

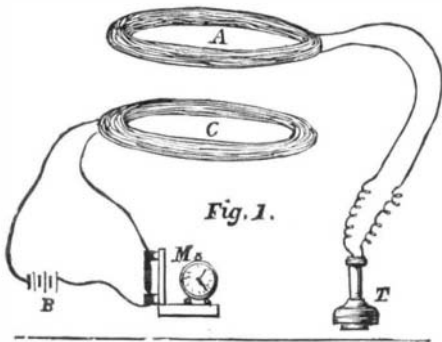
PROFESSOR HUGHES' INDUCTION BALANCE.

We condense from *Engineering* of March 14, 1879, the following description of Professor Hughes' induction balance:

The invention of the telephone by Professor Bell has placed in the hands of the physicist a detecting instrument of greater delicacy and sensitiveness than the most delicate galvanometer, and one which is instant in its action and convenient in use; and the invention of the microphone by Prof. Hughes has supplemented the telephone for electrical research, and has largely extended its field of usefulness. So sensitive is the telephone, or perhaps it would be more correct to say, so sensitive is the human ear, aided by the telephone, that variations of electric currents so small as to be far removed from the powers of the most sensitive galvanometer to detect, are instantly made apparent by its use, and it is found next to impossible to work the instrument for business purposes in many places during business hours by reason of the induced currents produced in its conductors by the influence of neighboring lines conveying telegraphic messages.

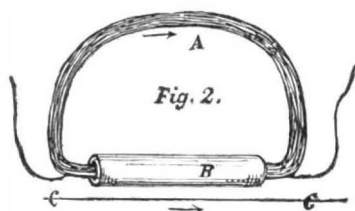
The elimination of the effects of induction for telegraphic working has hitherto been one of the great unsolved problems of the telegraph engineer, and several plans have been adopted whereby the evils resulting from it have been lessened, but all are far from satisfactory.

It has remained for Professor D. E. Hughes, the eminent inventor of the type printer, as well as of that still more



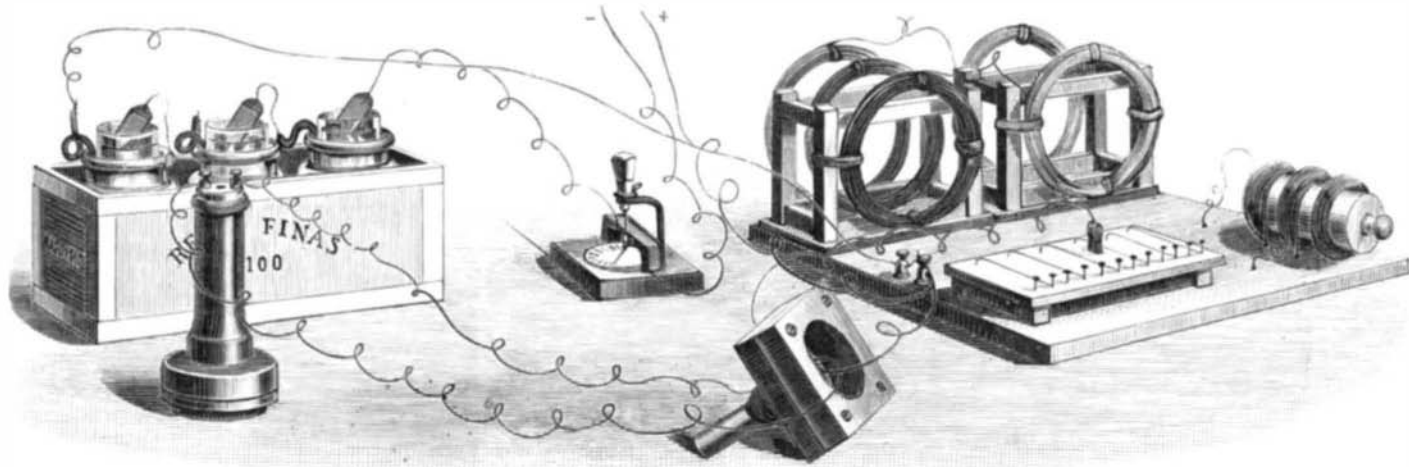
wonderful instrument the microphone, to solve the problem by which induction currents in telegraph lines may be absolutely eradicated, and his solution of this problem is as simple as it is scientifically accurate. His whole apparatus, part of which we illustrate, consists of a few coils of wire, a telephone, a microphone, a small three cell Daniell's battery, and a galvanometer.

The diagram, Fig. 1, represents an experiment arranged by Professor Hughes, which demonstrates a simple case of ordinary electrical induction. A and C are two circular coils of insulated wire, of which one, C, is placed in circuit with a battery, B, and microphone, M, upon which a small clock is placed, and the other coil, A, is joined up in circuit with a telephone. Upon placing the ear to the telephone the ticking of the clock is loudly heard by the induction currents produced in A, by the influence of the neighboring microphonic currents passing through C. When the two coils are placed one against the other the sound is nearly as loud as when the telephone was included in the primary circuit, and as the distance between the two rings is gradually increased, the ticking becomes fainter and fainter, but at several inches distance the ticking was louder than the origi-



nal sound emitted by the clock, and with several feet between them it remained distinctly audible. The demonstration of induction currents by means of two such rings does not, of course, possess any novelty, but the employment of a clock and microphone in conjunction with a battery as a simple automatic source of sound, or rather of electrical impulses, and of a telephone as the detecting instrument, forms together an exceedingly convenient arrangement, and we

mention it here because it forms the groundwork of the system upon which Professor Hughes' recent experiments have been carried on. We may mention here, in passing, that this arrangement forms a beautiful way of illustrating the diminution of induction influence by destroying the parallelism between the planes of the two rings, for if either of them be slowly turned about one of its diameters, the sound heard in the telephone gradually diminishes as the angle between the planes of the rings is increased, disappearing alto-



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gether at the moment that they become perpendicular to one another.

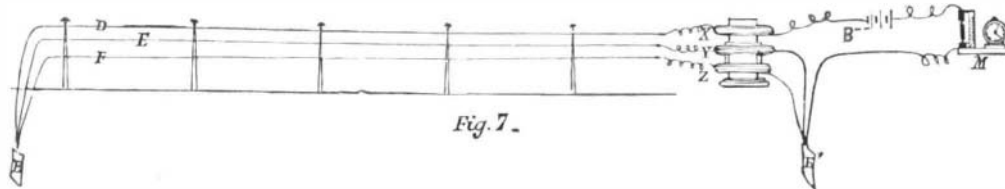
Professor Hughes placed between the coils a sheet of copper 12 inches square and one millimeter thick between the coils (joining both coils and plate to the same earth plate),



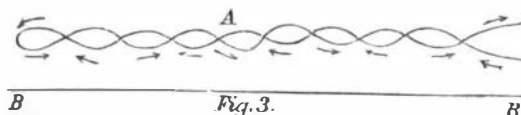
CLOCK AND MICROPHONE.

without disturbing the induction effects; he next tried the effect of introducing between the coils laminæ of sheet iron; but no perceptible reduction of the induction currents could be detected. Covering each of the coils with several layers of tin foil and immersing both in a vessel of salt water, with a plate of copper between them, did not diminish the induction as far as the ear could detect.

Fig. 2 represents a modification of the same experiment. A is a D-shaped coil of wire having a hundred turns, its two ends being joined to the terminals of a telephone, and the straight portion of the coil is inclosed in a heavy brass tube, B, one eighth of an inch thick. C C is a primary wire

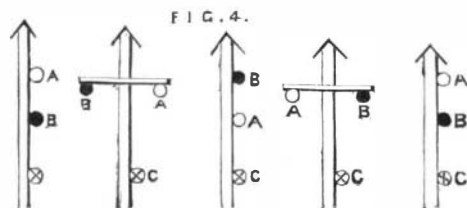


in connection with a clock microphone and battery. Upon placing the side, B, of this coil near and parallel to the wire, C, the sounds of the clock are distinctly audible, and hardly



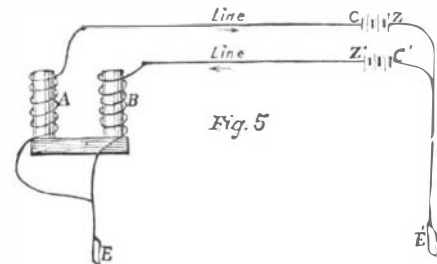
any difference of induction influence can be detected between the influence of the currents in C on the portion of the coil surrounded by the tube and on the unprotected parts of the secondary circuit.

Having demonstrated that a metallic sheathing or screen is altogether ineffectual for the protection of telegraph lines from the effects of lateral induction, Professor Hughes turned his attention to the question whether, although induction can-



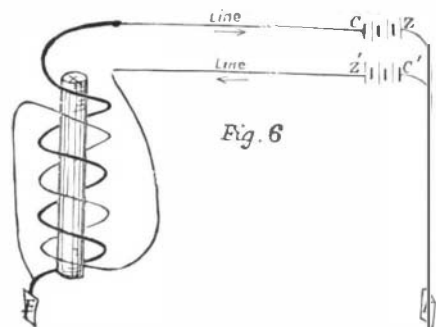
not be destroyed, it may not be neutralized or compensated. With this object in view he constructed a coil of four separate insulated wires, which could be joined up at their free ends in several combinations. Joining one wire to the microphone, and one of the others to the telephone, powerful induction, as might be expected, took place, the ticking of the clock being heard loud and clear, but no apparent increase or diminution of the sound was produced when three of the wires were in circuit with the microphone, in the same direction, and the fourth was connected with the telephone. By joining two of the wires to the microphone in such a manner that the current through one returns by the other, the inductive influence is completely neutralized, and absolute silence is the result. From this it follows that it is perfectly possible to protect a telephone line abso-

lutely from the inductive effects of a neighboring parallel telegraph line by employing a return wire instead of an earth connection, and fixing that wire upon the poles, so that the telegraph or primary wire is equally distant from the line wire and return wire of the telephone circuit. The disadvantage of such a system is that it introduces a double resistance and twice the cost of wire, and is a protection only as regards one particular telegraph line, but for that line the protection from induction is absolute and complete. As it would be practically impossible to insure the absolute equi-distance of the two telephone wires from the telegraph line, and in order to make the system equally protective against the influence of other wires running along the same line of poles, Professor Hughes tried the experiment of twisting the two wires (that is to say, the line and its return) together, so as to form a sort of cable, so that at each turn of the twist a portion of the line circuit



and the return circuit respectively would be alternately presented to the inducing wire. The diagram, Fig. 3, will make this clear, the arrows indicating the direction of the current. It will be seen by reference to this diagram that the portions of the secondary circuit, A, which are presented toward the primary line, B, are alternately positive and negative in direction, and therefore all effects of induction are neutralized. This is demonstrated by bringing the side of the rectangular coil against a twisted cable, such as shown in Fig. 3, no sounds whatever being heard in the telephone. It is not necessary to twist the wires into the form of a cable, for if they be attached to the poles in such a way as to cause one to rotate round the other, making one turn in a mile, or say at every four poles, it is equally effective. See Fig. 4.

In Fig. 5, A and B represent the two cores respectively of the horseshoe electro-magnet of a telegraph instrument at the receiving station, but it differs from the ordinary electro-magnets in the fact that the coil surrounding each core is connected with its own separate battery at



the transmitting station and with the earth; and the batteries are so arranged with regard to the transmitting key that each depression of the latter sends a positive current through one wire and a negative through the other, and as the coils of the magnet are so wound as to give opposite polarity to the two cores under the influence of this double current, its magnetic effect is exactly the same as that of an electro-magnet wound

In the usual way. An improved application of the same principle is shown in Fig. 6. The bobbin of the electro-magnet is wound with two coils of equal length and thickness. Each of these coils is connected with its own separate line and battery, and the connections at the transmitting station are so made that a depression of the key sends a positive current through one line and a negative current through the other, but the coils of the magnet are so connected to the lines at the receiving station, that the positive current traverses its coil in one direction as regards the magnet core, and the negative current passes in the opposite direction, so that, by the process of double reversal, the effect is the same as that of a single current of double the strength traversing the magnet in the usual way.

We now come to that portion of Professor Hughes' researches which constitute the important contribution to electrical science and to telegraph engineering. We have but little doubt that Hughes' induction balance—by which term we would include all instruments based upon its essential principle—will ultimately take its place side by side with Wheatstone's bridge in the history of the electric telegraph, for by its means the telegraph engineer will be enabled to eradicate from his lines the retarding and cost-entailing effects of electrical induction. In Fig. 7, let D, E, and F represent three lines of telegraph, supported on poles and running parallel to one another; if a current of electricity be transmitted by the line D, it will induce in each of the lines E and F a current in the opposite direction, whose relative strength will be determined by the distance of its corresponding wire from the inducing or primary wire, D. Now, if at the moment of sending a current through the latter, it were possible to transmit through each of the lines, E and F, a current in the same direction as itself of exactly the same strength as the currents produced in the opposite direction by induction, the two, being equal and opposite, would completely neutralize one another, and although, as a matter of fact, the induction would be exactly the same, its effects would be completely eliminated and destroyed.

At the transmitting end each of the lines is connected to a small induction coil or ring, X, Y, or Z, similar to those figured in Fig. 1, and placed one in front of the other, so as to exercise an inductive effect, the one upon the other. Now, from what has been said, it is clear that if the coils were all similarly connected to their respective wires the effects of induction between one circuit and the other would be increased by the addition of the inductive effects of the coils being superposed upon and added to the inductive effect of the lines; but if at the moment of transmitting a current through the primary wire the two ends of its corresponding coil were reversed, then the inductive effects of the line and of its coil would be acting on the lines and coils of the other circuits and in opposite directions, and the aggregate induction would be diminished by the difference between the two influences. By making the length of wire contained in each coil, however, proportional to the length of its corresponding line, and the relative distances between the coils proportional to the mean distances of the lines from one another, the inductive effects of the coils are exactly equal to the inductive effects of the lines, and if their directions be in opposite directions as is accomplished by the reversal of the coils, then the problem is solved and all effects of induction are eradicated.

For the purposes of practically demonstrating the system of compensation, Professor Hughes constructed the apparatus shown to the right of the general perspective view. The five rings of insulated iron wire attached to the board represent three lines of telegraph running parallel. The two coils of each of the outside pair are joined so as to form one circuit, consisting of one black ring and one white one, each pair representing one line of a certain length, and between them is a single coil representing an intermediate telegraph line of a shorter length; this difference of length was adopted by Professor Hughes in his experimental model in order to represent a somewhat complicated case, and to show that no matter what the relative lengths and distances apart of telegraph lines, their mutual induction may be compensated by suitably constructed and adjusted compensating coils. The compensation portion of the apparatus consists of three rings whose distances apart can be adjusted by sliding in or out the cylinder to which each of the outer coils is attached. On the left front corner of the board is the commutator, consisting of six stiff elastic wires, which can be sprung against twelve brass nails, and the connections are so arranged that the battery circuit may be sent through any one of the lines, with or without the balance in the circuit, and each line can be made either a primary microphone circuit, or a secondary line in connection with a telephone, by simply placing the commutator wires against their proper contact pins. The microphone and clock, which is the source of sound, and which is shown below, was placed in a distant room, and the direction of the currents throughout the whole apparatus was under perfect control by means of the commutator to which we have referred.

PROF. EDISON'S INDUCTION BALANCE FOR TELEPHONE LINES.

On the opposite page we give a full description of Professor Hughes' induction balance—an invention for which he claims originality, and for which he is receiving great credit in England. It is, however, identical in principle, and almost exactly the same in construction and arrangement as Professor Edison's apparatus, patented in England July 30, 1877, and in the United States April 30, 1878. The fact that Prof. Edison perfected his invention, patented it, and brought it into use so long before Prof. Hughes brought out his alleged invention, is *prima facie* evidence that he—Edison—is the first inventor of the induction balance.

From Edison's U. S. Patent Specification.

In telegraph lines there are very often numerous wires running in the same direction upon the poles, and it has long been known that currents passing through one or more of said wires set up induced currents in the other wires. These, ordinarily, are harmless in the Morse and other systems of telegraphy; but where a wire for a telephone, acoustic, or speaking telegraph, runs parallel to or within the field of the electric influence of another wire, there are false and con-

different battery powers and systems of transmission—many methods to meet special conditions are necessary. Thus in Fig. 2, where the circuits 1 and 2 employ powerful batteries and reversals, and many magnets are in circuit, the induced currents thrown into the telephonic wire are exceedingly powerful; hence a more powerful means of compensation is necessary.

In Fig. 2, *g* is an iron core, over which there are three or more coils—one for each line circuit. The coils 1 and 2 are in the ordinary or Morse circuits Nos. 1 and 2, while coil 3 is in the telephonic circuit. The coils are so wound and arranged, in relation to the induced currents thrown into the telephone wire by the proximity of the other wires, that they will act in the iron core, *g*, to set up a magnetism therein that will cause a powerful induced current to pass into coil 3 and telephonic line opposite in direction to the induced currents in the telephonic line due to the proximity of the other wires.

In cables containing a number of wires there is not only dynamic induction, but static induction. The latter appears sooner than the former, and is of exceedingly short duration, so that magnetic compensation alone is too sluggish. In Fig. 3 is shown a modification of Fig. 1 to meet this condition, which it does to a considerable extent, but not entirely. The induction coils, 1 and 2, are included in derived circuits from the line circuits, 1 and 2, that pass to the condensers, *c'* and *c''*, and to the earth. To obtain perfect compensation, both the static and dynamical induced currents must be set up in the compensations so they will circulate in the telephonic wire in a direction opposite to those induced by proximity of the wires; and to obtain these conditions both magnets and condensers are necessary—the former to set up dynamical induction currents, and the latter static currents. If current No. 1 is opened there first appears a short wave of current due to static induction, then an interval, and then the dynamical induced current appears, which gradually dies away to nothing, hence a compensation which will eradicate the dynamical current will leave that due to static induction free to circulate, and this cannot be eradicated by an induced current from a magnet, because time is required to charge and discharge the cores and the consequent production of the induced current.

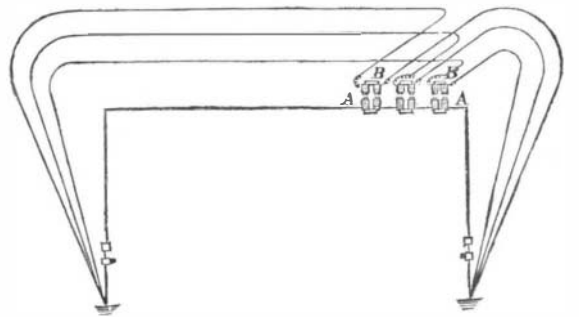
Upon short circuits a coil with two or more wires, wound side by side upon a wooden bobbin is used, as shown in Fig. 4. One wire is placed in the telephonic circuit, while the others are placed in the circuits to be compensated for, and so connected therewith that the currents thrown into the telephonic coil are equal but opposite to those due to induction resulting from the wires running parallel.

By employing large wire, and a large quantity of it, I am enabled to obtain nearly perfect compensation, as the coils set up both dynamical and static currents, no iron cores being used to retard the appearance of the currents.

From Edison's English Specification.

When several line wires run near each other, the wire used for the acoustic or speaking telegraph is influenced by induction, and false sounds will be produced. I counteract this tendency by placing one or more electro-magnets, A (Fig. 5), in the circuit of the speaking telegraph, and one or more electro-magnets, B, in the circuit of the adjacent wires,

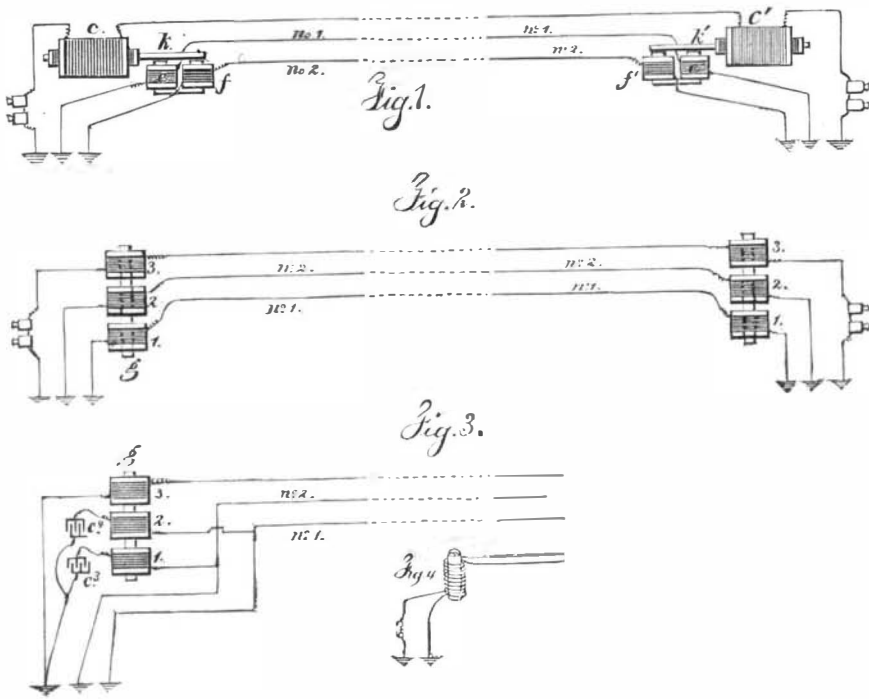
Fig. 5.



and bringing the opposite cores of B, at such a distance from the cores of A, that a certain magnetic action will be set up in A by induction in the opposite direction to the induction currents from the adjacent line or lines.

By adjusting the distance between these magnets when the speaking telegraph is not in use, until there is no sound at the diaphragm from the induction currents, then these currents will be neutralized, whether strong or weak.

Les Mondes calls attention to the success with which M Ravel, a merchant of Montagnac, near Riez, is cultivating the truffle. He is in a position at present to furnish thousands of these fungi, of excellent quality, at about 75c. each. He suggests that vines destroyed by phylloxera be replaced by truffle yielding oaks where the soil is calcareous or argillo-calcareous; this would be a means of recovering from the loss sustained. The products would be quickly realized, for M. Ravel has oaks six, seven, and eight years planted, which already yield truffles.



EDISON'S INDUCTION BALANCE.

using sounds at the receiving instrument that greatly interfere with hearing the message sent upon such acoustic lines.

The object of the invention is to compensate, neutralize, and destroy the extraneous or induced currents from contiguous circuits, so that the messages will not be in any manner interfered with by false currents. The invention consists, in the combination with the telephonic circuit, of an induction coil, connected with the contiguous circuits in such a manner that a reactionary induction is established in the telephonic line of a power corresponding and similar to the primary inductive action, but opposed to the same, so as to neutralize the action of the same.

In the engraving, Fig. 1 is a diagram representing one of the forms in which the compensation is effected. The large coils, *c* and *c'*, are included in the telephonic circuit at each end of the line. In the coils are iron cores, surrounded by a primary coil, the ends of which may or may not be connected together, according to the compensation desired.

The iron core extends outside of the coils some distance. The circuits, No. 1 and No. 2, running in close proximity to the telephone wires, induce a momentary current in it every time the circuits are opened or closed, the strength of which is proportionate to the proximity of the wires to each other and the number of miles that they run side by side. These induced currents are in one direction in closing the circuit, and the opposite direction on opening the circuit. To neutralize the induced current from, say, No. 1 circuit, electro-magnets, *e* and *e'*, are placed at each terminal in the circuit of circuit No. 1.

These magnets are then adjusted to approach the iron cores, *k* and *k'*, until the induced current thrown into the coils, *c* and *c'*, and telephone line by the action of the magnets, *e* and *e'*, is equal, but opposite to, the induced current from the circuit No. 1 thrown into the telephonic wire by running parallel to it. Thus a perfect compensation is attained.

If the two lines run parallel for long distances the two ends of the primary coil on *c* and *c'* are connected together, and thus retard the magnetism and demagnetization of the cores, *k* and *k'*, and consequently lengthen the induced currents thrown into *c* and *c'* by the action of *e* and *e'*.

Having thus compensated for circuit No. 1, the compensation for circuit No. 2 is exactly similar. If the latter circuit does not affect the telephone circuit as strongly as No. 1, the electro-magnets, *f* and *f'*, are placed a greater distance from *k* and *k'*; the latter may be elongated, and compensation attained from many circuits by employing separate magnets in each circuit which affects the telephonic circuit.

Owing to the great diversity in the character of the induced currents thrown into telephonic wires from wires in close proximity—due to different lengths and the employment of