An investigation has recently been made by Prof. P. E. Shaw on the amplitude of the movement of a telephone diaphragm by means of an extremely sensitive micrometer which he has devised. I will cite one result as showing how extremely small are the quantities with which we have to deal in telephony. He finds that the movement of the diaphragm corresponding to a just comfortably loud impulsive sound is only one twenty-thousandth part of a millimetre, and that something less than one-fiftieth of this is still just audible. The diaphragm has a frequency of

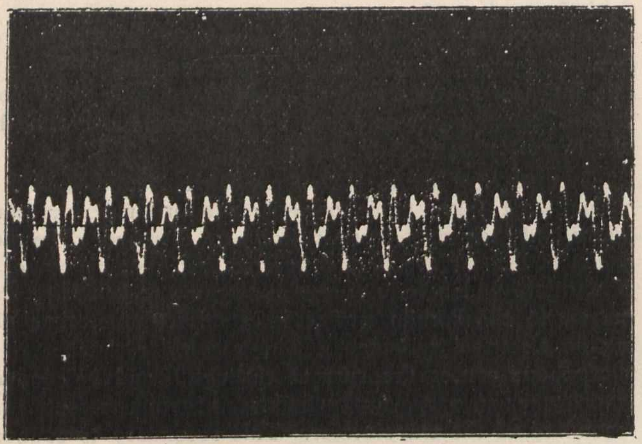

Fig. 4.—Vowel o in Ho.

vibration of its own which in ordinary receivers may be about 500 complete vibrations per second; it will therefore tend to reinforce (due to resonance) notes having the same frequency as itself—i.e., about the octave above middle C. This leads to the very unpleasant accentuating of certain notes when music is transmitted telephonically. It seems as if this might be overcome by applying some form of damping to the diaphragm, or by making its frequency of vibration very much higher. To test the electrical part of the apparatus, we require some means of measuring small alternating currents of fairly high frequency and also some method of producing these currents. At first sight it would seem comparatively easy to construct an alternator to produce these currents, as the highest frequency does not exceed about 2,000 periods per second, and alternators have been constructed to give very much higher frequencies. The real difficulty is to obtain a machine which will give a strictly sinusoidal current under all conditions. This is necessary to enable the experimental results to be easily compared with theory.

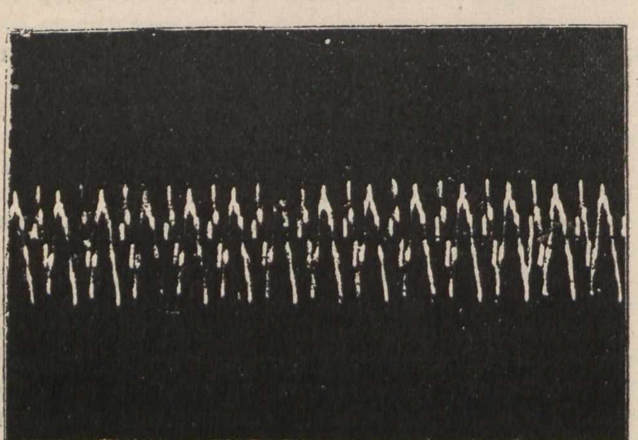

Fig. 5.—Vowel e in Me.

There are other methods of producing high-frequency currents, such as: (1) the humming telephone; (2) the musical arc; (3) the musical vacuum tube, which is produced by shunting a vacuum tube, supplied with high-voltage direct current, with a condenser and self-induction in series in a similar way to the musical arc; (4) the vibrating bar of Mr. Campbell which works in a manner analagous to the electrically maintained tuning-fork, except that the contact is replaced by a small microphone. This latter apparatus gives a very constant frequency and current. Although electromagnetic instruments such as dynamometers have been constructed sufficiently sensitive to measure telephonic currents, the relatively high self-induction of these instruments have prevented their general application. Practically all the instruments which are at present being applied to the measure of high-frequency currents are thermal instruments, that is to say, they depend for their action on the heating produced by the current when it flows through a suitable small high-resistance conductor. These instruments may be broadly divided into three classes, according to whether the rise in temperature of the conductor and consequently the current is measured by (1) the expansion of the conductor; (2) the change in its resistance; (3) the E.M.F. of a thermocouple either forming part of or near to the heated conductor. The first method—viz., the use of the expansion of the conductor as a measure of the current—has not up to the present lent itself to the product on of very sensitive instruments. The second and third methods above have each given instruments of high sensibility such as the "barretter" employed by Dr. Kennelly, and the thermogalvanometer. From the point of view of ultimate sensibility there is very little choice between these two instruments, but the simplicity and ease of standardisation of the thermo-galvanometer make it the more convenient in practice.

Some very interesting results have been obtained by Dr. H. V. Hayes on the attenuation of the current through cables and long overhead lines, and on the improvement that can be obtained by adding self-induction to the line. These experimental results amply bear out the theoretical conclusions of Heaviside as to the great advantage of in-

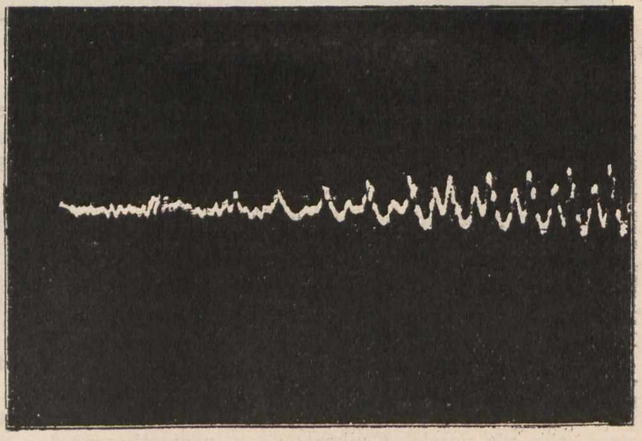

Fig. 6.—K and First Part of e in Key.

creasing the self-induction, or "loading" the line for long-distance transmission. The great importance of avoiding reflection of the current at the terminal apparatus, and the means of reducing it by the use of a "terminal taper," is also very clearly shown. It is greatly to be hoped that these investigations will be actively pursued, and a satisfactory design of loading coil will be developed, as increasing the self-induction of the circuit gives great promise of successfully increasing the length (now limited to about 50 miles) of subterranean or submarine cable through which telephony can be commercially accomplished.

So far the methods of measurement dealt with only give the root-mean-squared or heating value of the current. To investigate the distortion in the sound pattern when translated into a varying electric current as it flows along the line and through the different pieces of apparatus, we require to be able to record the current at every instant and also at two or more points in the circuit. This can be easily accomplished by means of an oscillograph, and the sound patterns given at the commencement of this discourse were thus recorded. Mr. A. Blondel, and the engineer-in-chief of the Post Office, Mr. Gavey, have published many results obtained in this way.

A most complete insight into the distortion produced by different parts of the apparatus and line can be obtained by gearing small mirrors to both the transmitter and receiver diaphragms, so that records can be obtained simultaneously of the movement of the transmitter diaphragm, the current flowing into the line or cable, the current flowing out of the line, and the movement of the receiver diaphragm.