cell of insulating material has at

its bottom a flat-headed platinum

screw G ; on the top of G is a

layer of carbon powder C, on the

top of that a thin platinum disk

D, and above that, forming the

cover of the cell, a disk of ivory B, held in

position by a ring E. Resting on the

centre of this disk is a small piece of

rubber tubing, which is lightly pressed by

the diaphragm A, and this, as in the

hand telephone, is held in position by the mouthpiece

Μ. The varying pressure on A, when a sound is pro­duced near it, causes corresponding variations in the

pressure on the carbon powder, and this produces

similar variations in its electrical resistance. Thus,

when the instrument is included in an electric cir­cuit through which a current is flowing, undula­tions in the pressure on the diaphragm produce corre­sponding undulations in the current.

Perhaps the best known forms of the microphone

are those introduced by Prof. Hughes. One of

the commonest is shown in fig.11 . It consists of

two rectangular pieces of wood, B and D, fixed to­

gether with their planes at right angles to each other. D forms the base, and to B two small blocks of carbon C, C are attached. Between these a light rod A of the same

material is supported on small cups formed

in C, C. To the blocks two electrodes *e, e*

are connected for the purpose of inserting

the instrument in an electric circuit. The ma­terial which Hughes found most suitable for the carbon blocks and rod was wood charcoal metallized by heating it to redness and plunging it while hot into mercury. If this microphone is joined in circuit with a telephone and a small battery, say one or two small Daniell cells, the vibration pro­

duced by a fly walking on

the base D can be distinctly heard in the telephone. The same apparatus will also act as a microphone transmitter, but the sounds are apt to be harsh. A better form for this purpose is shown in fig. 12. In this a light pencil of carbon M is pivoted at *h* and has one end resting on two blocks of carbon c, c, the lower one being fixed to the base.

The pressure of M on the carbon block is regulated by a spring *s.* This ar­rangement is en­closed in a box of thin wood, against which the sound is directed. It is capable of acting well as a transmitter, and especially in a modified form used by Hughes as a microphone receiver. The lower block *c* is then attached to the centre of a vertical diaphragm aud against it the sounds are directed.

The Blake transmitter, which is perhaps most widely used of all, is a simple modification of the Hughes instrument last described. It consists (fig. 13) of a frame F, to which is attached a diaphragm D of thin sheet iron ; in front of this is a cover Μ, M provided with a suitable cavity for directing the sound-waves against the dia­phragm. The microphonic arrangement consists of a spring S, about the hundredth of an inch thick and the eighth of an inch broad, fixed at one end to a lever L, and carrying at its free ex­tremity a brass block W. In one side of W a small disk C of gas carbon is inserted, resting on the hemispherical end of a small platinum pin K, about the twentieth of an inch in diameter, held in position by a thin spring A. The pressure of the carbon on the platinum point can be adjusted by the screw N, which turns the lever about the flexible joint G. The electrical connexions of the instrument as arranged for actual use are also illustrated in the figure. The current circuit goes through S, W, C, K, A, and the primary circuit of the induction coil I to the battery B, and thence to S again. This forms a local circuit at the transmitting station. The line of circuit passes through the secondary of the induction coil I to the line, from that to the telephone T at the receiving station, and then either to earth or back to the induction coil by a return line of wire.

*Telephonic Circuits.*

The lines used for telephone purposes are, generally speaking, so far as erection, mode of insulation, and so on are concerned, much the same as those used for ordinary telegraphs. In towns where a very large number of wires radiate from one centre or exchange, as it is called, where thick wires are unsightly, and where it is often necessary to provide for long spans, a comparatively thin wire of strong material is employed. For this reason various bronzes, such as silicon, aluminium, &c., have come to be extensively used for making wires for telephone lines. They are made from about the twentieth to the thirtieth of an inch in diameter, and are found to wear well in the somewhat mixed atmosphere of a town ; and owing to their lightness and considerable tensile strength it is com­paratively easy to erect them and keep them in order. The main objection to them is the high electrical resistance they oppose to the current. The lines on a town exchange system are not, how­ever, as a rule, so long as to make this objection of great import­ance. But long lines, such as those extending between towns some miles apart, should be made of pure copper wire hard drawn. It has lately been found possible to draw copper so hard as to be almost equal to bronze in strength, and yet to retain about three times the electric conductivity of that substance. Copper and bronze wires possess great advantages for telephonic purposes over the iron wires employed in telegraph lines, in that they offer a much lower effective resistance to the rapidly undulating and intermittent currents pro­duced by telephonic transmitters. The electric resistance opposed by a wire to the passage of such a current is always greater than that opposed to a steady current, and this difference is much more marked when the wire is of magnetic material like iron. This in­creased resistance rises in proportion to the rapidity of the undula­tions of the current ; consequently high notes are more resisted than low notes. Besides this variable resistance, telephony has to contend with “self-induction” (see Electricity, vol. viii. p. 76 *sq.* ) of the current on itself, and this is by no means unimportant, especially on long circuits.@@1 The marked difference between iron and copper for long circuits is plainly shown by the fact that Rysselberg and others have spoken clearly to a distance of over 1000 miles through a copper wire insulated on poles, whereas Preece could not work a similar line of iron wire between London and Manchester.

The electrostatic capacity of the line (see Telegraph, p. 115 above) is also diminished by the use of thin wires of highly con­ducting material. They should all if possible be erected on poles at a considerable height above the earth. It is not practicable to work an ordinary underground line through more than 20 miles, and cable telephony through distances of over 100 miles may in the present state of science be put down as an impossibility.

Another element of great importance in connexion with telephone

@@@1 See papers by Prof. Hughes, *Proc. Soc. Tel. Eng.,* vol. xv. p. 6, and *Proc. Roy. Soc.,* vol. xl. p. 468, with remarks on them by Prof. H. F. Weber, *Tel. Journ.,* vol. xviii. p. 321 and vol. xix. p. 30; by Oliver Heaviside, *Phil. Mag.,* vol. xxii. p. 118; by Rayleigh, *Phil. Mag.,* vol. xxi. p. 381 and vol. xxii. p. 469. See also Prof. Chrystal on the “ Differential Telephone,” in *Trans. Roy. Soc. Edinb.,* vol. xxxi. pp. 609-636.