No. 627,814. Patented June 27, 1899.

C. H. ARNOLD.

TELEPHONE EXCHANGE SWITCH APPARATUS AND CIRCUIT.

(Application filed Mar. 31, 1899.)

(No Model.) 2 Sheets—Sheet 1.

Fig. 1.

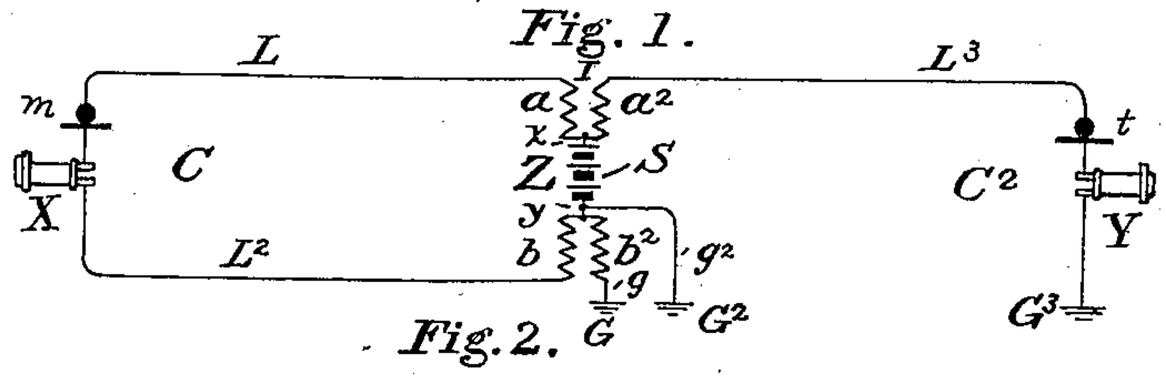


Fig. 2.

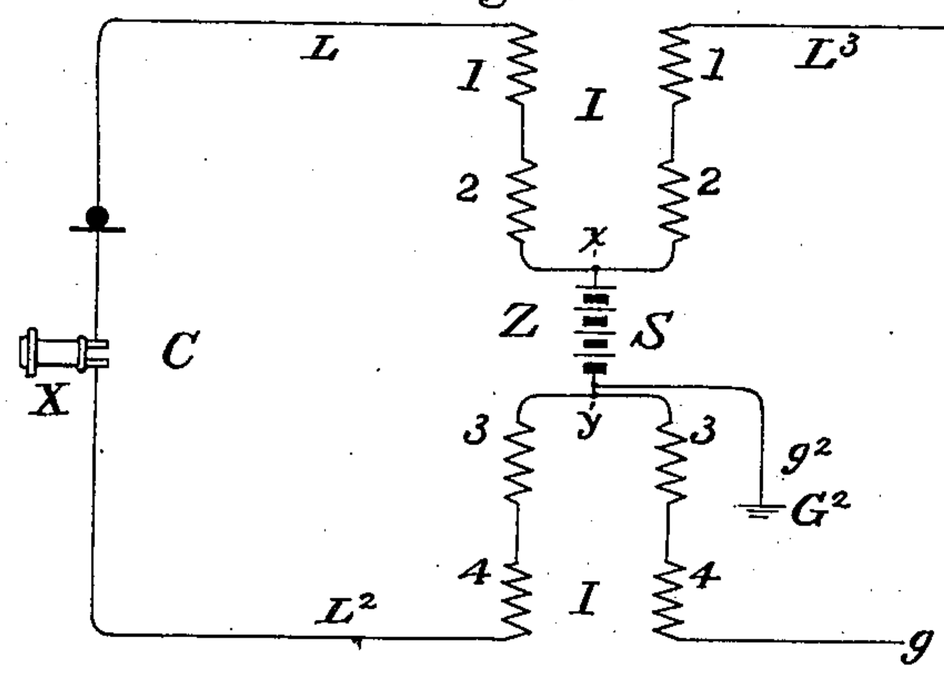


Fig. 3.

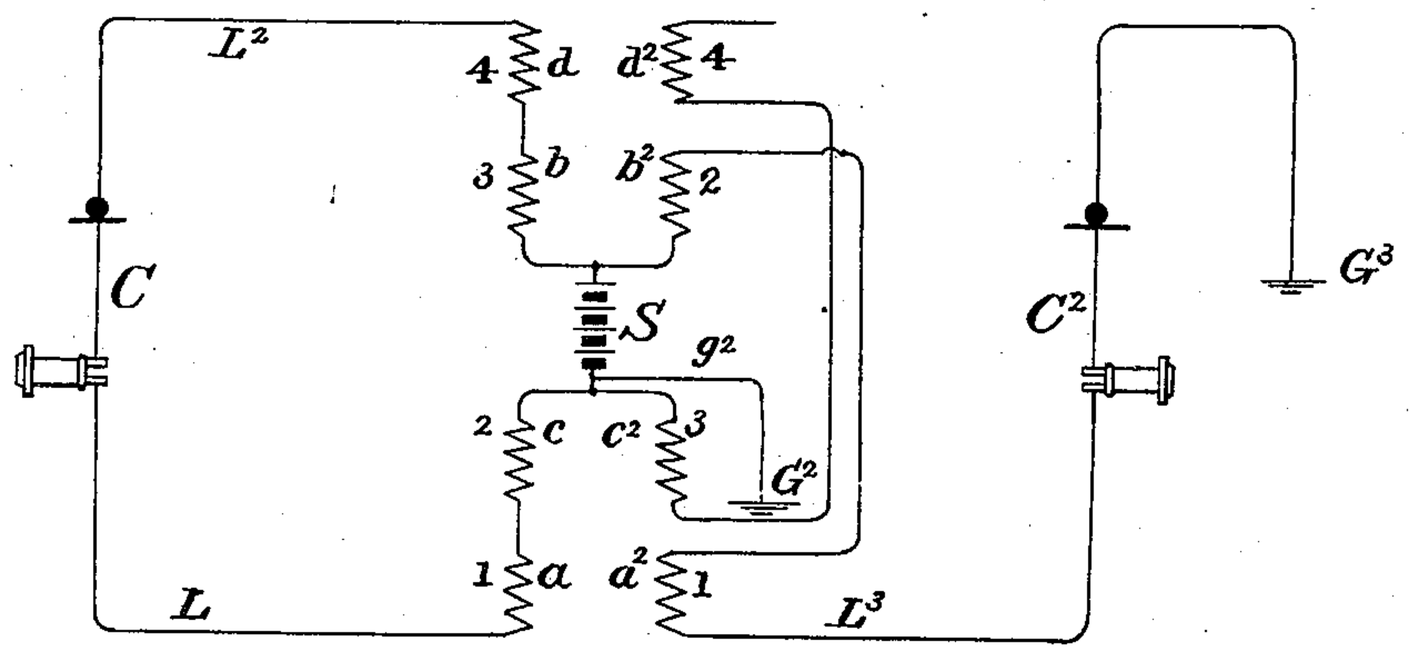
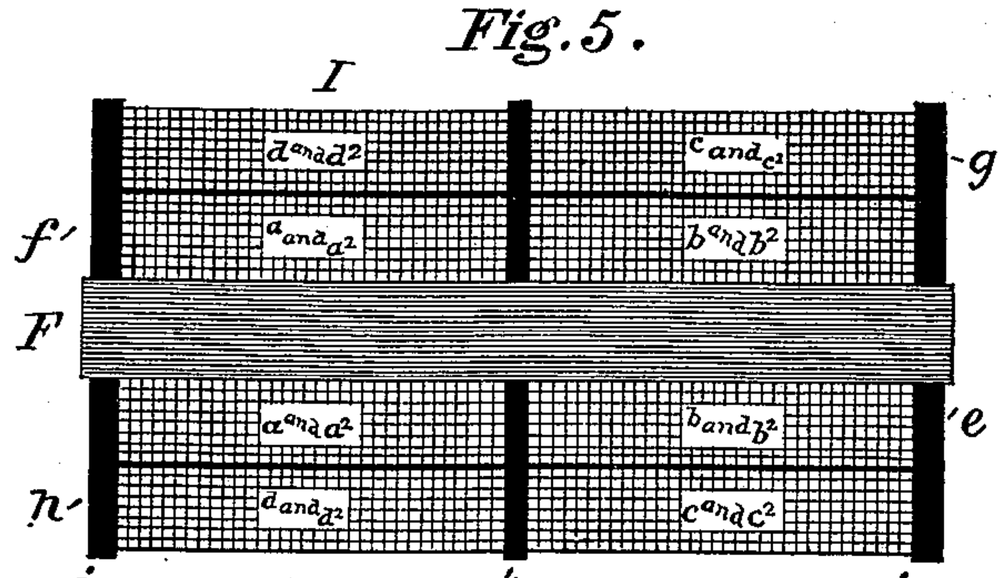


Fig. 5.



Attest.

Katharine Dunfee

Geo. Willis Pierce

Inventor,

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TELEPHONE EXCHANGE SWITCH APPARATUS AND CIRCUIT.

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(No Model.) 2 Sheets—Sheet 2.

Fig. 4.

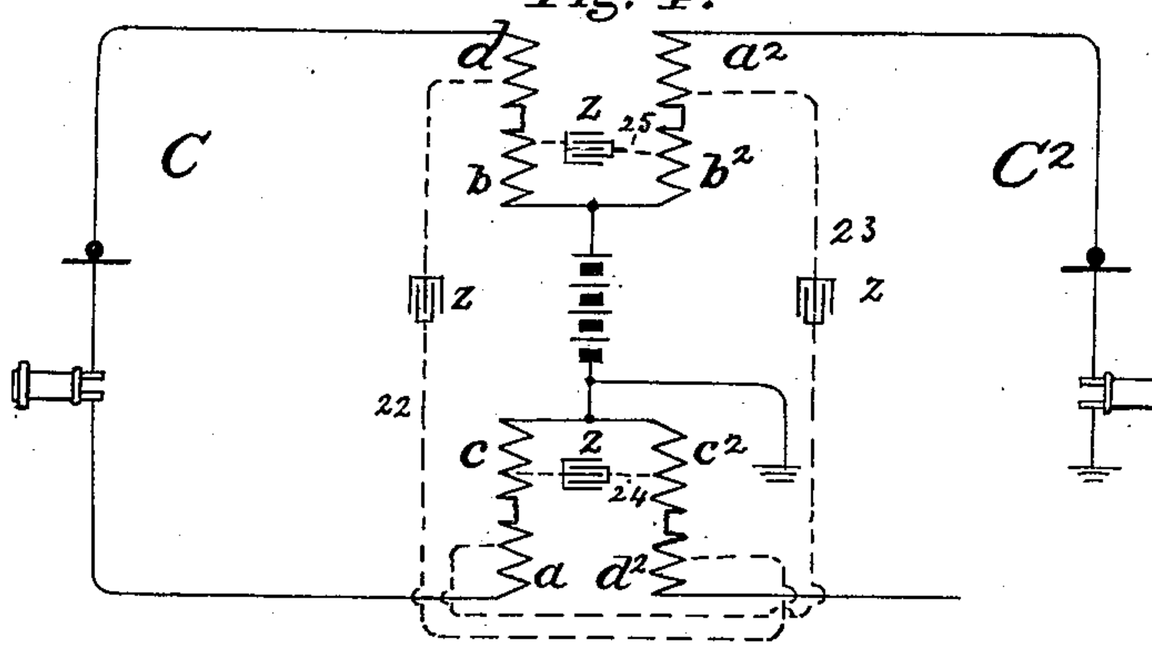
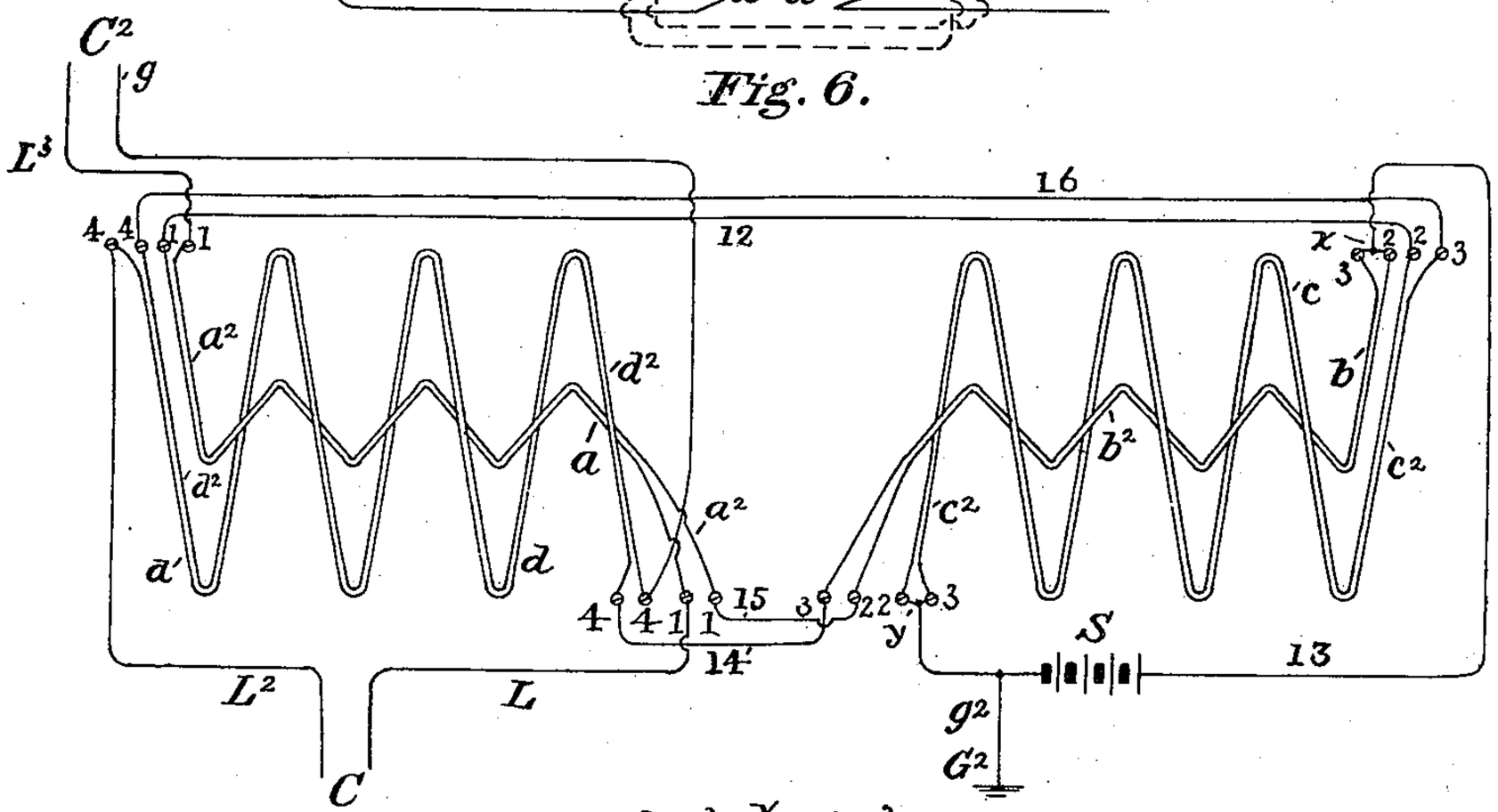


Fig. 6.



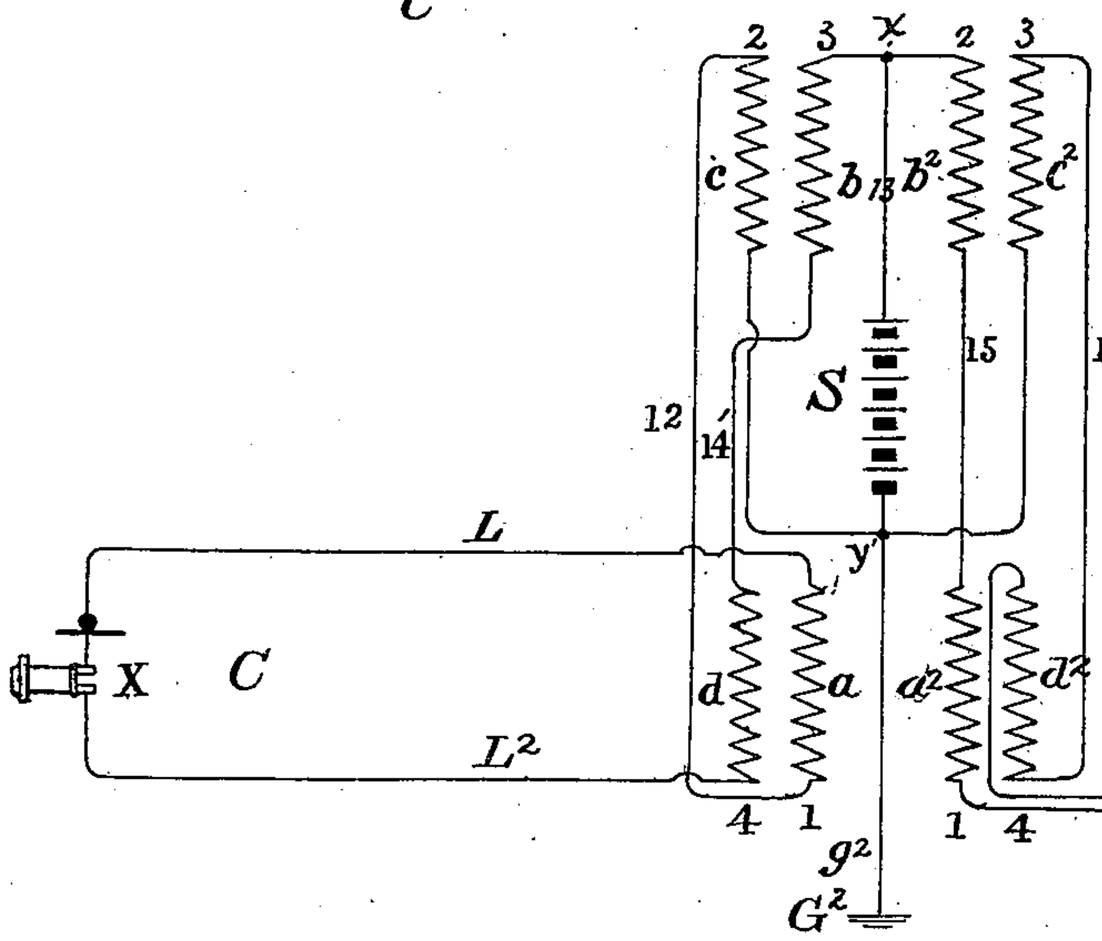


Fig. 7.

Attest.

Frank C. Lockwood.

Geo. Willis Pierce

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Chester H. Arnold

UNITED STATES PATENT OFFICE.

CHESTER H. ARNOLD, OF BOSTON, MASSACHUSETTS, ASSIGNOR TO THE AMERICAN BELL TELEPHONE COMPANY, OF SAME PLACE.

TELEPHONE-EXCHANGE SWITCH APPARATUS AND CIRCUITS.

SPECIFICATION forming part of Letters Patent No. 627,814, dated June 27, 1899.

Application filed March 31, 1899. Serial No. 711,273. (No model.)

To all whom it may concern:

Be it known that I, CHESTER H. ARNOLD, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented certain Improvements in Telephone-Exchange Switch Apparatus and Circuits, of which the following is a specification.

This invention concerns telephone-exchange central-station apparatus, and relates more particularly to repeating induction-coils and to their association with switchboard circuit-conductors and such substation-circuits as may be temporarily connected therewith or united thereby. It has especial adaptation to telephone-circuits having their substation-transmitters supplied with current from a central source which may be common to a number of circuits or pairs of circuits. In central-station switching apparatus of this class it has been found of practical advantage to connect the source of current-supply, usually a battery, in a bridge-conductor or section of conductor made common to both of any two substation-circuits united for conversation and to interpose the repeating induction-coil between the said source and the main circuit-conductors of these circuits, the two helices of the said coil being connected in the said two circuits, respectively, in the manner generally disclosed by Letters Patent of the United States No. 474,323, granted May 23, 1892, to Hammond Vinton Hayes.

In Letters Patent No. 551,056, granted December 10, 1895, to Theodore Spencer and Thomas C. Wales, Jr., is described an improvement which, among other matters, provides that the two helices of the repeating-coil shall each be made up of two independent windings connected in series and placed in each conductor of its circuit, so that each of two connected circuits shall contain a different helix of the induction-coil, half of which helix shall be in the circuit-conductor connected with one pole of the current-supply generator and half in the other conductor of such circuit—viz., that which is connected with the other pole of the said generator. The repeating-coils employed in this way have been constructed by winding the four conductors over a common iron core, both ends of all four being made accessible and furnished with binding-screw or other terminal attachments, whereby they may readily and conveniently be united to the several main circuit-conductors and battery-terminals. This arrangement has been found useful in installations where metallic circuits only are to be manipulated or interconnected at the switchboard for through communication, but is not fully satisfactory in central stations to which ground return-circuits also converge, and in cases where a metallic and a grounded circuit are united for conversation. It is a fact that the impedance of a winding of an electromagnetic coil depends not solely upon the properties or characteristics of the winding itself and the iron core surrounded thereby, but also to a considerable extent upon the condition or properties of such circuits as may be conductively or inductively associated with it. In the interconnection by this system of grounded and metallic circuits while the two free ends of one of the helices of the repeating-coil have been united to the two conductors, respectively, of the metallic circuit one end only of the other helix could of course be so united with the grounded circuit, the same having but one conductor, and the remaining end of the helix has been united to an earth connection; but in such a connection of metallic and grounded circuits the influence of the two windings of the grounded-circuit side of the repeating-coil upon the two windings of the metallic-circuit side inductively associated with them, respectively, is different and unequal, and as a result the metallic circuit was left in an unbalanced condition in regard to the central-office earth connection, a tendency to disturbance of the talking-circuit and to reduced efficiency being thus brought about.

The object of the present invention is to prevent such an unbalanced condition and the disadvantageous results accruing therefrom, or, stated conversely, to maintain a perfectly-balanced condition of the two circuits in the repeating-coil, both electromagnetically and electrostatically, and thereby to avoid disturbance and facilitate the telephonic interchange of conversation between the two circuits.

To this end the invention provides that the

repeating-coil shall have eight substantially equal independent windings—that is to say, each of its helices shall be constituted of four serially-connected windings, each one of the four being so placed in regard to some one of the other four as to have a close or intimate inductive relation therewith, such relation being, however, so arranged that the first and last windings of the four of each helix are inductively paired with the first and last, respectively, of the other. The second winding of one helix is similarly paired with the the third in serial order of the other, while the third winding of the said first-mentioned helix is inductively paired with the second of the said other. By this arrangement two windings of both helices are placed at one side of the terminal attachments of the current-generator, and the remaining four, two in each helix, on the other, so that for each of the helices two serially-consecutive windings are adapted for connection in each conductor of each of any two circuits, between which the repeating induction-coil is placed for the establishment of inductive intercommunication. The order of inductive relation is, however, not the same as that of conductive series, but is so systematized that the two windings of one of the helices, which are connected in series with the terminal attachments of one side of the generator, have intimate inductive relations, respectively, with two windings of the second helix that are not consecutive members of their series and that are connected with the terminal attachments of different sides of the said generator, while the other two windings of the said first helix are in like manner in close inductive relation with the two remaining windings of the second helix, which, of course, also are not consecutively successive in conductive series, and are associated, respectively, with the terminal attachments of different sides of the generator when the said generator is connected.

The intimate inductive relation desired between any two windings can conveniently be secured by winding them together, and I find that an efficient and satisfactory construction of the improved repeating-coil producing good results is one wherein each of the four windings of each helix is wound side by side with the appropriate winding of the other helix over an iron core, the four pairs of windings so formed being wound in two equal longitudinal sections over the core, one of the pairs in each section being wound next to the said core and the other outside thereof and concentric therewith. The first winding in series of both helices, for example, may together occupy the innermost position from one end to the middle of the core. The third winding of helix No. 1 and the second of helix No. 2 may jointly fill the inner longitudinal section from the other end to the middle of the core. Over these last the second winding of No. 1 and the third winding of No. 2 may be wound, and over the first pair the last winding of helix No. 1 may be wound, together with the last of No. 2.

The invention further consists in combining such a repeating induction-coil with two telephone-circuits, and more particularly with a metallic telephone-circuit and a grounded telephone-circuit, in a manner presently to be described at length, as shown in illustrative drawings and as especially pointed out in the several clauses of claim which form a part of this specification.

In the drawings whereby this specification is illustrated, Figure 1 is a diagram illustrating the state of the art immediately prior to my invention. Fig. 2 is a diagram illustrating one phase of my improvement and showing the four windings of the two repeating-coil helices in their serial conductive relation only. Fig. 3 is a similar diagram, but indicating also the mode in which the windings of each helix or circuit are inductively paired with those of the other circuit. Fig. 4 shows substantially the same arrangement as Fig. 2, but is illustrative of the electrostatic inductive properties and the electrostatic balance of a repeating-coil constructed in accordance with the invention. Fig. 5 is a longitudinal vertical central section of a form of repeating induction-coil suitably embodying my invention. Fig. 6 is a diagram supplementary to Fig. 5 and is indicative of the mechanical as well as the conductive and inductive relations of the several coil-windings; and Fig. 7 is a diagram of another mode of indicating the same relations and may be considered as illustrating the ideas of Fig. 6 in terms of Fig. 3.

As hereinbefore indicated, Fig. 1 shows the repeating-coil arrangement employed extensively in central and universal current-supply circuits prior to my invention.

Z is a central telephone-station, and X and Y are substations.

C is a metallic main telephone-circuit extended between X and Z, and C^2 an earth-completed or ground-return main circuit between Y and Z.

At the central station S is a source of current-supply or current-generator of any desired type furnishing direct current, connected in a section of conductor between the points x y common to both main circuits. I is a repeating induction-coil with four windings a a^2 b b^2, usually wound over a common iron core, a and b being in series with one another in the metallic circuit C, but on different sides of the current-generator S, and a^2 b^2 being in series also at different sides of the generator in the grounded main circuit C^2.

L L^2 are the outgoing and return conductors of the metallic circuit, and L^3 the single main conductor of the grounded circuit, the latter having a central-station earth branch g grounded at G.

From that pole of the generator which is most distant from the main conductor L^3 an earth-conductor g^2 also extends to ground G^2

to complete a circuit of the said generator for testing and signaling purposes, and, in brief, for all purposes where a circuit closed to ground independent of the path through winding b^2 is desired.

G^3 is the substation ground of main circuit C^2, and m and t represent, respectively, the transmitting and receiving telephones at the substations X and Y. The windings are inductively associated in pairs, a and a^2 forming the pair on one side of the generator, and thus in the main conductors L and L^3 of the two main circuits, respectively, and $b\,b^2$ forming a pair on the other side of the generator in the main conductor L^2 of circuit C and the complementary earth-conductor g of circuit C^2, respectively. Experience, however, has demonstrated that when two circuits, one metallic and the other grounded, are connected through such a repeating-coil in the above-described manner, the influence of winding a^2, which is in the main conductor L^3, upon winding a is so materially different from that exerted by winding b^2, which is placed in the relatively short ground branch g and between two earth connections upon winding b, that the impedance of the windings a and b is also caused to differ considerably, notwithstanding the fact that the dimensions of the said windings are the same. The result of such difference is of course that the two sides L L^2 of the metallic circuit become unlike and the metallic circuit is as a whole unbalanced, introducing disturbance to the telephone-circuit and generally bringing about a lower grade of efficiency in operation.

Referring now to Fig. 2, which is the first of the group of drawings illustrating my invention, it will be observed that eight distinct windings are employed. These all have the same number of turns and are arranged four in series in each circuit. The generator S occupies the same position as before in the section of conductor common to the circuits C and C^2 between the points x and y; but the ground connection of circuit C^2 at the central station is dispensed with, the complementary branch g thereof being left discontinuous, so that while the main conductor part L^3 of the circuit is closed through the subsidiary ground connection G^2 the complementary branch g of the circuit is open. Four of the eight windings are in the metallic circuit C and the other four connected with the grounded circuit C^2. They are in this figure shown in their serial conductive relation without regard either to their mechanical position in the repeating-coil as a concrete piece of apparatus or to their inductive relations each with a winding of the other circuit. The metallic circuit is assumed to enter at the upper side L and to pass through the windings 1 and 2, the generator S, and the windings 3 and 4, all in series, continuing from the latter to conductor L^2 and back to the substation. The grounded circuit passes at the upper side through windings 1 and 2 of the other helix, then through the generator, and then through the windings 3 and 4, consecutively, of the open branch. The ground connection g^2 is attached in such position as to leave the generator in the circuit of conductor L^3. The four windings of each helix are each associated with a different one of the four windings of the other, so that we have four pairs of wires, the members of which pairs are in intimate inductive relation to one another, and we may assume that winding No. 1 of circuit C is thus associated with winding 4 of circuit C^2, winding 4 of circuit C with winding No. 1 of C^2, and windings 2 and 3 of C with 2 and 3, respectively, of C^2. This is diversely shown in Figs. 3, 5, 6, and 7, and while I have indicated the serial conductive relations of the several windings of both circuits by numerals 1 to 4 I will for the purpose of their inductive relation denominate the respective pairs of windings by letters of reference, as $a\,a^2$, $b\,b^2$, $c\,c^2$, and $d\,d^2$.

For convenience in illustration and description the conductors L and L^2 of circuit C have been made to exchange places, it being now assumed that the metallic circuit enters the central station Z by the lower wire L, so that the lower coil-winding is now numbered 1, and the remaining windings are numbered serially therefrom. The conductor L^3 and discontinuous branch g have also in the diagram been reversed.

In Fig. 3, which does not purport to indicate the mechanical position of the windings in the repeating-coil, the windings are shown in the proper inductive relation each to its appropriate mate of the other circuit, windings Nos. 1 and 4 of each circuit being inductively paired with the similarly-numbered winding of the other circuit, and windings 2 and 3 of each being inductively paired with windings 3 and 2, respectively, of the other. To indicate the said inductive relation, it becomes convenient to show the grounded circuit c^2 as entering at the lower side of the figure, and it is now evident that one winding a^2 of the line-conductor portion of the circuit c^2 has established an inductive relation with one side L of the metallic circuit through the paired windings a thereof on one side of the generator and that the other winding b^2 of the circuit c^2 has established a similar inductive relation with winding b of the other side L^2 of the said metallic circuit on the other side of the generator, whereby the windings a^2 and b^2, exercising like influences, are enabled to act equally on both sides of the metallic circuit, which is therefore balanced. In the same way the two serial windings c^2 and d^2, the third and fourth in conductive series, respectively, of the grounded circuit C^2 are paired or wound together with c and d, the second and third in conductive series, respectively, of the metallic circuit C, and their influence also is similarly balanced between the two sides of the same metallic circuit.

In Fig. 5, which represents one practical

mechanical arrangement of the repeating-coil I, its core F, and its eight equal windings, the said repeating-coil is shown as having two longitudinal sections bounded, respectively, by the central non-conducting partition *j* and the end disks *i* and i^2. Each of these longitudinal sections accommodates two pairs of windings, one pair in each case being wound next to the core, and the other external thereto and concentric therewith, so that the right-hand longitudinal section may be described as having two concentric sections, an inner one *e* and an outer one *g*, while the left-hand longitudinal section is similarly divided into an inner concentric section *f* and an outer one *h*, each adapted to contain one of the two remaining pairs of windings.

Carrying out the terminology of the inductive relation of the windings illustrated by Fig. 3, the windings *a* a^2 are wound together in section *f*, *b* and b^2 in section *e*, *d* and d^2 in section *h*, and *c* and c^2 in section *g*. This construction is further illustrated by Figs. 6 and 7, which more clearly indicate the arrangement in conductive series, in inductive relation, and mechanically of the four pairs comprising the eight windings, the conductive serial arrangement being indicated by the numerals and the intimate inductive relation by the same reference-letters as are employed in Fig. 3. These Figs. 6 and 7 indicate also the connections of the main telephone-circuits and the central-office generator. The metallic circuit C, leading from substation X, is shown as having its main conductor L united to the inner terminal of winding *a* and its main conductor L^2 to the outer terminal of winding *d*. Between these points the circuit may be traced as follows: winding *a*, conductor 12, winding *c*, point *y*, generator S, conductor 13, point *x*, winding *b*, conductor 14, and winding *d*. The grounded telephone-circuit C^2 is shown with its main line L^3 entering the coil at the outer end of winding a^2 and passing successively the said winding a^2, conductor 15, winding b^2, point *x*, conductor 13, generator S, point *y*, winding c^2, conductor 16, and winding d^2, and thus to the conductor *g*, where it is left open or discontinuous. The earth connection g^2 extends to ground at G^2 from that side of the battery which is most remote from the entering-point of the line L^3. The first windings of the two circuits paired inductively, as *a* and a^2, are wound to constitute the inner section from one end to the middle of the core and the fourth or last windings of both, paired as *d* and d^2, are together wound over the first to form the outer section of the repeating-coil at the same end. The third winding of the metallic circuit and the second of the grounded circuit are paired, as *b* b^2, and wound together nearest to the other end section of the core, and the second winding of the metallic and third winding of the grounded circuit are paired, as *c* and c^2, and wound together over *b* and b^2 to form the outer section of this end of the coil.

In Figs. 6 and 7 the several windings of each circuit are indicated as being connected in a particular way with respect to their inner and outer ends. It will of course be understood by those skilled in the art to which my invention relates that no arbitrary rule in respect to these connections can be stated, since the mode of connection depends on the direction in which the several windings are wound, and this, in many instances, is in turn dependent upon mechanical considerations which determine the action of the workmen engaged in the construction of the appliance. It may, however, be stated that the several serial windings of each circuit must be relatively wound or connected, so that a given current circulating through them will excite in each magnetizing influences of such direction that the several windings will act coöperatively in developing uniform polarity in the core.

Fig. 4 is a theoretical diagram which does not illustrate any feature of construction or connection, but does illustrate the electrostatic advantages of my improvement. The dotted lines and condensers shown have no independent existence, but are intended to indicate that the intimate relationship of each of the windings for a particular one of the others, and the consequent balanced condition of the circuits is not electromagnetic only, but is also electrostatic. The figure is based, substantially, upon the mode of delineating the circuits adopted in Fig. 2, and between the first winding *a* of circuit C and the first, a^2, of C^2 a close electrostatically-inductive relation exists and is symbolized by the dotted line 23 and its condenser *z*. A similar relation exists between the last windings *d* and d^2 of the two circuits, the second winding *c* of C and the third c^2 of C^2, and the third winding *b* of C and second of C^2, these being all in like manner symbolized, respectively, by the dotted lines 22, 24, and 25 and their condensers *z*. Moreover, since the electrostatic inductive influences of the two windings of conductor L^3 of the grounded circuit are exerted equally upon the two sides of the metallic circuit, and since the two windings of the discontinuous branch of the grounded circuit act likewise upon the said two sides of the metallic circuit, an electrostatic balance is obviously secured.

While Figs. 3 to 7, inclusive, of the drawings show the two circuits or helices of the repeating-coil as each having their first and last windings inductively paired with the first and last, respectively, and the second and third of each as being paired with the third and second, respectively, of the other, it is manifest that the invention includes equally the reverse arrangement wherein the first and last windings are each inductively paired with the last and first, respectively, of the other and the second and third with the second and

third of the other. This, in fact, is suggested by the arrangement of Fig. 2 and is shown to be merely a question of definitions, since an underlying principle of the invention is that when the repeating-coil is connected serially between two circuits the two windings associated with each main conductor of one of the circuits shall be inductively paired with two windings of the other circuit in different main conductors thereof.

I claim—

1. A repeating induction-coil comprising two conductive circuits, both constituted of four substantially equal serially-connected windings, each having an intimate inductive relation with a different winding of the other circuit; the first and last windings of the series of each circuit being thus paired with the first and last respectively of the other, and the second and third serial windings of each circuit with the third and second respectively of the other, substantially as set forth.

2. In a repeating induction-coil for telephone-circuits, the combination with two conductive circuits, both constituted of four substantially equal serially-connected windings each wound side by side with a different winding of the other circuit; of battery connections for both circuit-windings, adapted to be connected with a battery in a section of conductor common to both circuits, two of the windings of each circuit being arranged on each side of the said battery connections, and thereby in each main circuit-conductor; the first and second windings in serial succession, of one circuit, and the third and fourth windings of the other circuit being on one side of said battery connections and the third and fourth windings, and first and second windings of the said circuits respectively, being on the other side of said battery connections; but the second and third windings of each, being in close inductive association with the third and second windings respectively, of the other; substantially as and for the purposes specified.

3. The combination in a repeating induction-coil of an iron core; and eight substantially equal windings, four in serial succession for each of the two circuits thereof, each winding of each circuit being wound side by side with one of the windings of the other circuit, and the four pairs of windings so constituted being wound in two longitudinal sections over the core, one of the pairs in each section being wound next to the said core, and the other concentric therewith.

4. A repeating induction-coil having eight substantially equal windings, four in serial succession for each of the two circuits thereof, each winding of each circuit being wound in close juxtaposition with one of the windings of the other circuit, so that the first and last windings of the series of each circuit shall be paired in intimate inductive relation with the first and last respectively of the other to form terminal pairs, and the second and third windings in serial arrangement of each circuit with the third and second respectively of the other to form intermediate pairs; the said terminal pairs being wound in concentric sections over one longitudinal section of the core, and the said intermediate sections being similarly wound in concentric sections over the other longitudinal section of the said core, substantially as described.

5. The combination of two telephone-circuits each extending from a substation to the same central station, and there completed or closed through a section of conductor common to both, including an electrical generator; and a repeating induction-coil having eight windings, four for each circuit, interposed two in series between the two poles of the said generator and the conductors of the said circuits respectively, the two terminal windings of the series of each circuit being wound together or placed in close inductive relation with the two terminal windings respectively of the other, and the second and third windings of the said series in each circuit having a like inductive relation with the third and second windings respectively of the other or vice versa; substantially as set forth.

6. The combination of a metallic telephone-circuit, and a grounded telephone-circuit extending from independent substations to the same central station, and there completed or closed through a section of conductor common to both, which common conductor contains a source of current-supply; of a repeating induction-coil placed between the said circuits, and having eight substantially equal windings, four of the said windings being connected in series in the metallic circuit, two in each main conductor thereof; two other of the said windings being included in the grounded circuit, and wound in intimate inductive relation with two of the metallic-circuit windings, one in each of the two main conductors thereof; and the remaining two windings in a conductively-discontinuous or electrostatic branch of the said grounded circuit, wound in close inductive relation with the two remaining metallic-circuit windings, one in each of its main conductors; substantially as hereinbefore specified.

7. The combination of two telephone-circuits each extending from a substation to the same central station, and there completed or closed through a section of conductor common to both, including an electrical generator; and a repeating induction-coil having eight windings, four in each circuit, interposed two in series between the poles of said generator and the conductors of said circuits respectively, each of the four windings in one circuit being wound in close inductive relation with a winding of the other circuit, thus forming four pairs of windings, the windings composing each of two of said pairs being connected respectively in two of the circuit-con-

ductors leading to opposite poles of the generator, and the windings composed each of the other two of said pairs being connected respectively in two of the circuit-conductors leading to the same pole of the generator.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 15th day of February, 1899.

CHESTER H. ARNOLD.

Witnesses:
GEO. WILLIS PIERCE,
JOSEPH A. GATELY.