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(sperando di invogliare qualche giovane talentoso a rifare i geniali esperimenti con magneti, telefono, microfono e reotomo qui descritti)

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PHOTOGRAPHED FOR THE JOURNAL BY MR. J. E. MAYALL.

PROFESSOR D. E. HUGHES.

DAVID EDWIN HUGHES was born in London in 1831. His parents came from Balla, at the foot of Snowdon, in North Wales, and in 1838, when David was seven years old, his father, taking with him his family, emigrated to the United States, and became a planter in Virginia. The elder Mr. Hughes and his children seem to have inherited the Welsh musical gift, for they were all accomplished musicians. While a mere child, David could improvise tunes in a remarkable manner, and when he grew up this talent attracted the notice of Herr Hast, an eminent German pianist in America, who procured for him the professorship of music in the College of Bardstown, Kentucky. Mr. Hughes entered upon his academical career at Bardstown in 1850, when he was nineteen years of age. Although very fond of music and endowed by nature with exceptional powers for its cultivation, Professor Hughes had, in addition, an inborn liking and fitness for physical science and mechanical invention. This duality of taste and genius may seem at first sight strange; but experience shows that there are many men of science and inventors who are also votaries of music and art. The source of this apparent anomaly is to be found in the imagination, which is the fountain-head of all kinds of creation.

Professor Hughes now taught music by day for his livelihood, and studied science at night for his recreation, thus reversing the usual order of things. The college authorities, knowing his proficiency in the subject, also offered him the Chair of Natural Philosophy which became vacant; and he united the two seemingly incongruous professorships of music and physics in himself. He had long cherished the idea of inventing a new telegraph, and especially one which should print the message in Roman characters as it is received. So it happened that one evening while he was in the glow and enthusiasm of musical improvisation, the solution of the problem flashed into his ken. His music and his science had met at this nodal point.

All his spare time was thenceforth devoted to the development of his design and the construction of a practical type-printer. And as the work grew upon him he became more and more engrossed with it, until his nights were almost entirely given to experiment. He begrudged the time which had to be given to teaching his classes; and the fatigue was telling upon his health, so in 1853 he removed to Bowlingreen, in Warren Co., Kentucky, and acquired more freedom by taking pupils.

The main principle of his type-printer was the printing of each letter by a single current; the Morse instrument, the only other rival then in the field in America, required, on the other hand, an average of three currents for each signal. In order to carry out this principle it was necessary that the sending and receiving apparatus should keep in strict time with each other, or be synchronous in action; and to effect this was the prime difficulty which Prof. Hughes had to overcome in his work. In estimating the Hughes' Type-Printer as an invention we should never forget the state of science in those days, a quarter of a century ago. He had to find his own governors for the synchronous mechanism, and here his knowledge of acoustics helped him. Centrifugal governors and pendulums would not do, and he tried vibrators, such as piano-strings and tuning-forks. He at last found what he wanted in two darning needles borrowed from an old lady in the house where he lived. These steel rods fixed at one end vibrated with equal periods, and could be utilised in such a way that the printing wheel could be corrected into absolute synchronism by each signal current.

In 1854, Prof. Hughes went to Louisville to superintend the making of his first instrument; but the first patent for it was not taken out in the United States until 1855. In that form straight vibrators were used as governors, and a separate train of wheelwork was employed in correcting: but in later forms the spiral governor was adopted, and the printing and correcting is now done by the same action. In 1855, the invention may be said to have become a practical success, and no sooner was this the case, than Prof. Hughes received a telegram from the editors of the American Associated Press, summoning him to New York. The American Telegraph Company, then the leading one, was in possession of the Morse instrument, and levied rates for transmission of news which the editors could no longer stand. They therefore took up the Hughes instrument in opposition to the Morse. A company was formed, and the lines of the smaller fry of companies—among which was the Western Union Company, then doing business on a poor scale out West—were leased. After a time, they united in 1857 with these smaller companies to form one large corporation, the Western Union Telegraph Company of to-day. They bought over the Morse instrument too, and when the monopoly was all in their hands, the editors were again left in the lurch.

In 1857, Prof. Hughes, leaving his instrument in the hands of the Western Union Telegraph Company, came to England to effect its introduction here. He endeavoured to get the then Electric Telegraph Company to adopt it, but after two years of indecision on their part, he went over to France in 1860, where he met with a more encouraging reception. The French Government Telegraph Administration became at once interested in the new receiver, and a commission of eminent electricians, consisting of Du Moncel, Blavier, Froment, Gaugain, and other practical and theoretical specialists, was appointed to decide on its merits. The first trial of the type-printer took place on the Paris to Lyons circuit, and there is a little anecdote connected with it which is worthy of being told. The instrument was started, and for a while worked as well as could be desired; but suddenly it came to a stop, and to the utter discomfiture of the inventor he could neither find out what was wrong, nor get the printer to go again. In the midst of his confusion, it seemed like satire to him to hear the commissioners say, as they smiled all round, and bowed themselves gracefully off, "*Tres-bien, Monsieur Hughes—tres-bien. Je vous felicite.*" But the matter was explained next morning, when Prof. Hughes learned that the transmitting clerk at Lyons had been purposely instructed to earth the line at the time in question, to test whether there was no deception in the trial, a proceeding which would have been strange, had not the occurrence of a sham trial some months previous rendered it a prudent course. The result of this trial was that the French Government agreed to give the printer a year of practical work on the French lines, and if found satisfactory, it was to be finally adopted. Daily reports were furnished of its behaviour during that time, and at the expiration of the term it was adopted, and Prof. Hughes was constituted by Napoleon III. a Chevalier of the Legion of Honour.

The patronage of France paved the type-printer's progress into almost all other European countries; and the French agreement with Prof. Hughes, respecting it became the model of those of other nations. On settling with France in 1862, Prof. Hughes went to Italy. Here a commission was likewise appointed, and a period of probation—only six months—was settied, before the instrument was taken over. From Italy Prof. Hughes received the Order of St. Maurice and St. Lazare.

In 1863, the United Kingdom Telegraph Co., England, introduced the type-printer in their system.

In 1865, Prof. Hughes proceeded to Russia, and in that country his invention was adopted after six months' trial on the St. Petersburg to Moscow circuit. At St. Petersburg he had the honour of being a guest of the Emperor's in the summer palace, Czrarskoizelo, the Versailles of Russia, where he was requested to explain his invention, and also to give a lecture on electricity to the Czar and his court. He was there created a Commander of the Order of St. Anne.

In 1865, Professor Hughes also went to Berlin and introduced his apparatus on the Prussian lines. In 1867, he went on a similar mission to Austria, where he received the Order of the Iron Crown; and to Turkey, where the then Sultan bestowed on him the Grand Cross of the Medjidie. In this year, too, he was awarded at the Paris Exhibition of 1867, a grand *hors ligne* gold medal, one out of ten supreme honours designed to mark the very highest achievements. On this occasion, also, another of these special medals was bestowed on Cyrus Field and the Atlantic Telegraph Company. In 1868, he introduced it into Holland; and in 1869, into Bavaria and Wurtemburg, where he obtained the noble Order of St. Michael. In 1870, he also installed it in Switzerland and Belgium.

Coming back to England, the Submarine Telegraph Company adopted the type-printer in 1872, when they had only two instruments at work. They have now (1878) twenty of them in constant use, of which number nine are working direct between London and Paris, one between London and Berlin, one between London and Cologne, one between London and Antwerp, and one between London and Brussels. All the continental news for the *Times* and the *Daily Telegraph*, is received by the Hughes type-printer, and is set in type by a type-setting machine in the very act of arriving. Further, by the International Telegraph Congress it was settled that for all international telegrams only the Hughes instrument and the Morse were to be employed.

In 1875, Professor Hughes introduced the type-printer into Spain, where he was made a Commander of the Royal and Distinguished Order of Carlos III. In every country which it was taken to, the merits of the instrument were recognised, and Professor Hughes has none but pleasant souvenirs of his visits abroad.

During all these years, the inventor was not idle. He was constantly improving his invention; and in addition to that he had to act as an instructor wherever he went, and give courses of lectures explaining the principles and practice of his apparatus to the various *employés* into whose hands it was to be consigned.

What with this work, and his various journeys, Professor Hughes can have had little time for original work in other directions. But very soon after the type-printer was finally off his hands, his attention was drawn to the telephone. The researches of Sir William Thomson on the variation of electric resistance in a wire subject to stress, led him to enquire whether or not sonorous waves could not be made to vary the resistance of the wire itself of the telephone circuit by stressing it, and the result of his discovery was, as everyone knows, the microphone. The Hughes type-printer was a great mechanical invention, the greatest in telegraphic science, for every organ of it was new and had to be first fashioned out of chaos; an invention which stamped its author's name indelibly into the history of telegraphy, and procured for him a special fame; while the microphone is a discovery which places it on the roll of investigators, and at the same time brings it to the knowledge of the people. Two such achievements might well satisfy any scientific ambition. Professor Hughes has had a most successful career; and probably no inventor ever before received so many honours, or bore them with greater modesty.

THE SOURCE OF SOUND IN THE TELEPHONE.

AN EXPERIMENTAL INVESTIGATION BY AID OF THE MICROPHONE.

By PROF. D. E. HUGHES.

A RECENT discussion upon the theory of the telephone* has caused me to make a series of experiments to determine if the sounds in that instrument were produced by the molecular action described by De la Rive, Page, Wertheim, and others, where sounds were heard in wires and electro-magnets upon the passage of a strong intermittent current through them; or if simple electro-magnetic attractions and repulsions were sufficient to fully account for all the phenomena of the telephone.

From a few experiments made some time since without any diaphragm and in which sounds and speech were perfectly reproduced, I was inclined to believe that we must look to the molecular action as playing a very important part, but on submitting each part of the telephone to experimental investigation by aid of the microphone, I have been led to believe that the molecular action is so feeble compared with the electro-magnetic attractions and repulsions, that its action has really no important *rôle* where we deal with such feeble currents as are generally produced in the telephone.

In order that the telephonic effects should be strongly marked and at the same time too weak to produce any molecular sounds, three elements of Daniell's battery were employed. These gave me telephone sounds sufficient to be heard at a distance of two or three feet, but at the same time, on submitting each part to the microphone so that it should take up only those sounds due to the organ submitted to its examination, no sounds were heard that could be fairly attributed to molecular action, whilst the effects due to known electro-magnetic action were extremely marked and distinct.

The microphones, which were vertical ones, were arranged in two distinct circuits, the first being used as a transmitter of undulatory currents to the telephone coil which was under investigation, the second microphone was attached to a small board 6 inches square and insulated by india-rubber feet, and wires were led from this microphone through a battery to a telephone; the batteries in each circuit was

* Comte du Moncel and Col. Navez. See TELEGRAPHIC JOURNAL, Sept. 1, 1878.

three Daniell's elements. The transmitting microphone was placed in a distant room and the source of sound generally used was an ordinary French *reveil* clock, this giving the maximum of sound obtainable without interruptions of circuit. In many cases the results were verified by transmitting speech; but I had long before found that whenever the peculiar timbre of the clock could be heard, articulate sounds were also perfectly reproduced.

By this arrangement, the microphone being so adjusted that it was only sensible to sounds mechanically transmitted to it through the board, whilst insensible to sonorous waves transmitted through the atmosphere, each organ of the telephone could be investigated separately by putting that piece alone in contact with the microphone table, whilst the other organs were held at certain distances in the air.

The following is a sketch of this arrangement :—

were heard if the battery was increased to twenty elements. Different coils of size, shape, and number of wire were tried, but no sounds were audible on any. On now approaching a strong bar magnet (6 × 1 inch) near to the coil, say ¼ inch distant, I at once hear the sound with all its peculiar timbre, the sounds increasing or decreasing as I put the magnet nearer or farther from the coil. The sounds, however, at their maximum, were but one-fortieth (approximately) of ordinary telephonic ones.

It is here evident that the sound is due to the mutual action between the current in the coil and the strong magnetic field, in other words to that electro-magnetic action which tends to cause a current in a wire crossing the lines of force in a magnetic field to move in a direction perpendicular to itself and to the lines of force which it crosses.

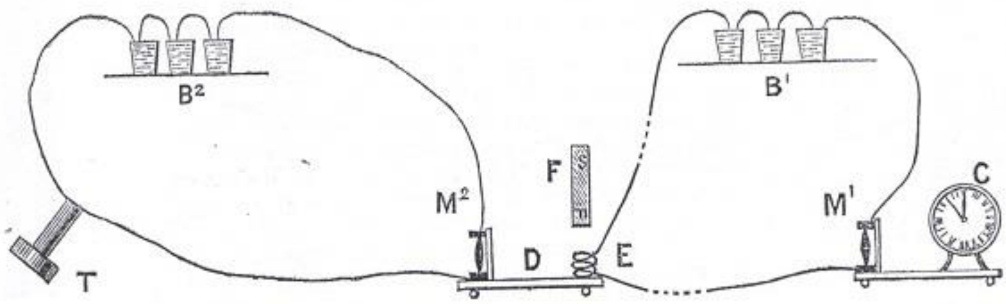


FIG. 1.

1st, or transmitting circuit :—C, clock, or source of sound; B¹, battery; E, coil, resting on sound microphone table; M¹, microphone transmitting electrical variations of current produced by clock C; F, natural magnet, held at certain distances but insulated by air from mechanical contact.

2nd, circuit upon which sounds produced upon the table were augmented by the microphone and transmitted to the receiving telephone; M², microphone; B², battery; T, receiving telephone, or microphone receiver.

This arrangement was used throughout the following microphonic experiments, and as we have now only to change the coil E, or affix to the table D any part under investigation, we shall in future refer only to the table D.

I will now speak of the experiments, which have all been reproduced several times at distant intervals, and on describing each, I will give the reasons for its result as they appear to me.

COILS.—Experiment I.—The ordinary coil of a telephone being placed on the table gave out no appreciable sounds. (I may here remark that, when I say no sounds, I merely state that with the feeble undulatory currents employed, no sounds were heard, although this same current was sufficient to produce exceedingly loud tones when all the organs of the telephone were put together and properly adjusted.) In the above case feeble sounds

II.—A coil of fine iron (covered) wire (No. 30) gave out at first no sounds, but gradually became audible as the wire itself became magnetised by the current. If the bar magnet was brought near, the sounds were much louder than the copper coil, being about $\frac{1}{30}$ of telephonic ones. The magnetic field is here increased by the wire itself being a magnet.

III.—Two coils of copper wire of similar length but of different shape; the one being 2 inches in height by 1 inch diameter, the other a flat coil of 2 inches diameter by ½-inch; each being tried separately it was found when the pole of the magnet was held near their centres that the flat coil gave out double the sound of the other, but if held near the sides, the reverse effects took place.

(The larger surface of the flat coil explains the increased sound when a magnet is held over its centre, but in the second case the longer surface of the 2 inch helix explains its increased action.)

IV.—The coil resting upon table giving out clear sounds when the magnet was near, the magnet was replaced by the coil of an electro-magnet without its iron core. With a strong local battery passing through this coil similar effects to those of the magnet were obtained, though not so strong, owing to the difficulty of inducing so strong a magnetic field as the magnet alone; but on introducing its iron core the sounds became as loud or louder in proportion to the strength of the field of force.

V.—If a flat magnet was laid on the table and the coil held at a distance, the sounds were louder and more metallic than in the cases when the coils were placed on the table. If the magnet was inside the coil and also resting on the table, the sounds were not nearly so loud as when the coil rested simply beside the magnet.

(In this case if the coil was absolutely fixed upon the magnet and no movement possible of the copper wire, we should only have the sounds due to the magnet and coil reacting upon the earth's magnetic field, and I found that if the coil was loose, much louder sounds were obtained than when it was fixed; but when it was placed flat on the side of magnet the full electro-magnetic reactions of coil on magnet were observed, consequently the sounds proved to be much louder than when the magnet was placed in the centre of the coil.)

VI.—If instead of the bar-magnet both poles of a horse-shoe magnet were introduced, the sounds were still heard, but far more marked when the coil lies on the sides of the horse-shoe. In this experiment the north and south pole, both being in the same coil, it would be natural to believe that one should neutralise the effect of the other, and I originally held this to be an argument in favour of the molecular theory; but we shall see in experiments under the head of "pendulum" that it is fully explained by the greater effect of the magnetic attractions than the repulsions.

VII.—If on one end of the bar magnet with its coil a microphone was attached so as to be influenced only by its elongation, no sounds whatever were heard—although it was sensitive to a hair lightly drawn across the pole. No trace of sound whatever could be heard; thus, if the sound was due to molecular changes, we should have certainly expected to have heard slight sounds at least from an undulatory current which was producing sufficient electro-magnetic changes to give out the loud tones upon the diaphragm, as already mentioned.

VIII.—If upon the microphone table I strained a wire 6 inches long, similar to a musical string, and through this wire pass the current, I heard no sounds; but on putting a strong horse-shoe magnet so that the wire was between the poles (which in this case should not be apart more than ½ inch), I heard very plainly, and remarkably so, when we consider that in the case above mentioned, there were but a few inches of the wire under the influence of the magnetic field. Sounds were thus obtained from a wire only one centimetre long on the board; fine iron wire gave out the loudest effect, but this was found to be due simply to its becoming magnetised and thus reacting more strongly on the field of force.

(In all the above experiments the sound obtained was not at its maximum more than one-twentieth of telephonic ones, so we cannot consider any of these points as predominant sources of sound.)

IX.—ARMATURES OR DIAPHRAGMS.—An iron armature, no matter what form or size, when placed upon the microphone table gives out loud tones, the magnet and coil being held in the air and thus insulated; the loud tones can only be due to the armature in contact with the table.

(The sounds here are due to magnetic attractions, the loudness depending upon the best conditions for movement and rapid action in a strong magnetic field. In some following experiments this point will be elucidated.)

X.—If a copper coil without the magnet, is held above these armatures, the sound is comparatively weak. An iron coil gives louder tones, due to its becoming magnetised, but both are very weak compared with those given by the side of the natural magnet. An electro magnet with iron cores was not equal to the natural magnet, because the battery was too weak to induce a high magnetic field.

XI.—With different metals and non-conductors, such as wood, glass, gutta-percha, ivory, metallic oxides, &c., &c., it was found that all conductors, if sonorous, gave out sound; but no continued trace could be found with mercury, and but slight traces with lead. All the non-conductors gave no sound whatever.

Compared with iron the following is an approximate value, being the mean of several repeated experiments :—

Iron	100
Silver	10
Copper	9
Bronze	9
Zinc	8
Gold	8
Brass	7
Cadmium...	6
Tin	4
Lead	2
Carbon	2
Mercury	1
Wood, Glass, and all non-conductors	0

(All the above non-magnetic conductors gave out sound by direct mechanical movement, caused by the induced currents re-acting upon the magnetic field, giving repulsions where iron was attracted. This will be shown in some following experiments.)

XII.—With all the non-magnetic metals, the sound was loudest if the armature had a large surface, as a plate or sheet; the sounds were at their maximum when the magnet and coil were held over the centre of the plate, and gradually diminished when moved towards the edges.

(This shows the importance of the diaphragm form of armature, and in the case of copper, the induced currents had a wider field for action when the magnet was held at the centre than when at its edges.)

XIII.—Each metal gave out its own particular timbre, which could be perfectly reproduced by touching it with a small strip of thin paper at the point where the centre of the magnet had been held.

(This shows that the supposed molecular sounds were really mechanical movements which could be reproduced by a feeble mechanical effort.)

XIV.—A coil of insulated copper wire placed on the table as an armature, gave but feeble traces of sound if the two ends of the wires were insulated, but on joining the wire or short circuiting the coils, loud and distinct tones were always obtained.

(This proves that the sounds are due to the re-action of induced currents in the coil upon the magnetic field.)

XV.—A coil of uncovered copper wire gave out sounds if the ends were open or closed, being then similar to a copper plate, where the currents can flow in closed circuits.

XVI.—A flat magnet gives out louder tones than an iron armature of the same form, and a still more remarkable difference is observed if a coil alone without its magnet is held above. In this case, the magnetic armature gives out tones ten times stronger than the simple iron, thus showing again the necessity for a strong magnetic field of action.

XVII.—A coil of covered iron wire gives out the same amount of sound whether the circuit be closed or open.

XVIII.—A thin iron plate armature gave out loud and clear tones; these tones were but slightly diminished by the interposition of another thin plate or plates, of iron, between the magnet and coil and armature. Sounds were thus obtained through fifteen interposed iron diaphragms, being then but a quarter of the original sound. If, however, the sum total of all the diaphragms could have been utilised, the total sound would have been greatly augmented.

XIX.—The coil of covered copper wire was laid on the top of a ferrotype iron plate; the natural magnet alone held above this, gave out strong tones, but if the coil was placed underneath the ferrotype, the sounds were but one-third of its previous force; this shows the advantage of having the coil direct in the magnetic field, between the magnet and its armature. In both cases, sounds were scarcely audible when the natural magnet was withdrawn: they were not one-twentieth of the original sound intensity.

(From this we cannot expect any perfect electromagnetic telephonic arrangement which does not employ a strong magnetic field for its reactions.)

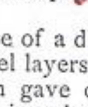
XX.—If we place on the microphone table a solid cube of iron (2 inch cube), the coil and magnet being held at a slight distance, we hear distinctly the tones, but far more feeble than in the case of a thin ferrotype of the same diameter. With the ferrotype we hear a clear metallic ring with each tone, but with the cube of iron there was no such ring, the tone being dull and muffled; in fact, the tones were those of the microphone table itself, thus indicating that the slight mechanical movement of the iron cube was transmitted to the wood, which, by it elasticity, became in reality the diaphragm or source of sound. To prove this, we found that sounds increased up to the moment when the natural magnet touched the iron, when they attained their maximum. On pressing the magnet on the iron with gradually increasing pressure, the sounds gradually faded until but slight traces were audible. On removing the pressure, sounds increased until the magnet raised the iron slightly: here was the maximum; but the instant the iron by its own weight broke the contact and thus again pressed more heavily on table, the sounds almost disappeared. Compared with the ferrotype, it was found that the latter gave out louder tones with the magnet and coil held at 3 inches distance, than upon the cube of iron at $\frac{1}{10}$ inch distance. At $\frac{1}{4}$ inch distance but feeble traces of sound could be heard in the cube, whilst the ferrotype gave out loud tones with its own peculiar metallic ring. In both cases the peculiar timbre of the cube and the ferrotype could be reproduced by touching it lightly with a thin strip of paper; thus, a slight mechanical movement would easily account for the sounds in both cases.

XXI.—A ferrotype diaphragm laid loosely on microphone table. Magnet and coil held above gave out with each sound a metallic ring exactly the same as when the same diaphragm was held to the ear and slightly touched by a piece of paper. If it was fastened on the table by its circumference, as in the telephone, we had one dominant musical note with each sound. If fastened only at its centre, the metallic ring would be prolonged long after electromagnetic sounds had ceased, it being then in a constant state of vibration from the slightest extraneous cause. If we glued or fastened this diaphragm to a thin cardboard, the metallic ring disappeared, and the tone became slightly weaker and muffled. If the diaphragm was glued throughout its surface to a similar piece of pine board 1 inch thick, the tones became very weak, resembling the cube of iron, and the tone was no longer that of iron, but that of wood.

(This shows that the tones could not be due to any particular molecular movement in the iron plate, but that the tone or timbre is due to the body actually in movement, as the metallic tones of iron can be gradually masked, partaking of the intermediate tones of iron and wood, until, by increasing the thickness of wood, the metallic tones are entirely lost by the predominance of those of the wood.)

XXII.—The surface of a diaphragm of cardboard had glued to it parallel layers of thin uncovered iron wire; this diaphragm gave out the tones of cardboard either on the microphone table or if it replaced the ferrotype in an actual telephone; in both cases the tone was comparatively weak, compared with the same amount of iron and surface in the ferrotype, a result due to the want of elasticity in the cardboard. The same iron wire glued to a thin glass plate gave out clear, sharp tones, but the tone was that of glass, and not that of iron. From this we should judge that the varnish on ferrotype serves an excellent purpose in slightly muffling the metallic ring of the iron plate.

XXIII.—In order to see if we could render these movements of the diaphragm visible to the eye or touch, a thick tin plate diaphragm was placed in a telephone in direct circuit of the first transmitting microphonic circuit. The sounds were very clear and loud, but no movement whatever of the diaphragm could be perceived by the eye or touch. A very thin charcoal iron plate was now used; the tones were louder than before, but still no visible movement. This plate then had a small narrow segment cut out of it from the circumference to the centre.

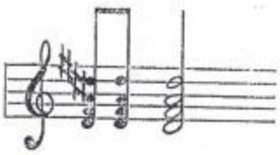


The sound was slightly diminished, but strong movements were visible both to eye and touch; by placing the finger on the divided portion not only could every beat of the clock be perfectly felt, but its peculiar timbre in a slight degree recognised.

(Here we have transformed a sound which in the first place gave out no visible movement, and which might from this be supposed to be due to some molecular motions, into one of direct mechanical movement recognisable by touch, and where molecular action is not at all necessary to its explanation.)

XXIV.—Knowing that each diaphragm in a telephone has its own dominant tone, which accompanies all sounds emitted, the diaphragm was divided into two slightly unequal portions. Clear loud tones were then produced as before, but they were accompanied with two dominant tones—in fact, a chord, due to the different dominant tones of each segment of diaphragm. By chance they happened to be an exact fifth, and the word "telephone," like all other words transmitted to it, was accompanied by the dominant chord, thus:

and I am convinced that by proper arrangements four segments reproducing the whole cord could have been obtained, thus:



(To be continued.)

at all, unless it be for lighting up their workshops. There are, indeed, signs that the companies recognise the hopelessness of attempting to monopolise the electric light, and are confining themselves to developing the capabilities of gas.

THE SOURCE OF SOUND IN THE TELEPHONE.

AN EXPERIMENTAL INVESTIGATION BY AID OF THE MICROPHONE.

By PROF. D. E. HUGHES.*

(*Continued from page* 455.)

PENDULUM EXPERIMENTS.—In order to verify the preceding experiments on a different system of observation, by means of which the attractions and repulsions could be rendered visible and the force estimated by its mechanical movement, the following instrument was constructed :

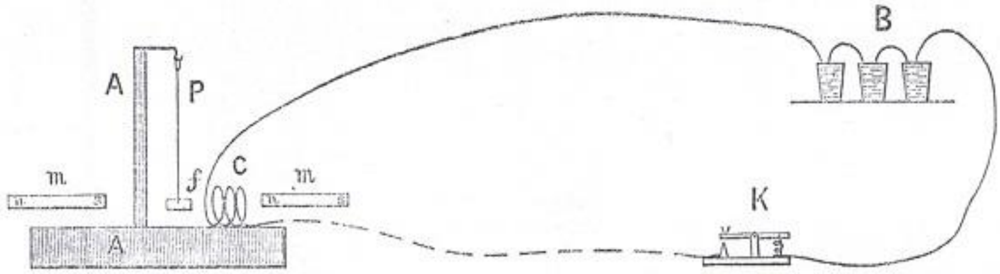


FIG. 2.

A A. Wooden stand for sustaining the pendulum wire.

P. Thin copper wire, hair, or glass thread, to sustain the piece of iron, or "bob," under observation, and by the weight of the bob and its freedom of motion to serve as the rod of the pendulum.

f. Iron, copper, or other metal bob under investigation ; the degree of continued swing being the approximate and comparative measure of the force of action upon the bob from the coil, magnet, &c.

C. Coil in communication with the three Daniell's elements. This could be shifted near or far at will by a slide.

m m. Magnets, which could be used at will to induce a magnetic field.

K. Key for closing the circuit, giving at will prolonged or momentary currents. By the introduction of a hammer and anvil microphone, undulatory currents could be used ; but as no difference was found except in the degree of force exerted, we will speak only of the maximum effect obtained in making and breaking circuit by the key.

B. Battery.

XXV.—A small rod of iron wire ½ inch long, ⅛th inch in diameter, being affixed to pendulum wire, the coil being brought within ½ inch of it, the key being opened and closed synchronously with swing of pendulum so as to sustain and increase its swing, gave but feeble results, the maximum swing being but ¼ inch. Iron bar introduced into coil improved it, giving ½ inch swing. Magnet in coil gave strong effects, but in order to measure its full effect it was necessary to remove the coil to 2 inches distance, yet even here the effect was remarkable, giving full 2 inches swing. Each closing of the circuit was marked by a strong action on the rod ; and taking into consideration the increased distance of the coil, the effect was fully twenty times as strong with the induced magnetic field as with the simple coils alone. The magnet, when removed from the coil and placed at the back of the rod, the coil thus being on the opposite side, gave feeble results, the swing being but ¾ inch. If the magnets were placed at both ends, one in the coil and the other at the back of the rod, the swing was but 1 inch ; the rod had an unstable movement as it fell under the influence of one or the other magnet. The swing was at its maximum when both magnets were placed in the coil, the similar poles being together ; it then reached 2½ inches.

XXVI.—Horse-shoe magnet or contrary poles being introduced into the coils in place of the bar magnet, the iron rod at once placed itself at right angles, and on the passage of the current through the coils, would turn on its axis slightly as a galvanometer. Notwithstanding this it commenced at once to swing, giving at its maximum 1 inch range. At first glance we should have supposed that the rod would simply have turned on its axis, but as the attraction is much stronger than the repulsion, we had here the differential results, of this action, and consequently this explains why we hear the sounds in a telephone whose magnets consists of two separate and opposing poles.

XXVII.—Copper, zinc, silver, and all non-magnetic bodies attached to the pendulum in the place of the iron show feeble repulsion where iron shows strong attraction. The swing obtained from copper, &c., was very feeble, not being more than ¼ inch at the maximum, and that only when the coil was as near as possible. No effect whatever could be obtained by the coil alone, but the introduction of the magnet at once gave evidence of the repulsions.

XXVIII.—A coil of fine covered copper wire placed on the pendulum gave no repulsions as long as the circuit of this coil was open, but on joining

* Communicated by PROF. HUGHES to the *Telegraphic Journal*. We state this because the article has been copied in a mutilated form by a contemporary.

the wires so as to form a closed circuit in which the included currents could circulate, clear repulsions were obtained.

(This proves that the movement obtained is due to the reaction of the induced currents upon the magnetic field, and as these currents are in the contrary direction to the direct or primary currents, repulsion instead of attraction takes place. This fully explains the reasons of repulsion in all the non-magnetic conductors, and also why we obtain sounds from such bodies.)

XXIX.—A coil of fine (covered) iron wire having replaced the copper coil, gave strong attractions, and but little difference could be observed when the circuit of the coil was closed or open, owing to the fact that the greatly increased swing necessitated the removal of the primary coil. In the case of the copper coil we had but one-eighth inch swing at the maximum, but with the iron coil 2 inches. (No doubt the induced current in the closed iron coil reacted upon the magnetic field tending to feeble repulsion, but the strong magnetic movement of the iron so overpowered it as to render it almost inappreciable.)

XXX.—All non-conductors gave no evidence of movement simply from want of a conducting body in which the induced currents could circulate. With copper, zinc, &c., short momentary contacts were quite as effective as prolonged ones; but with iron a very marked difference was shown in favour of prolonged contacts, thus showing that the movement was not due to any instantaneous molecular changes, but simply to electro-magnetic attractions, as we have all long since understood.

XXXI.—If we take two small bars, one of tempered steel magnetised, and the other of soft iron, both being exactly the same size, and placed alternately on the pendulum, we find that the maximum of swing is obtained with the steel bar, it giving 3 inches swing for 2 inches of soft iron. If we place in the coil a bar of soft iron similar in size to the permanent magnet, we obtain but 1 inch spring. Knowing as we do, that iron possesses far greater power as regards electro-magnetic changes under a given force than steel, the superior results obtained by the use of a steel magnet, both in the coil and on the pendulum, can only be due to a greater change in the field of force, and not to electro-magnetic molecular change in the magnet itself.

(To be continued.)

PRITCHETT'S IMPROVEMENTS IN TELEPHONES.

The Dual Telephone.—Telephones as now generally used consist of the well-known cases held by the hand, and are applied to the ear and to the mouth for receiving and transmitting purposes. By a patent recently published, the disadvantage and uncertainty consequent upon shifting the instruments, or by using two separate instruments, is obviated. One form of instrument covered by the patent is shown by fig. 1. One end of a hinged and covered magnetised bar is fitted with a padded receiving ear-piece, and its other end is fitted with a transmitting mouth-piece. This instrument is held by one hand, and is adjusted to the ear and mouth by one motion, obviating any shifting or the necessity of having to use two telephones.

Another great advantage is that this form of instrument leaves one hand free for writing or reporting as the message arrives at the ear, whilst at the moment after the user can transmit or ask for a repetition of a message or word by means of the mouth-piece. This form, the patentee, Mr. G. E. Pritchett, F.S.A., of Bishop's Stortford, Herts., terms a dual telephone.

The Triple Telephone.—Another form (fig. 2) shows a nearly similar arrangement in a triple form. It has two ear-pieces for receiving, and one mouth-piece for transmitting purposes, and is held by the handles A shown in the figure. The ear-pieces in both figs. being padded, deaden external sounds, and make the instruments, which are light and handy, very useful. Both instruments can be folded up and placed in the pocket or in a small case, and connected and disconnected at will with circuits as required.

Fig. 3 is a very handy form of instrument where it is desirable to have both hands free for writing, &c. It consists of a pair of bent magnetised and covered bars fitted with padded ear-pieces and adjusted to the ears. These ear-pieces are secured to the ears by an elastic band passing under the chin and over the head. The wires are connected up in the usual way, and brought from any convenient point or from a reel as may be desired, thus both hands of the person receiving are free, and he can report, write, and manipulate with other instruments at will. A tube is inserted above the disc for transmitting as required. It cannot fail to be seen how useful such instruments will be to gentlemen connected with the press or law courts; whilst for transmitting purposes Nos. 1 and 2 are adapted for relay, as the operator can transmit as rapidly as he receives, it being only necessary to connect up the mouth-piece with the required circuits by bringing the electric switch into use.

Fig. 4 shows Mr. Pritchett's method of capping existing telephone-cases so as to form them into multiple instruments. The caps are formed of any suitable material, and are attached to the top of the telephone. A clip at B is adjusted to fasten on to a coat collar, or a strap or button may be used to suspend the telephone. From the cap or caps a self-adjusting tube is carried up and adjusted by a pad or otherwise to the ear; or the tube may also be carried on to the other ear, and secured by an elastic band, so as to bring both ears into use for receiving. A mouth-piece is also formed in the caps for transmitting purposes, as shown at C. Thus the hands of the persons using the telephones are entirely free for writing or manipulating, as before mentioned. One telephone takes the place of two or more if desired.

Fig. 5 shows ordinary telephone cases, mounted on an adjusting stand, which can be placed on a table. Above the telephones a horizontal hollow bar is adjusted, provided with projecting pieces fitting down into the mouth of the telephones. From this bar several elastic tubes can be led off and handled, and used for receiving or transmitting purposes. For example, a number of reporters could, one and all, receive and note down "speeches" or "evidence" at the same moment.

THE TELEGRAPHIC JOURNAL.
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THE SOURCE OF TELEPHONIC SOUNDS.

In this issue we give the conclusion of Professor Hughes' interesting investigation into the source of sound in the speaking telephone. These experiments are of course applicable only to those telephones, typified by the Bell, in which a magnetic field and diaphragm are employed; and they show very clearly that we cannot hope to improve an electro-magnetic telephone by abandoning either the one or the other.

Without the telephone, the microphone would not have seen the light; but in the work in question Professor Hughes has paid his debt to the telephone by investigating the true source of its sounds, with the help of the microphone. Many of the results educed in his research had been got before; but no one has so thoroughly and consistently traced the telephone sounds to their seat as Professor Hughes has done. The condition of the problem before these experiments were made was well stated by Professor Fleeming Jenkin (see Telegraphic Journal, Vol. VI., p. 441, Nov. 1), who referred the chief source of sound to molecular action in the core (Page effect), supported by the vibrations of the disc. "Thus," he says, "when the ferrotype receiving disc is present we hear at least two simultaneous voices—the voice of the disc, which is strong, and the voice of the magnet, which is weak. When for the ferrotype disc we substitute a wooden plate, this plate will act as a sounding board for the Page effect." When the diaphragm is a conductor a third source of sound (Ampère effect) is caused by the induction of the changing magnetic field; and a fourth source might exist in the self-induction of the coil on itself (De la Rue effect).

It remains to be seen what interpretation different *savants* will place upon Professor Hughes' results; but it appears to us that the Professor's own conclusions are just, and that the main source of sound in the telephone is the sensitiveness of the diaphragm, *as a magnet transversely polarised*, to changes in the magnetic field around it. On this supposition, were the earth's magnetism powerful enough, no permanent magnet would be required for the telephone. It appears to us that an attentive study of Prof. Hughes' paper will lead to improvements, not only in the telephone itself, but in other electro-magnetic and induction relations. It will be seen from it that the inventor of the telephone, groping blindly as he did, has arrived at a form which is very nearly the best theoretically. The improvements on it that may be effected relate to the thinness and elasticity of the plate, and the form of the coil and its position with respect to the magnet and disc.

Experiment XXXII has a particular bearing on the changes which go on in a magnetic field, the action of the current in the coil when the current passes being apparently to quench the magnetism of the field around the pole of the magnet. This is a case which might be elucidated by Prof. Sylvanus Thomson's magnetic figures, and we take the liberty of recommending it to his study.

In conclusion, we may add that we shall shortly publish an investigation by Prof. Hughes in a different direction, and which, we think, will open up an entirely new field of research and electrical advance.

THE SOURCE OF SOUND IN THE TELEPHONE.

An Experimental Investigation by Aid of the Microphone.

By Prof. D. E. HUGHES.

(*Concluded from page* 471.)

XXXII.—Pendulum Experiments, *Continued.*—If the pendulum bob be a small and strongly magnetised steel bar or needle, and the flat coil be placed parallel to it, as in a galvanometer, but at a distance of 1 inch, the needle turns upon its axis on the passage of the current through the coil, like the needle in an ordinary galvanometer; but if we place a bar magnet at a distance from the coil and needle of 2 inches, and perpendicular to the axis of the coil, we find that upon the passage of the current the needle has only a feeble tendency to turn on its axis, whereas it has a strong tendency to *swing* in the line of the magnet along the coil; the needle being now repelled from the magnet by the current which attracted it when the same pole of the magnet was put in the coil. In these conditions we obtain a full swing of 3 inches right across the poles of the coil under whose influence it is set in motion. We wish to point out in this experiment the remarkable power of the coil on the magnetic field in comparison with its effects upon the magnet itself. If the coil had changed the polarity or distribution of magnetism upon the magnet, it should have done so transversely and not longitudinally; the needle then instead of swinging in a line with the magnet should have turned on its axis as it did before it was brought under the influence of the magnet.

(A confirmation of this experiment also takes place in the telephone; for if, instead of having the coil on the magnet as usual, we place the coil exterior to it and its axis perpendicular to the magnet, the sounds obtained are almost if not quite as loud and distinct as when the magnet is inside the coil.)

XXXIII.—If we compare on the pendulum, iron or steel feebly magnetised, and steel strongly magnetised, when acted upon by the flat coil alone, we find that iron gives but ¼ inch swing, steel feebly magnetised ¾ inch swing, and the same steel strongly magnetised 2 inches swing. Comparing again the action of the long ordinary helix and flat coil, mentioned in Experiment III, we find that the long helix gives but ¾ inch swing against 2 to 3 inch swing for the flat coil, thus demonstrating the entire concordance of the pendulum experiments with those previously made by means of the microphone; the one giving the results in visible motion, the other in sound.

The pendulum experiments were repeated by changing the mode of suspension, using a square frame 10 by 10 inches, over which was stretched a fine linen cloth, the piece of steel or other material under investigation being attached to its centre. Thus we had a true diaphragm whose movements were visible, but as it is evident that the mode of suspension could not change the laws by which such bodies are put in motion, we do not deem it necessary to detail the results which, of course, were identical.

Again to verify the acoustical results obtained by the microphone; a small wooden resonant box was used, which could be placed to the ear and serve as a mechanical microphone. We could thus hear most of the experiments, the sound being sufficiently strong; but although we could thus obtain indications, they were far less reliable than those given by the microphone, the box giving out only those sounds which were almost sufficiently audible without, and the tones being not the true timbre of the piece under investigation, but those simply of the box itself. The microphone on the other hand revealed sounds which were quite inaudible without its aid, and rendered the true timbre peculiar to each object.

The whole of the preceding microphonic experiments were repeated with induced currents in place of the voltaic currents. The transmitting microphone then acting in the primary circuit, the currents from the secondary being directed upon the organ under investigation, no difference whatever was found in the comparative results. The current was also reduced gradually by resistance until feebler than ordinary telephone currents, giving still the same comparative results. As the currents decreased in strength the effects dwindled until they finally disappeared. The object of this experiment was simply to meet any objection to the effect that the experiments having been carried on by voltaic currents, the results, with induced or feeble telephonic currents, would be different.

We have seen that with strong currents the movements of the diaphragm became visible, and gradually faded as the current became weaker. There can be no reason to suppose any change of law as regards the reaction on the diaphragm, during its gradual decline of movement. For if we strike a wine glass or bell with sufficient force we may easily render the vibrations visible, but if we touch it lightly, we still hear distinctly its sound, although its vibrations are no longer visible. It is simply a proof of the wonderful sensitiveness of the human ear to feeble but rapid vibrations; and to the ear alone is due the perception of feeble mechanical movements by feeble currents in the telephone.

We can clearly trace the telephone backwards to the one great discovery of Oersted of which the galvanometer was simply an extension; and as the telephone is based upon similar principles to the galvanometer, it is not so remarkable that both should be the most sensitive organs we possess for investigations by means of voltaic currents. The one is a visual, the other an auricular arrangement of the same forces, and the telephone may be regarded simply as an acoustical galvanometer, or rather, galvanoscope.

After careful verification of the preceding experiments (which, it must be understood relate exclusively to those receiving telephones which employ a diaphragm and magnetic field), I have come to the conclusion that it is not at all necessary to call on any molecular theory to explain the action of the telephone, and that all its effects have, from a theoretical point of view, long been known. From the preceding experiments I draw the inference that the extreme sensitiveness of the telephone to feeble but rapid changes of current is due to a large surface of iron under excellent conditions as regards elasticity and freedom of motion in a high magnetic field, such as the diaphragm is known to be, and that the comparatively large motion that we obtain in this diaphragm from feeble currents is not so much due to electro-magnetic changes taking place in the diaphragm or magnet itself (see Ex. XXXI.) as to the sensitiveness, all fixed magnetic bodies possess to any change in their field of force. And if we are able thus to perceive sounds from actions so comparatively feeble it is due to the fact that the human ear is capable of appreciating sonorous waves caused by a motion too small for the perception of any other of our senses.

THE WANDERING ELECTRIC SPARK.

By GASTON PLANTÉ.

THE condensers, with mica plates, which are employed in the construction of my *rheostatic* machine (1), are sometimes pierced when the plates of mica are very thin, under the action of a current from 800 secondary batteries, in the same way as the glass of a Leyden jar would be pierced when charged too highly by an electrical machine.

These accidents have given me an opportunity of observing a very curious fact, viz., the slow and progressive march of the electric spark, and of noteing the successive development of its capricious sinuosities.

One of the condensers being placed upon an insulated metal plate, connected to one pole of the secondary battery, if the upper condenser plate is touched with the other pole of the secondary battery, a spark bursts on a point of the surface of the condenser where the mica is too thin, or cracked. This spark moves about in the form of a small and

(1) *Telegraphic Journal*, Vol. 5, p. 309. Comptes-Rendus, Vol. 85, p. 794, and Vol. 86, p. 761.

EXPERIMENTAL INVESTIGATIONS BY AID OF THE TELEPHONE AND MICROPHONE.

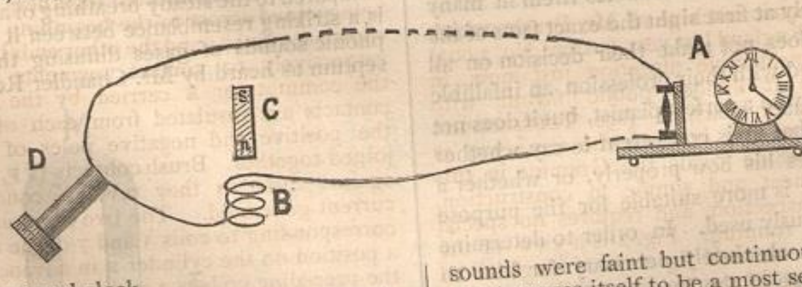
By Prof. D. E. HUGHES.

INDUCED CURRENTS.—Up to the present time the microphone has only been used in connection with voltaic currents, but it has also a remarkable power when connected with an ordinary telephone to detect induced currents too feeble to be observed upon a galvanometer, and also too feeble to be heard by the telephone alone. In order to detect feeble voltaic or induced currents upon the telephone, unaided by the microphone, we should construct a De la Rive's Rheotome, in order that by sufficiently rapid interruptions and contacts, a sufficient number of vibrations of the diaphragm may be obtained to produce a tone sensible to the human ear.

The microphone, however, when used with a clock or any other source of sound, not only transmits the regular beats of the clock, but all its timbre and its infinite varieties. Thus, a clock which beats half seconds, would in a second give four complete waves of sound, and superposed on these an infinite number of variations due to the timbre of the source of sound, consequently the waves of electricity transmitted instead of taking a uniform curve, would be represented graphically thus :—

And we shall see in some following experiments how fully it serves the object intended, giving them a power of research into feeble induced currents that we have hitherto not possessed.

In the following first series of experiments no voltaic currents were used. The microphone in a distant chamber being connected direct to the coil or organ under investigation, thence to the telephone and return wire, thus :—



A, microphone and clock.
B, coil in which a natural magnet C, can be introduced.
D, telephone.

I.—INDUCTION BY MOVEMENT OF A MAGNET NEAR THE POLES OF AN ELECTRO-MAGNET.—An electro-magnet with an iron core being put in circuit with the receiving telephone, no battery being employed, and a magnet made to touch the iron core, distinct tones could be heard in the telephone, confirming what had already been observed by many experimenters; but if the magnet was moved to $\frac{1}{2}$ inch distance, and oscillated through a small space, no sound could be heard, consequent upon the current generated being feeble and not of sufficient rapidity to produce an audible sound. If, however, under these conditions, one of the wires connecting the electro-magnet to the telephone line was cut, and the ends put together again in a loose contact, with but a slight pressure, so that by a constant vibration of the first wire, the circuit was made and broken with great rapidity, clear crackling tones could be heard by simply holding the magnet near the electro-magnet, and it is impossible to hold with the hand the magnet steady enough not to produce innumerable induction currents, plainly perceptible on the telephone. That these currents are due to the unstable position of the magnet whilst in the hand, is proved by firmly fixing the magnet in a strong mechanical support, when the sounds are no longer audible.

II.—In place of the vibrating contact above described, the transmitting microphone with clock, but without battery, was employed; louder sounds could now be heard, or rather the beats of the clock, by simply moving the natural magnet near the poles of the electro-magnet. If we replaced the electro-magnet by a simple coil the clock could be distinctly heard when the magnet passed near to the coil, but more so when the magnet was introduced into the coil. The coil having an inside diameter of 2 inches, allowed the magnet to be drawn through it easily without touching it. It was remarkable how continuous this induced current became when we moved the magnet slowly through the coil, thus for a magnet only 6 inches long, we obtained a continuous current during a slow passage of 3 seconds. If the magnet moved quickly, sounds were equal to 1 Daniell element; but when the magnet moved very slow the sounds were faint but continuous. This arrangement proves itself to be a most sensitive and useful means of demonstrating feeble induced currents—too feeble to be perceived by any other known means.

III.—If in place of moving the magnet near the coil, we move the coil itself near the telephone to which we are listening, we then hear distinctly the clock upon the microphone; but if we suppress the microphone we hear no sounds or production of induced currents by the movement of the coil near the telephone.

IV.—If we suppress the coil, having simply in circuit the microphone and telephone (without battery), we can hear the clock sounds, simply by moving a strong bar magnet near the telephone to which we are listening, and we have thus obtained articulate sounds which were perfectly understood.

Here we have the remarkable fact, that the coil of the telephone that produces the current, also, at the same time, by aid of the variations produced by a microphone, serves to reproduce upon its diaphragm the sounds transmitted to it from a distant station.

V.—The above experiment may be varied by joining the microphone circuit direct to a coil of an electro-magnet, and the telephone to a secondary coil surrounding the primary coil. Thus the microphone is in the primary circuit, and the telephone in the secondary, both direct and without battery. If now we move a natural magnet near the two coils, we hear perfectly the sounds transmitted by the microphone. We have here simultaneously double induced currents, re-acting on each other directly in proportion to the innumerable variations of resistance introduced into the primary circuit by the microphone.

VI.—Instead of using a coil and magnet we may connect two telephones in direct circuit with the microphone, and upon pressing gently upon the diaphragm of one, and listening with the other, we hear distinctly the sounds transmitted by the microphone, but not those due to the movement of the finger upon the diaphragm of the telephone; and with a diaphragm of thin charcoal iron, the slightest pressure of the finger upon it, is sufficient to make the microphone sounds audible, and if this pressure is slightly but continuously varied, we hear the microphone sounds as continuously.

Many similar experiments could be cited, but we deem that the ones already mentioned are sufficient to prove that we possess in the telephone and microphone powerful aids to the investigation of feeble magneto currents. In some following experiments we will show how remarkable are its powers in relation to currents induced by voltaic electricity.

THE BRUSH ELECTRIC LIGHT.

THE dynamo-electric machine of Mr. Brush, which was patented in England last year (patent No. 2,003) is attracting considerable attention just now in America, where it divides public favour with the Wallace-Farmer machine (see TELEGRAPHIC JOURNAL, Vol. 6, p. 431), in much the same way as the Siemens' machine rivals the Gramme in this country. It is neat and simple in construction, readily open to inspection, and requires no special attendance when running. Fig. 1 is a view of the machine as it stands, and fig. 2 is a longitudinal section of it along the centre line, while fig. 3 is a vertical section across the middle. It will be seen that it consists essentially of two horse-shoe magnets H H, placed with their like poles N N, S S, opposite each other, but far enough apart to allow a coiled armature A to rotate between in the usual manner, the currents being drawn off by hard metal brushes rubbing against a commutator E, on the shaft to which the armature coils are connected The novelties of the machine consist in the arrangement of the armature and the commutator. The armature A (fig. 1 and 2), consists of a soft iron wheel, preferably cast, with a heavy rim, fixed by the hub B to the shaft C, which is driven by a belt on the pulley D. The continuous rim of this wheel is niched out at regular intervals, and insulated copper wire is coiled into each niche in the same direction for all. In the machine represented there are eight separate coils, each occupying a niche in the rim. In the Gramme armature the iron ring has a uniform cross section in every part; but Mr. Brush claims for the niched ring that the projecting parts between the coils are brought closer to the poles of the electro-magnets N, S, where they experience stronger induction, and that these exposed surfaces help to radiate away the heat generated in the ring by the rapid changes of magnetism which take place in it. It is a peculiar feature, too, of these American machines, the Brush and Wallace-Farmer, that the cores of the armature and electro-magnets are sometimes perforated, as shown in fig. 1, by cylindrical holes, for the double purpose of getting rid of superfluous material and increasing the heat radiating surface. Another improvement patented by Mr. Brush consists in insulating from one another, either wholly or in part, the two halves of the armature core which would be obtained by splitting it in its own plane. The object of this device is to prevent the electric currents induced in the core itself by its motion in the magnetic field from circulating entirely across the rim. By splitting up the rim in its own plane, and interposing insulating material between the halves, these currents (which traverse the rim in a direction at right-angles to the direction of its motion) are cut off and confined in their flow to each half of the cross section, and their heating effect diminished. Instead of employing a layer of insulating substance between the halves of the rim, Mr. Brush also cuts a deep narrow groove round the periphery of the latter, and in this way, without entirely splitting the rim, he inserts an insulating layer of air, and secures the advantages which he aims at. A second groove (shown in fig. 1) is cut round the *sides* of the rim, for a similar purpose.

The arrangement of the commutator is sketched in figure 4. Each pair of opposite coils on the armature A are connected together, the end of one being joined across to the beginning of the other, as shown at 3 and 7; and the other ends being connected respectively to contact segments S 3 and S 7 of the commutator E carried by the shaft. These contacts are insulated from each other, and form the positive and negative poles of the two coils joined together. Brush contacts (F F, fig. 3) rubbing against these as they revolve, conduct away the current generated. The two segments, S 3 and S 7, corresponding to coils 3 and 7 of the armature, hold a position on the cylinder E in advance of those of the preceding coils, S 2 and S 6, to the same angular extent that the coils 3 and 7 are removed from 2 and 6 on the armature, so that the brushes draw off currents of equal strength from each succeeding pair of coils and in this way maintain the uniformity of the resultant current. When a coil is passing the "neutral" points, at right-angles to the line joining the poles of the inducing magnets N S, the plates F are in contact with the insulating material inserted between the corresponding contacts on the cylinder E, and thus the coil in question, which is which are insulated from each other, and connected consecutively with the rheostats, as shown on the plan. The arm *l* and spring *m* are connected with the other pole of the battery *j*, which is also connected to the earth. To the handle *k* is attached a pointer *o*, moving outside the dial of the instrument over a circle of figures corresponding to the number of rheostats in the circuit.

Connected to one end of each of the rheostats included in bracket *f*, is a thermostat, the insulated screw of which *d* (figs. 1 and 2), is connected to the earth. On an undue increase of heat taking place, the band *c* (figs. 1 and 2) of the thermostat makes contact with the insulated screw *d* (figs. 1 and 2), and thus completes the circuit with the battery *j*, as shewn by the dotted line *p*.

The electric current from the battery *j* passing thus through the alarum *i* rings it, and also passing through one side of the differential coil *h*, deflects the disc *q*, which is fixed to the axle of a permanent magnet contained within the coil *h*. On the alarm being thus given, the person summoned moves the handle *k* round the dial of the instrument, and as soon as the spring *m* comes into contact with the particular plate *n* connected with the rheostat that corresponds with the line rheostat which has been put to earth by the thermostat at the point from which the alarm is given, the electrical balance of the differential coil *h* is re-established, and the disc *q* returns to zero.

The pointer *o* indicates the number on the dial of the station instrument which corresponds with the number of the place on the station list from which the alarm emanates.

In the plan of the apparatus, as drawn in figs. 3, 4, and 5, only fifteen protected places are shewn, but a larger or smaller number can, of course, be connected.

Figs. 5 and 6 shew a train of clockwork brought into action by a differential relay, which moves round the contact maker in connection with the station rheostats in case of fire, until the balance between the station rheostats and the line rheostats is re-established, when the indicating hand attached to the axle of the contact maker (as in the apparatus worked by hand shown at fig. 3) points to the number showing the locality of the fire. In this figure *a*, a^1, are the differential coils of the relay; *b* is the contact maker influenced by them; *c* is the battery of the line and station circuit, and *d* the battery of the local relay circuit; *e* is the coil of the alarum, and *f* is an electro-magnet actuating an armature *g*, and thus releasing the escapement or detent h^1.

EXPERIMENTAL INVESTIGATION BY AID OF THE TELEPHONE AND MICROPHONE.

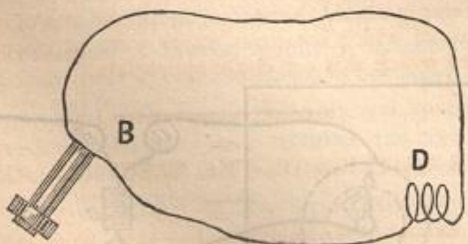
By PROF. D. E. HUGHES.

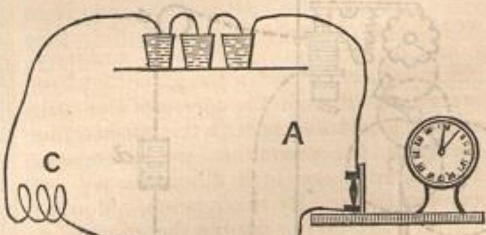
INDUCTION BY VOLTAIC CURRENTS.—It is well known how remarkably sensitive the telephone is to induced currents. They were remarked at once upon all the telegraph lines, and have in a great measure prevented its use upon lines which contained several other wires worked by the Morse or other telegraph systems. The microphone greatly aids us in researches of this nature, and we will cite a few experiments which are interesting, both from a scientific and practical point of view.

The arrangement of the circuits were as follows: The sounds of the clock being transmitted by the microphone to a coil of wire, and, from a separate coil superposed or near this primary coil, conveyed to an ordinary telephone upon which the results were observed. Thus—

I.—Two similar coils, of 60 turns, No. 30 covered copper wire, and 2 inches diameter, the one being used at C for primary, the second at D for secondary. Sounds and speech could be clearly heard in the telephone with a perfection of timbre very remarkable. If the coils were near each other, the sounds were nearly as loud as if the telephone had been in primary circuit; on gradually removing it, although the sounds gradually diminished, they could be clearly heard 12 inches apart. In moving the secondary coil D round C, there was no position either in a line or otherwise, in which the sounds could not be clearly heard, and that at really surprising distances, except when they were exactly at right angles, when there was absolute silence.

II.—But little difference could be observed in the induced currents if a magnet was placed in the coil C or D, but they were stronger if the same magnet was placed in the centre of both coils. A bar of iron two feet long increased the force when placed in coil C, and if both coils were placed around the middle





A Microphonic circuit.
B Telephonic circuit.
C Primary coil.
D Secondary coil yielding induced currents which were listened to in the telephone B.

of this bar, 10 inches or more projecting on each side, the maximum results were obtained, they being far superior to those from the permanent magnet; thus with induced currents a constant magnetic field induced by a natural magnet plays but little part;

the electro-magnetic changes taking place in a bar of iron have important and easily recognisable effects.

III.—The coils C and D being held firmly on stands at a fixed distance of 4 inches. No appreciable difference could be observed by the interposition of any non-conductor, such as wood, gutta-percha, &c.; but of conductors there was a difference, copper being the most marked, equal to six plates of iron of same dimensions; but it was remarkable how little difference this made, for, with fifteen interposed sheets of iron, the sound still had about one-quarter of its original force, and when we remember that on each of these plates strong induced currents were produced, it was remarkable that there should still have remained a surplus force to produce the clear and distinct tones by the induced currents produced after all this work.

IV.—Coils being as above, but 5 inches apart, so as to allow of the introduction between them of a half-pound reel of No. 30 covered copper wire, and ends of this wire left open, no appreciable diminution of sound was remarked; but the instant the circuit was closed by joining the two ends of the half-pound reel the sounds were diminished so as to be hardly audible: the telephone here verifying a fact long well known of the influence of closed circuits in cutting off the induced currents; but that the effect is in all cases proved to be but partial was by the introduction of one or two coils similar to C and D between them having closed circuits. The screening effect of these coils was hardly perceptible.

V.—Four coils were constructed all of exactly similar wire and length. Two were of a flat wide surface, 3 inches diameter, ½ inch high. The other two were formed after the ordinary helix pattern of an electro-magnet, 1 inch diameter, 2 inches high. It was found that the flat coils (used by Henry, Hare, and Matteuci for induced currents) were far more powerful than the two ordinary helices placed at any distance from each other; the flat coils were fully three times more powerful. One of these electro-magnetic helices was then unwound and rewound over the second, similar to the arrangement in the Ruhmkorff coil, and compared with the flat coils resting on each other, the winding of the coil *à la Ruhmkorff*, had decidedly improved their force, but still the flat coils showed a marked superiority, being about one-half stronger, as near as it was possible to judge from estimation by sound.

VI.—If we change the conditions of the last Experiment, and replace the coil C by an ordinary telephone, placing the coil D below the diaphragm, so that its ordinary coil will be in the centre of this coil, we shall then hear loud tones in both telephones, the first in the primary, the second in the secondary, or induced circuit, and very little difference will be perceived between them. By this system, a double telephone can be used, giving double the effect of a single one, and that without introducing more resistance in the primary circuit than a single telephone, a very remarkable advantage where two telephones are used, and what is still more remarkable is, that if we withdraw the magnet and coil of the primary circuit, so that it is no longer in perfect adjustment, giving feeble tones, the second telephone worked by the secondary coil stationary near diaphragm, gives out almost as loud tones as originally, thus the secondary circuit then becomes far the loudest and clearest.

VII.—We have already shown that we can, by the induction of one coil near the other, hear distinctly all the sounds of the microphonic circuit. If now, instead of using one primary coil and one microphonic circuit, we use two or more distinct primary circuits, each connected with its special microphone, and these primary coils placed near one another, the single secondary coil placed at a distance intermediary from these separate primary coils; we hear then in the telephone not only the clock of the first primary, but in addition, say, articulate sounds on second primary, and singing or music on third. We have here a compound induction of three distinct undulatory waves of primary resolved into one undulatory wave, giving us at the same time the effect of the whole. We might thus have a piano in one room, singing without words in another, and words only in the third, and these, not in any way directly connected to telephone line, would by simple induction give us the effect of a song with words and piano accompaniment.

VIII.—Having seen by numerous experiments that the induced currents act at great distances, we thought that by simply placing a diaphragm in a high magnetic field we should hear distinctly from the diaphragm, notwithstanding that the coil was separated several inches from it. To this end we took out the coil of an ordinary telephone, leaving simply the magnet and diaphragm. The magnet was carefully adjusted near diaphragm, and the coil C of the microphone circuit held near this skeleton telephone. Loud sounds could be clearly heard when coil near telephone, no matter in what position or direction; the coil might be held several inches distant, and still the sounds were audible. If we withdrew the magnet no sounds were audible, however near the coil might be; but on re-adjusting magnet, by careful listening, the sounds could be heard when coil was 12 inches distant, and on placing the skeleton telephone to one ear and the coil to the other, clear sounds could be heard. On removing the telephone, which was not in any circuit, and listening to the coil which was, and from which the force proceeded, no sounds whatever could be heard. On replacing the telephone, the clear and comparatively loud tones at once became audible. Thus the electro-magnetic induction passed through one ear unperceived to put the diaphragm beside the second telephone in motion, by means of which sonorous waves were at once produced which that ear could appreciate.

THE CRITERIA OF THE ELECTRIC LIGHT.

WE extract the following passages from a very instructive lecture to the Royal United Service Institution, by Mr. W. H. Preece :—

Heat and light are identical in character, though different in degree; and whenever solid matter has imparted to it motion of a very high intensity—in other words, when solid matter is raised to a very high temperature—it becomes luminous. The amount of light is dependent upon the height of this temperature; and it is a very remarkable fact that all solid bodies becomes self-luminous at the same temperature.