(No Model.)

T. D. LOCKWOOD.

TELEPHONY.

No. 435,438. Patented Sept. 2, 1890.

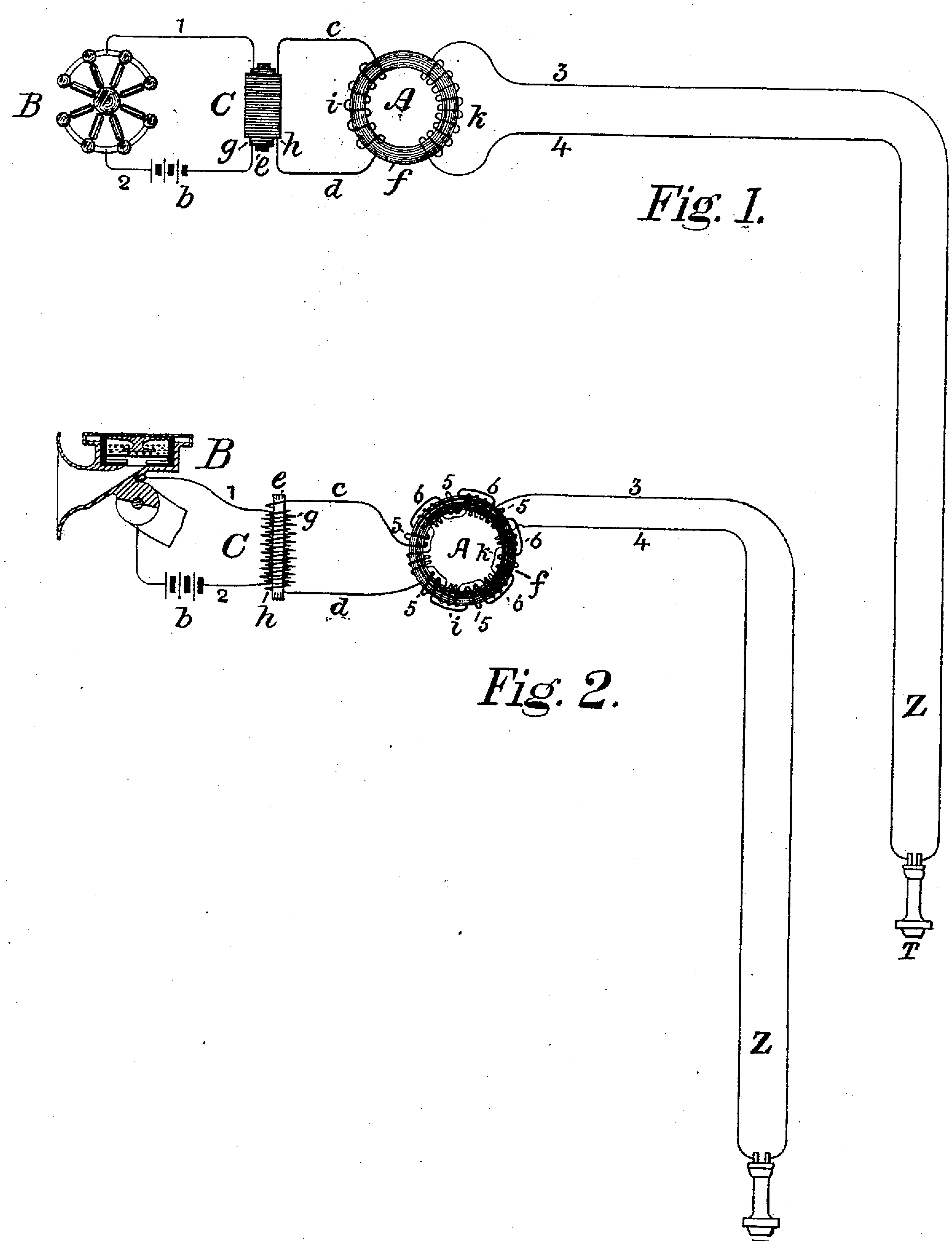

Fig. 1.

Fig. 2.

Witnesses.

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TELEPHONY.

SPECIFICATION forming part of Letters Patent No. 435,438, dated September 2, 1890.

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To all whom it may concern:

Be it known that I, THOMAS D. LOCKWOOD, residing at Melrose, in the county of Middlesex and State of Massachusetts, have invented certain Improvements in Telephony, of which the following is a specification.

It has long been customary to employ induction-coils in association with telephonic transmitters for the purpose of transforming the low-potential current of the energizing-battery into one of higher potential and better fitted to traverse the long line-conductor and to overcome with little loss of energy the resistance thereof, as well as for the analogous purpose of very materially increasing the margin of variation producible by the operation of the transmitter, this latter function being due to the circumstance that while the variation of resistance which can be developed in a given transmitter may practically be regarded as being constant, irrespective of the length or resistance of the circuit within which it is included, the value of said constant is very materially increased as the external resistance of said circuit is decreased. Thus by placing the current-varying part of said transmitter, together with a battery, in the primary circuit of an induction-coil, which primary has a very low resistance, it is clear that the resistance variations developed by said transmitter will have a much wider range in proportion to the entire resistance of the circuit, and consequently will effectuate much greater changes in the strength of the current than would be possible were the transmitter included directly in the main-line telephone-circuit. The wide fluctuations thus produced in a primary of low resistance can, however, be transferred to a secondary without material loss, the variation value being substantially unchanged by the transfer, while the potential in the secondary circuit will be proportionate to the number of convolutions in the secondary helix. It is well known that induction-coils can be used either to raise or to lower potential, and that the potential difference between the primary and secondary helices of an induction-coil corresponds to the ratio between the respective numbers of their convolutions.

Heretofore and prior to my invention it has been customary to employ in telephony induction-coils having cylindrical iron cores, it being easier and simpler to make induction-coils in the form of a cylinder than in any other form. Researches which have been made recently indicate, however, that the core plays a much more important part in the inductive transformation of electrical energy than was formerly believed, and the general statement of the physical actions involved is that the variation of the primary current produces a variation of magnetic induction in the core, and this again in turn acts to develop an induced electro-motive force in the secondary circuit. Hence we can picture to ourselves the waxing and waning primary current to be followed by a rise and fall of the number of lines of force running in endless loops round the core, and this again by a pulsation of secondary current in the secondary circuit. At any instant the total induction in the core or total number of lines of induction linked with both circuits depends upon the magnetizing force to which the iron core is subjected, and the efficiency of the entire organism thus depends, first, upon the efficient action of the primary upon the core, and, second, upon the efficient action of said core upon the secondary. Now the cylindrical iron core is obviously uneconomical in that it necessarily completes its lines of force through the air from the pole at one of its ends to the pole at the other. Moreover, its induction is necessarily unequally distributed, because its very form cannot fail to establish poles at the ends. These considerations indicate that induction-coil cores with closed magnetic circuits or "annular cores," as they may be called, can advantageously be used in telephonic transmission, and should be so used.

The advantages accruing from the employment of endless iron cores having closed magnetic circuits of soft iron are that the lines of force are given an opportunity to traverse the iron instead of the air, and are thereby closely associated with the surrounding helices all through their career, and, further, that an annular core, or one which in principle is annular, though in form not necessarily so, provided it be longitudinally continuous, (such, for example, as one made up of two bar electro-magnets united at both ends by armatures,) properly wound, is non-polar, and therefore is better adapted to exercise uniform induction on all parts of the conductors wound over it. These advantages are not merely matters of theory, but have been experimentally demonstrated in the fullest sense in electric lighting and welding and other industrial applications of electricity in which currents of considerable volume are required. In all such utilizations it is comparatively easy to operate the induction-coils by means of reversals of the primary current, because, since the secondary currents to be evolved need have no special form, character, or quality, these reversals may readily be produced by using an alternating dynamo as a source and by sending its currents unrectified through the primary helix. No such procedure is possible in telephony, for the voice-currents developed in the secondary circuit of the induction-coil, which are to traverse the line and reproduce speech at the distant station, must, so to speak, be an electrical copy of the variations of the sound-waves initiating them, and also of the sound-waves they are to reproduce. Any such arbitrary alternation as can be produced by an alternating dynamo would result merely in noise in the distant receiving-telephone.

Up to the present time it has not been found practicable and convenient to produce reversals in the primary circuit of transmitting-telephone induction-coils, and in all such instruments which have gone into use the change which the operation of the transmitter effects in the primary circuit is not a reversal of current, and hence cannot result in a reversal of magnetism with its inherently-consequent zero moment. It is not even a succession of absolute cessations and emissions of current, as in the make and break of the Ruhmkorff induction-coils. The change which is effected by such operation is the variation of current strength, tending to produce a variation of magnetic intensity in the core, which, if produced, results in corresponding magneto-electric currents in the secondary helix and line; but the magnetism of an iron-ring core once magnetized does not greatly vary when simple changes only are made in the strength of the magnetizing-current, for in this respect such changes or even intermittences are not equivalent to reversals of current, which necessarily produce a forcible reversal of the core's magnetism and a consequent radical rearrangement of the lines of forces passing through the coils, for the magnetic particles in a closed magnetic circuit once polarized are not as ready to assume their unpolarized condition as in a non-continuous core and are not elastically responsive to gradations in the polarizing force. Thus, while it tends to advantage to employ induction-coils having closed magnetic-circuit cores, such a procedure demands also a practical method of producing reversals in the primary circuit of the induction-coil and the arrangement of an organization adapted to effect such reversals and to enable induction-coils with closed magnetic-circuit iron cores to be practically and advantageously employed, and to provide such an organization of devices is the object of my invention.

In the drawings which accompany this specification, Figure 1 is a diagram disclosing an organization of devices illustrating and embodying my method in a practical apparatus; and Fig. 2 is a similar diagram indicating portions of the arrangement more fully and illustrating certain modifications in details.

The essentials are identical in the two figures. The method which I have devised is based upon the principle that induced currents generated in the secondary by action in the primary, whether that action be in the nature of intermittences, variations in strength, or alternations, are themselves necessarily alternating in direction, the induced current caused by an increasing impulse in the primary being always of a direction opposed to that of said impulse, while the induced current caused by a decreasing impulse is of like direction therewith. The said method consists in transforming an electric current which varies in strength only into a current which varies also in direction, the potential being unchanged, and in then transforming the alternating currents so produced into a second series of alternating currents and simultaneously raising the potential under which the last series are developed. It consists, further, in producing changes of strength in a current of constant or uniform direction flowing in an electric circuit by the operation of a telephone-transmitter included therein, together with the battery evolving said circuit, in transforming the voice-currents so produced into alternating currents of like form or character and under a like potential, and in then transforming the said alternating currents into other alternating currents, still preserving the same form, but under a higher potential. It also consists in operating or exciting the potential-raising transmitting induction-coil having its secondary helix included in the line-circuit by means of alternating or alternately-reversed currents circulating in the primary helix of said induction-coil, the said alternations being generated in the secondary conductor of an exciting induction-coil in virtue of current strength variations developed in a battery-current of uniform direction flowing through the primary conductor of said auxiliary coil by means of a variable-resistance transmitter adapted to be operated by the sound-waves of the human voice. These methods are in practice embodied in certain organizations of telephonic apparatus in which the current-varying transmitter is included, together with a battery, in the primary circuit of an induction-coil of the ordinary or usual cylindrical form, and which I call the "exciting-coil," having a secondary of substantially the same number of convolutions and resistance as the said primary. The said secondary helix is connected in circuit with the primary wire of another induction-coil having a ring or continuous core, or, in other words, a core which, when magnetized, is a closed magnetic circuit, the said primary being also of like resistance and number of convolutions as each of the two conductors of the first coil. The secondary conductor of the closed-core induction-coil is, however, formed of a much greater number of convolutions, and to bring these into the requisite proximity to the core it is wound of fine wire, and has consequently a much higher resistance. This conductor is connected in the line-circuit leading to the distant telephone, and, in fact, serves as the source of the undulatory electric energy required for the operation of such line in the electrical transmission of speech, and this induction-coil may properly be called a "potential-raising" coil.

In the figures, A is the ring-core induction-coil, C is the exciting or ordinarily-formed induction-coil, and B the current-varying transmitter.

In Fig. 1, B is a multiple-contact microphone, and, as shown, is by the connecting-wires 1 and 2 placed in the circuit of a battery *b*, in which also is serially included the primary conductor *g* (formed, of course, of insulated wire) of the induction-coil C. This circuit may be termed the "local circuit." The secondary conductor *h* of the said coil has substantially the same number of convolutions and is formed of insulated wire of the same or like size, and both are, as usual, wound upon a cylindrical core *e* of iron wires or rods or small plates. The induction-coil A has a continuous core *f*, made of wires, plates, or strips of soft iron, and constituting a closed magnetic circuit. This has a primary conductor *i*, made of insulated wire, the same size and length as that employed in the two helices of the first coil, which is joined up in circuit by means of wires *c d* with the secondary conductor *h* of induction-coil C, and the closed circuit so constituted may be termed the "intermediate circuit." Thus alternating currents generated in conductor *h* inductively by changes of current in conductor *g* will be of like character with such changes, and will of necessity circulate in and through the primary conductor *i* of induction-coil A. The resistance of the several conductors *g* and *h* and *i* is in all cases to be low, and is preferably but a fraction of an ohm.

The secondary conductor *k* of coil A is formed of fine insulated wire for the purpose of securing a great many convolutions, it being required not only to transfer electrical energy from the reversals circulating in *i* to the secondary conductor *k*, but to raise the potential also in the act of transfer, whereby the said induced currents are developed under a sufficient electro-motive force, and whereby the range of variation is made in some degree, at least, proportionate to the length and resistance of the main circuit. As indicated, the secondary *k* of the induction-coil A is connected with the wires 3 and 4 of the main telephone-circuit Z, leading to the distant station and telephone-receiver T. This figure indicates merely the mode of making the connections, and is not intended to particularly specify any mode of winding the several coils, and, though shown as being associated with a metallic telephone-circuit, is of course equally well adapted for use in connection with a circuit completed through the earth.

The two conductors of both induction-coils may be wound, as indicated at C, in the ordinary way, the primary being first wound on and over the core and the secondary being superposed thereover, or, if desired, in two longitudinal sections, the primary in one section and the secondary in the other being nearest the core, and vice versa, or, as indicated in the coil A, Fig. 1, the primary on one side of the diameter of the ring-core and the secondary on the other. The mode I prefer, however, and which I consider as most advantageous, is to wind the two conductors in a number of alternate short longitudinal sections, as indicated at A, Fig. 2. Moreover, although I have shown the core *f* of the induction-coil A as being circular, it is to be understood that I am not restricted as to form, this being intended merely to indicate its magnetic continuity, and it may be of any form, provided it forms a complete magnetic circuit. For facility of winding it may be made of a number of pieces, which can be bolted or clamped together after winding.

In Fig. 2 a granular carbon transmitter B is indicated as being in the battery-circuit, and is connected exactly as in the former diagram with the primary *g* of the induction-coil C. The position of the second induction-coil A and its connections are also the same as that of the former figure, the only difference being that the mode of preferred winding is indicated. The primary *i* of coil A, connected in closed circuit with the secondary of coil C, is wound over the core *f* in alternate longitudinal sections 5, spaces being left between each longitudinal section for similar sectional windings 6 of the secondary *k*. In practice the section-spaces will be of equal size, the difference in the respective number of convolutions being compensated for by the difference in the sizes of the conductors, respectively. The advantage of this mode of winding is that the magnetization is thereby distributed with uniformity, and hence is enabled to act equally upon all parts of the core.

The operation of such an organization is readily understood. The current of the battery *b* circulates through the transmitter and first primary *g*. When sounds are uttered in the vicinity of said transmitter, the said current is thrown into variations which correspond to the variations of the waves of sound.

An induced electro-motive force is developed by said variations in the first secondary, which, having its circuit closed, results, of course, in the induction of currents; but, the primary and secondary being of like length and size, the induced potential and the strength of the resulting current are both unchanged. In accordance, however, with the well-known laws of induction the induced currents are alternating or alternately reversed. The secondary of the first induction-coil being joined up with the primary of the second, it is obvious that the reversals developed in the former necessarily circulate also through the latter, serving as alternating exciting-currents for the second induction-coil, these being much more efficient in varying the magnetization of an iron core closed on itself than are simple variations in strength, and the final result is that being by such means enabled to employ an endless or closed core, in which all of the lines of force are utilized or conserved, the waste of energy is very slight, and induced impulses possessing a superior degree of energy are generated in the secondary of the second induction-coil A, none of the characteristics of the original voice-currents necessary to an accurate and efficient reproduction of the original sounds having, however, been lost in conversion, and these induced currents being thrown upon the line traverse the same, and acting upon the distant telephone-receiver are therein retransformed into sounds which are a close copy of those which initiated the operation.

It will be observed that the function of the first induction-coil is to develop alternating currents in the intermediate circuit without raising the potential of such currents. If the potential in this circuit were to be raised, it would be necessary to multiply the convolutions of both the helices included in it, with a consequent increase in cost, in resistance, and in waste of energy. Furthermore, it is of great importance to keep down the resistance of this intermediate circuit, for the reason that in telephony self-induction is a potent factor in opposing the proper operation of the current, and the self-induction of any circuit of which coils or helices form a part is mainly dependent upon the number of their convolutions. Hence there is special utility in employing a few convolutions of thick wire instead of a greater number of convolutions of thinner wire in the intermediate circuit.

I claim—

1. The hereinbefore-described improvement in the art of transmitting articulate speech, which consists in transforming an electric current which varies in strength only into a current or series of currents varying also in direction, the potential being unchanged, and in then transforming the said alternating currents into a second series of alternating currents, and in simultaneously raising the potential under which the last series is developed.

2. The described method of producing alternating currents under a comparatively high potential, which method consists in varying the strength of an electric current of constant direction by varying the resistance of its circuit, transforming the varying currents so produced into alternating currents of like form and under like potential, and by these alternating currents exciting other alternating currents of like form under a higher potential, as set forth.

3. The described improvement in the art of transmitting sounds electrically, which improvement consists in producing in a primary circuit variations in current strength corresponding in form to sound-waves, transforming such varying currents by induction into reversed or alternating currents of like form and under like potential, and transforming such reversed or alternating currents into other reversed or alternating currents of like form under a high potential, as set forth.

4. The combination, with a variable-resistance telephone-transmitter, of a potential-raising induction-coil, and a telephone-circuit connected with the secondary helix thereof, and an exciting induction-coil having its two helices of like size and length, one of the said helices being connected in circuit with the said transmitter and a battery and the other with the primary circuit of the said potential-raising induction-coil, whereby the latter may be excited by alternating voice-currents, substantially as and for the purposes specified.

5. In a telephone system, a current-varying telephone-transmitter, an induction-coil therefor having its primary helix included with said transmitter in the circuit of a battery, and a second induction-coil having an endless core interposed between the first induction-coil and the main telephone-circuit, having its primary helix connected with the former and its secondary helix with the latter, whereby the variations of strength produced by the transmitter in the primary of the first coil may be enabled to induce reversed exciting-currents in the primary of the second.

6. The combination, substantially as hereinbefore described, of a telephone-circuit, a potential-raising induction-coil having a closed magnetic-circuit iron core, the secondary helix thereof being connected with said telephone-circuit, a variable-resistance telephone-transmitter in a battery-circuit, and an exciting induction-coil, the two helices thereof having substantially the same number of convolutions of the same size of wire, one of the said helices being connected in circuit with the transmitter and the other with the primary helix of the potential-raising coil, whereby the said coil may be excited by alternately-reversed voice-currents and the maxi-

mum change in magnetization of its closed circuit-core thereby developed.

7. The combination, in a telephone system, of a telephone-circuit and a receiving-telephone included therein, a main-circuit induction-coil having a primary helix of few turns, a secondary helix of many turns, and a soft-iron ring-core, an exciting induction-coil having primary and secondary helices of an equal number of turns and of low resistance, and a cylindrical soft-iron core, a current-varying telephone-transmitter, and a battery, the said transmitter being included with the primary helix of the exciting-coil in circuit with the battery, the secondary of the exciting-coil being included in circuit with the primary of the main-circuit coil and adapted to circulate induced reversals therein on the operation of the transmitter, and the secondary of said main-circuit induction-coil being included in the said main telephone-circuit and adapted to serve as a source of undulatory electrical energy therefor.

8. In a telephone system, a main telephone-circuit extending to a distant station, a local circuit including a battery and a transmitter at the transmitting-station, an intermediate or exciting circuit also at the transmitting-station, an exciting induction-coil, as described, having its primary in the local-battery circuit and its secondary in the intermediate circuit, both helices being of the same size and length, and a potential-raising induction-coil constructed as described having its primary in the intermediate circuit, and its secondary in the main telephone-circuit, all substantially as described.

9. In a telephone system, a current-varying transmitting-telephone, an induction-coil therefor having its primary helix included with said transmitter in the circuit of a battery, and a second induction-coil interposed between the first induction-coil and the main telephone-circuit, having its primary helix connected with the former and its secondary helix with the latter, the said helices being wound, respectively, in successive longitudinal sections on a ring or continuous soft-iron core, substantially as described.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 13th day of February, 1890.

THOS. D. LOCKWOOD.

Witnesses:
GEO. WILLIS PIERCE,
FRANK C. LOCKWOOD.