W. E. GOLDSBOROUGH.

INDUCTANCE NEUTRALIZING COIL WOUND CORE AND COMMUTATING IMPEDANCE COIL FOR ELECTRIC MACHINES.

APPLICATION FILED DEC. 22, 1902.

952,899. Patented Mar. 22, 1910.

4 SHEETS—SHEET 1.

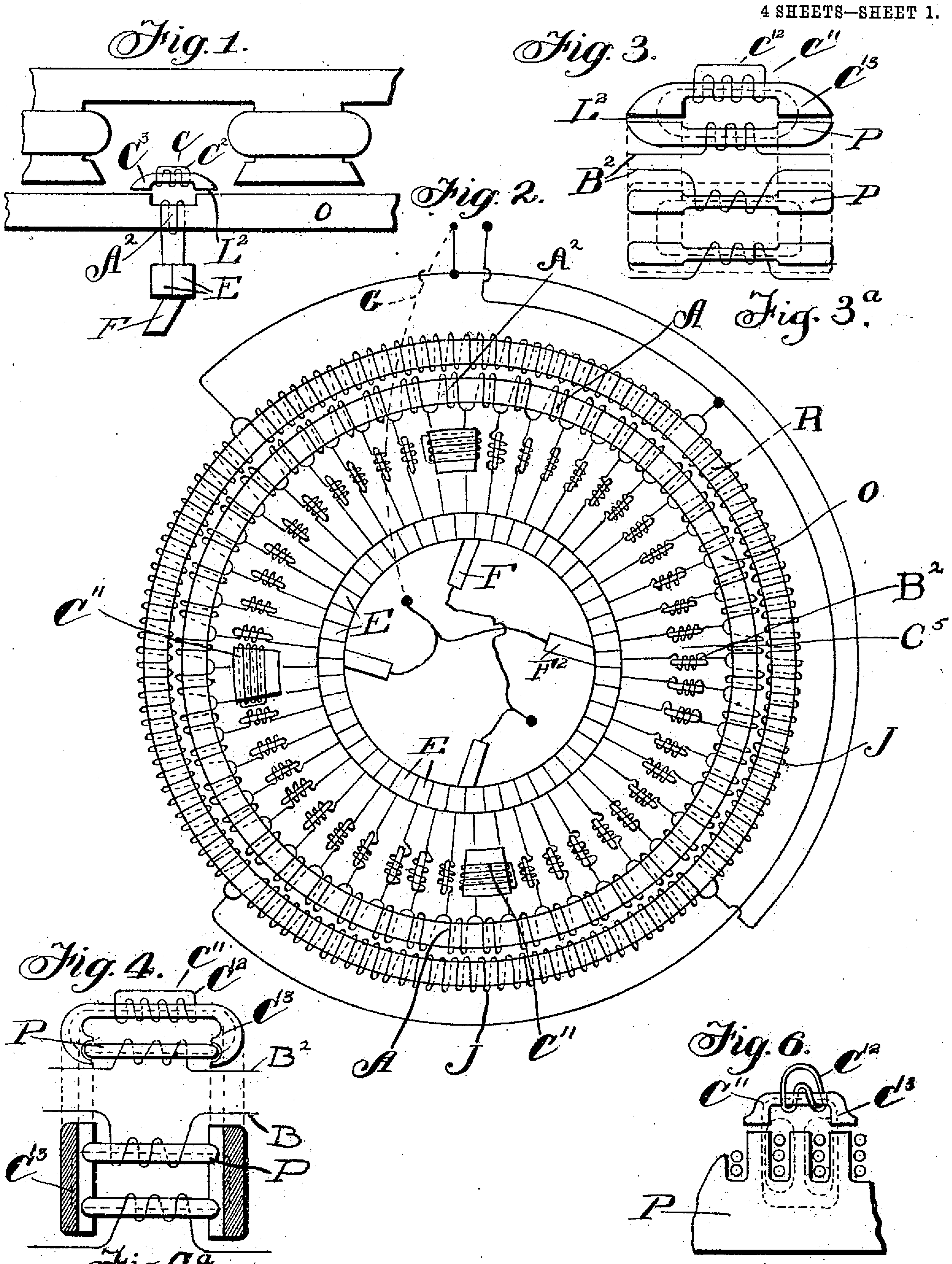

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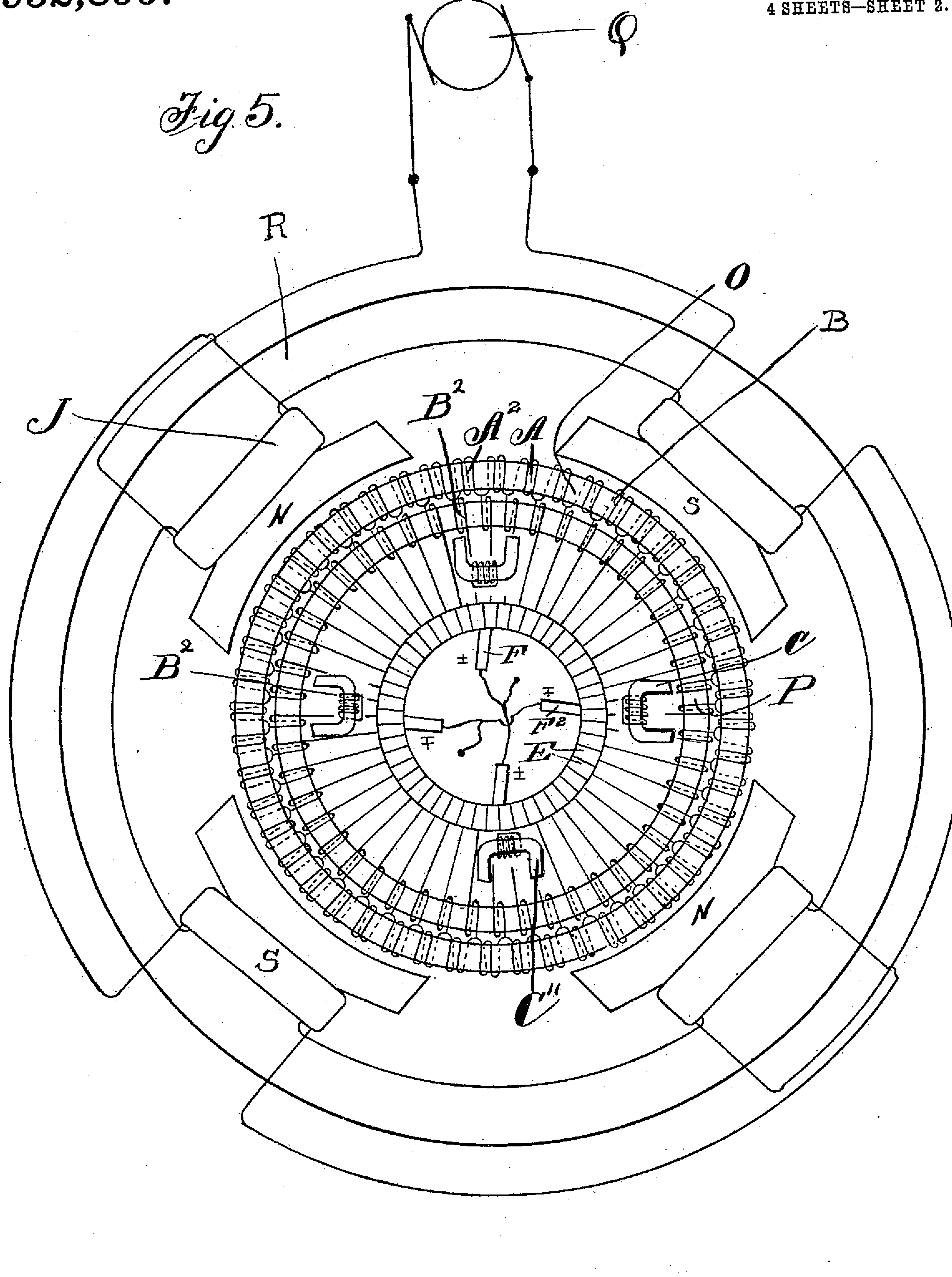
Fig. 5.



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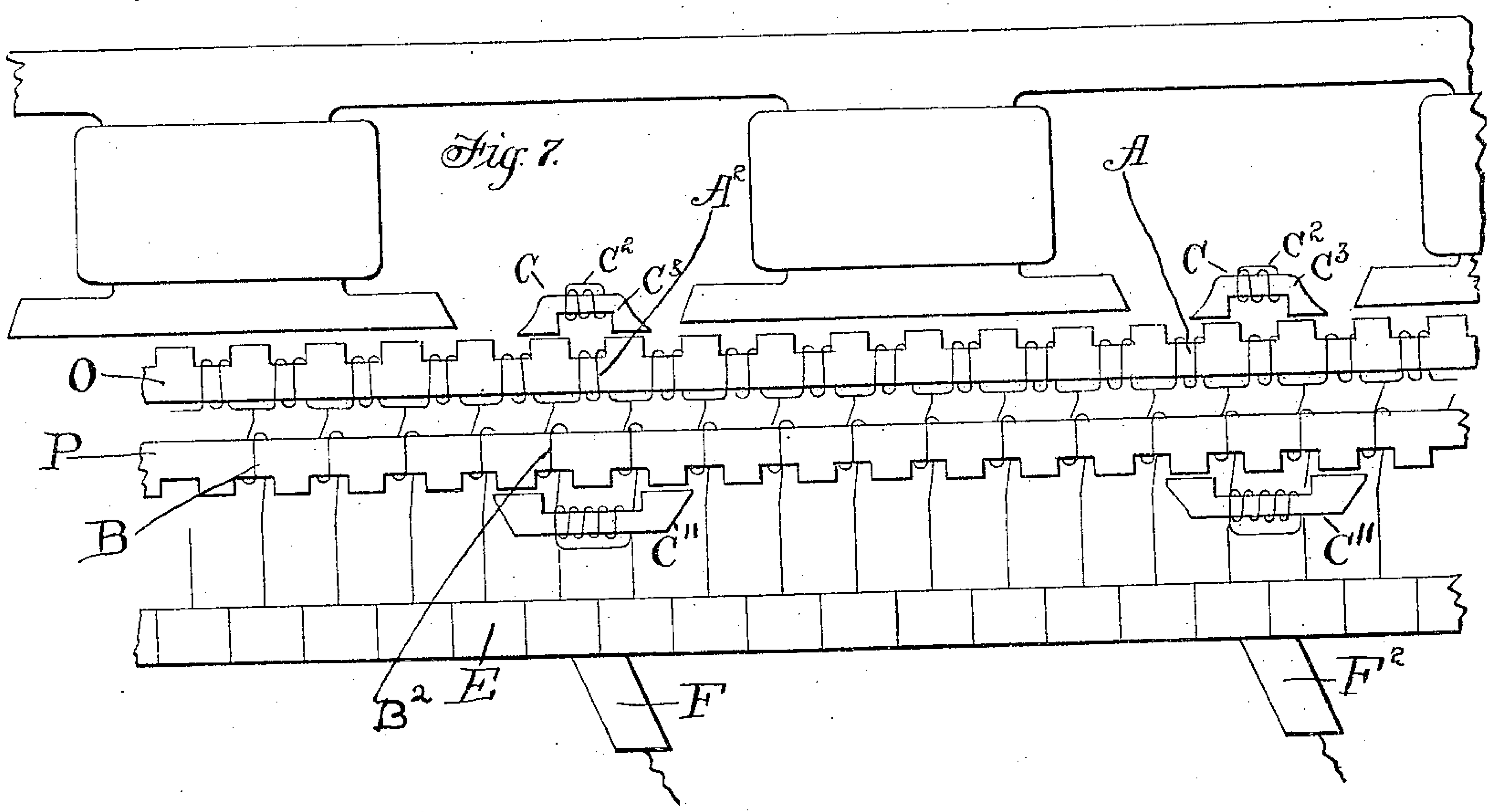


Fig. 8.

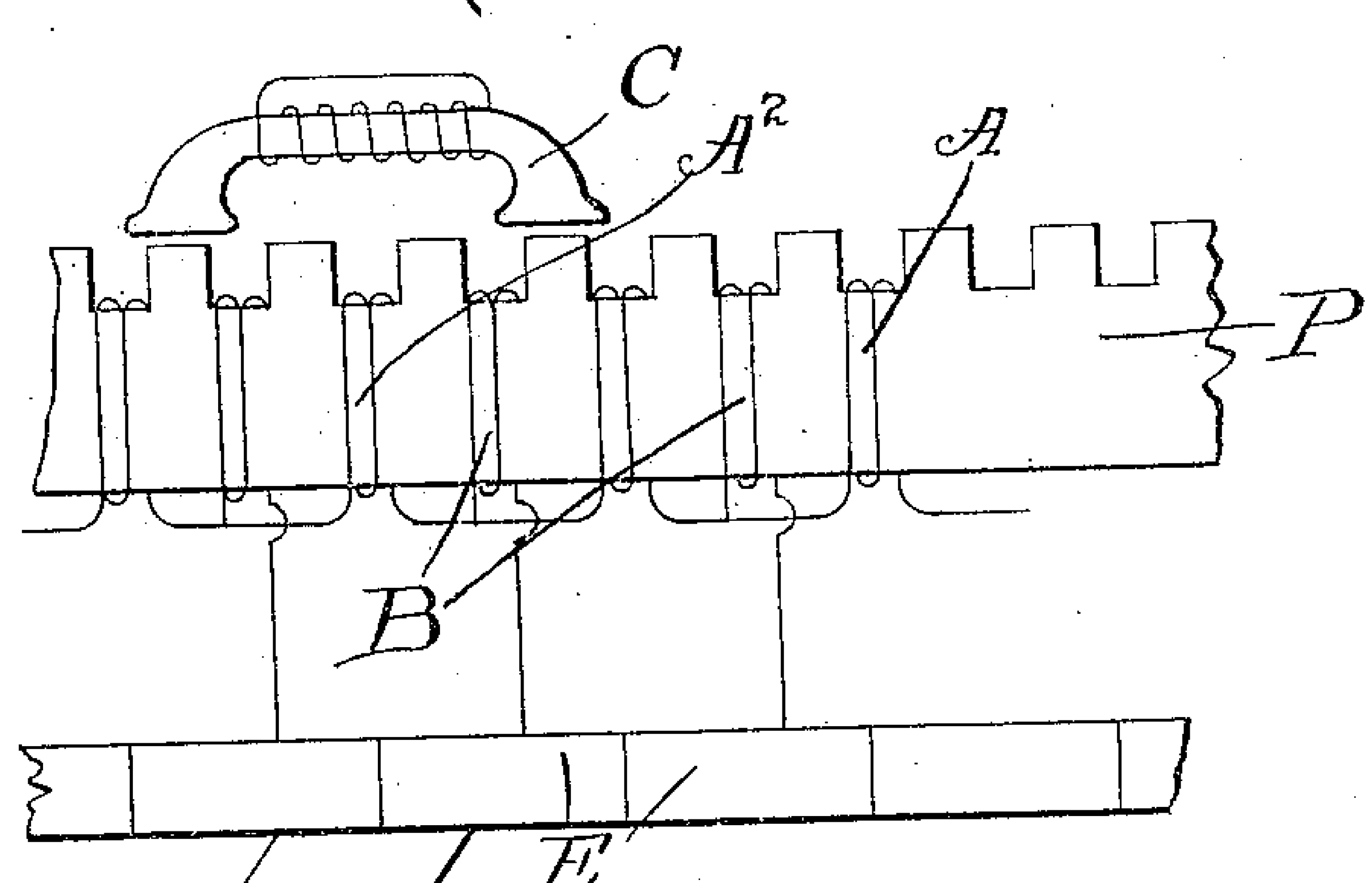
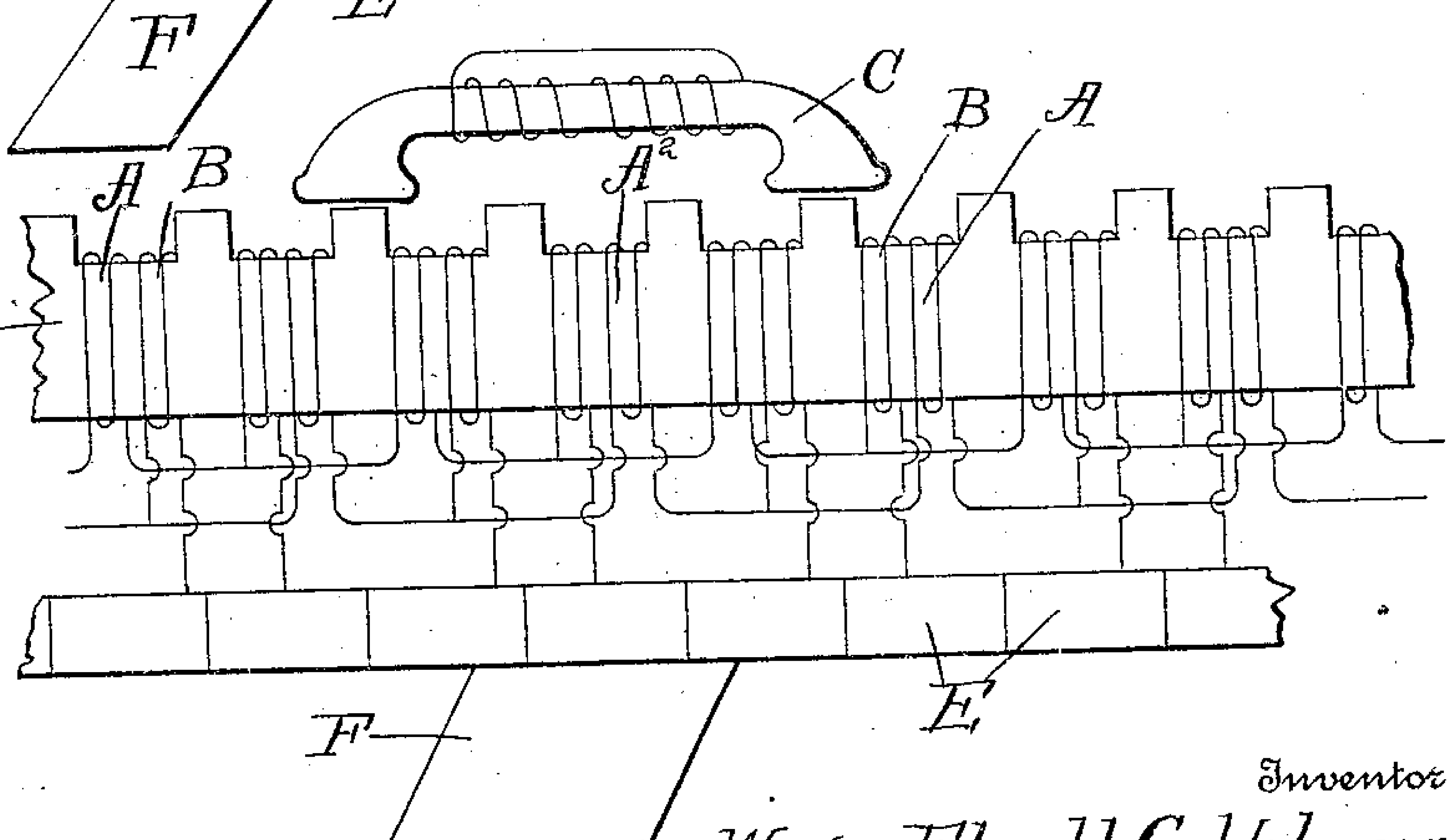


Fig. 9.



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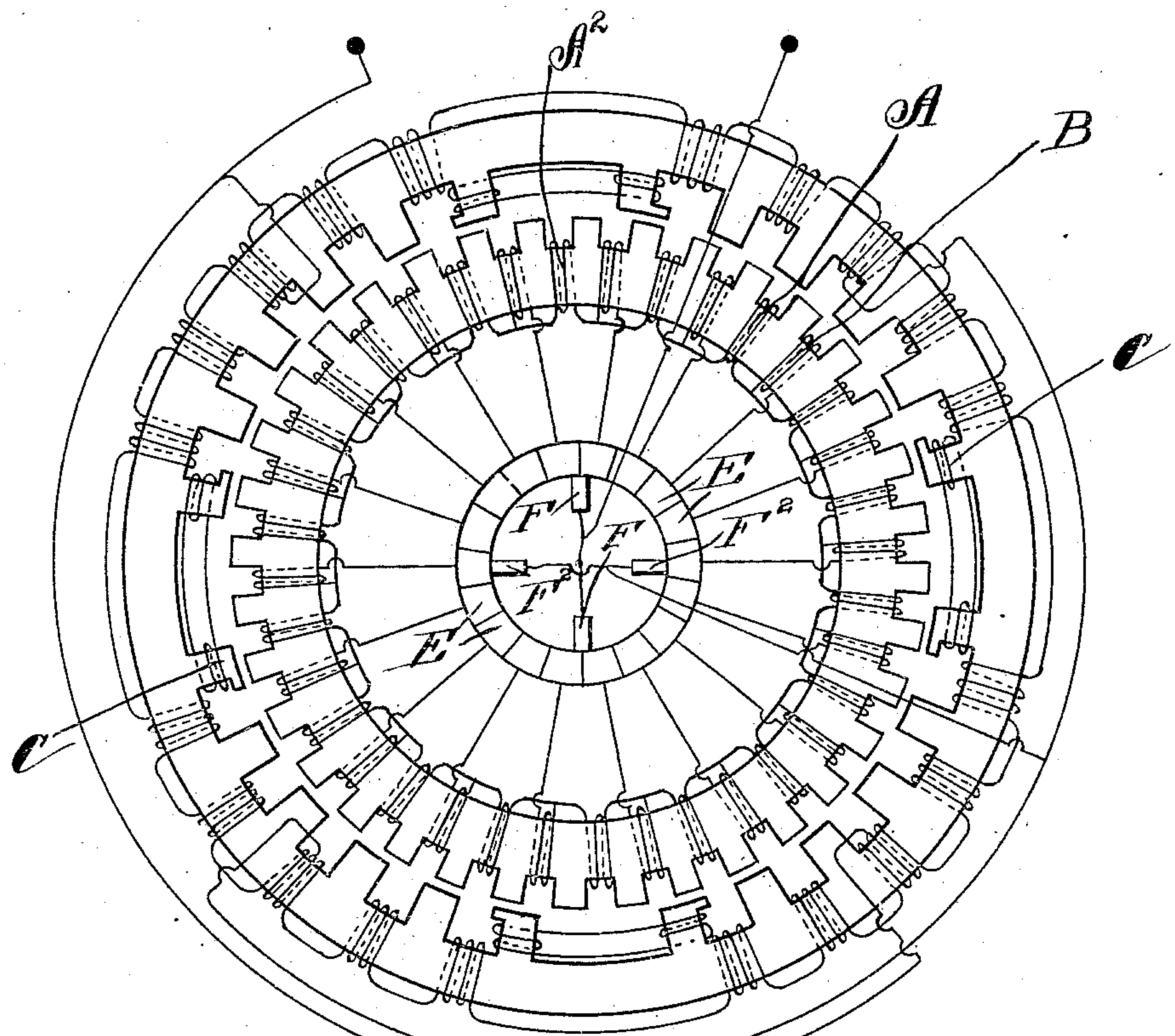
4 SHEETS—SHEET 4.

Fig. 10.



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UNITED STATES PATENT OFFICE.

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INDUCTANCE-NEUTRALIZING COIL-WOUND CORE AND COMMUTATING IMPEDANCE-COIL FOR ELECTRIC MACHINES.

952,899. Specification of Letters Patent. Patented Mar. 22, 1910.

Application filed December 22, 1902. Serial No. 136,171.

To all whom it may concern:

Be it known that I, Winder Elwell Goldsborough, a citizen of the United States, residing at La Fayette, in the county of Tippecanoe and State of Indiana, have invented certain new and useful Improvements in Inductance-Neutralizing Coil-Wound Cores and Commutating Impedance-Coils for Electric Machines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

The purpose of the invention is to facilitate the act of commutation.

The invention consists in a novel construction and combination of coil-wound cores with the armature of an electric machine whereby the impedance of the circuit formed through an armature coil during the time of commutation is increased without increasing the inductance of the circuits between brushes through the armature windings, and in reducing the inductance of the active portion of an armature coil while it is short-circuited during the period of commutation.

As a means of carrying out my invention I propose to provide short circuited elements in inductive relation to the armature coils and the commutation leads. In one form of my invention there is a single set of these short circuited elements in inductive relation to both the armature coils and the commutation leads. In another form of my invention there are two distinct sets of short circuited elements, one in inductive relation to the armature coils and the other in inductive relation to the commutation leads.

In the accompanying drawings forming a part of this specification, and in which like letters of reference indicate corresponding parts, I have illustrated several ways of carrying my invention into effect, it being understood that the forms of apparatus herein shown may be departed from and still be within the scope of my invention, and, in these drawings, Figure 1 is a view exhibiting diagrammatically a portion of an electric machine supplied with one of my inductance neutralizing coil-wound cores; Fig. 2 is a diagrammatic view of an electric machine having my commutating impedance coils inserted in the commutator leads of the armature coils, and having superposed over these commutating impedance coils at the points of commutation, my inductance neutralizing coil-wound cores; Fig. 3 is a view exhibiting diagrammatically in side elevation the arrangement of my commutating impedance coils with reference to my inductance neutralizing coil-wound cores placed over the said commutating impedance coils at the points of commutation; Fig 3^a is a view exhibiting diagrammatically in plan the arrangements shown in Fig. 3, the core of the inductance neutralizing coil-wound core being indicated in dotted lines. Fig. 4 shows diagrammatically another arrangement of commutating impedance coils with the superposed inductance neutralizing coil-wound cores; Fig. 4^a is a view exhibiting diagrammatically in horizontal section the same arrangements as are shown in Fig. 4. Fig. 5 shows a diagrammatic view of an electric commutating machine, in which all of the commutating impedance coils connected in the commutating leads of the armature coils are wound over a common core, and in which, at the points of commutation, my inductance neutralizing coil-wound cores are shown in inductive relation to the commutating impedance coils; Fig. 6 shows the method of adjustment of the inductance neutralizing coil-wound cores when the commutating impedance coils are given the shape of formed coils and wound on a slotted core. In this case, the design and arrangement of the commutating impedance coils follows the construction common in the building up of formed coil armature windings; Fig. 7 shows diagrammatically an electric commutating machine in which two inductance neutralizing coil-wound cores are used at each point of commutation, one of these inductance neutralizing coil-wound cores being placed over the armature in inductive relation to the armature coils between the pole tips in the plane of commutation, and the other inductance neutralizing electro-magnet being placed in inductive relation at the points of commutation to the commutating impedance coils shown connected in the commutator leads of the armature coils, and wound about a common core; Fig. 8 shows a diagrammatic view of an armature core, every other slot of which contains the conductors of the armature coils, while the intermediate slots contain the conductors of my commutating impedance coils, while above the teeth of the said armature core over the point of commutation is placed one of my inductance neutralizing coil-wound cores; Fig. 9 is a diagrammatic view of an armature that is provided with a double winding. By this arrangement, each slot contains the conductors of an armature coil as well as the conductors of one of my commutating impedance coils. Above the teeth of the armature core and over the point of commutation is shown one of my inductance neutralizing coil-wound cores; and Fig. 10 is a diagrammatic view of a combination of parts similar to those shown in Fig. 8, except that the inductance neutralizing coil-wound cores are made a part of the field ring of the electric machine, as shown.

Referring to the drawings and to Fig. 1 thereof, A^2 represents a coil undergoing commutation. The brush F short-circuits the coil A^2 since it bridges over the commutator bars E, which form the terminals of the said coil A^2. Over the coil A^2 is placed the core C^3 wound with a short-circuited coil C^2. The combination of the core C^3 and the coil C^2 constitutes one of my impedance neutralizing coil-wound cores C, and the core C^3 may, commercially, be so adjusted as to admit of the air-gap L^2 between the core C^3 and the armature core O to be made as large or as small as may be necessary. The presence of the short-circuited inductance neutralizing coil materially assists the act of commutation of the coil A^2 inasmuch as, in relation to the coil A^2 considered as the primary coil of a transformer, the coil C^2 plays the part of a short-circuited secondary coil of the same transformer and, accordingly, the inductive reaction of any variable current that may flow in the coil A^2 induces electric currents in the coil C^2 which react, and thereby reduce the effective inductance of the coil A^2. The inductance neutralizing coil-wound core C may include one, two, or more armature coils if a design requires it. In the matter that follows, armature coils are designated by the symbols A and A^2. A^2 is used to indicate only those armature coils that are undergoing commutation; while A is employed to designate the armature coils in general. In like manner the commutating impedance coils bear the reference letters B and B^2, B being applied to any one of these coils, and B^2 referring only to those coils that are within the influence of the inductance neutralizing coils, or that are connected in the commutator leads of an armature coil undergoing commutation.

Referring to Fig. 2, the outer core R, which is supplied with four windings J, constitutes the field-magnet system of the motor; the inner core O carries the armature coils, in the commutator leads of which are inserted the commutating impedance coils B. C^{11} designates and shows the position of my inductance neutralizing coil-wound cores in a lagging position, relatively to the direction of rotation of the armature, as the neutral plane lies midway between the terminals of the coils on the field ring. The dotted connection G between one field terminal and one armature terminal indicates a series connection between the armature and field circuits in the machines shown in this figure.

Figs. 3, 3^a, and 4, 4^a show two arrangements of my commutating impedance coils with reference to my inductance neutralizing coil-wound cores. C^{13} represents the core of the inductance neutralizing coil-wound core and C^{12} the short-circuited winding which surrounds it. L^2 is the clearance or air-gap space between the core C^{13} of the inductance neutralizing coil-wound core and the core P of the commutating impedance coils. B^2 is a coil which surrounds one of the cores P and one of these is connected in series with the commutator lead of each connection between the armature coils and the commutator-bars, as indicated by B in Fig. 2.

Referring to Figs. 3, 3^a, 4 and 4^a, it will be evident that the relative arrangement of the commutating impedance coils B^2 therein shown to the inductance neutralizing coil-wound cores C^{11}, the commutator bars E and the brushes F and F^2 therein shown, is such that currents delivered from or received by the armature coils from the brushes so react magnetically upon the core C^{13} of the inductance neutralizing coil-wound cores C^{11} as to induce currents in the coil C^{12} of the said inductance neutralizing coil-wound cores C^{11}: which currents, thus induced in the coils C^{12}, so react upon the commutating impedance coils B^2 as to neutralize in great measure the inductance of the said commutating impedance coils, thereby giving the commutator leads but a slight impedance to the passage of the armature currents. The inductance neutralizing coil-wound core which has position at C^5 is removed to show the commutating impedance coils. On the other hand, the relative position assumed by the commutating impedance coils B, relative to the inductance neutralizing coil-wound cores C^{11} during the period of commutation, is such that the currents which circulate in the armature coil, during the time when it is short-circuited by the brush F, react magnetically in such manner, during their passage through the commutating impedance coils located in the commutator leads of the said armature coil undergoing commutation, as to add the inductance of the two commutating impedance coils, and place these inductances in series relation to the inductance of the coil undergoing commutation. By the arrangement shown, therefore, the inductance neutralizing coil-wound cores C^{11} are not effective in diminishing the inductance of the commutating impedance coils in the leads of the armature coil undergoing commutation as related to the currents which permeate the short-circuited armature coil.

The arrangement of parts shown in Figs. 2, 3 and 4 makes it evident that, by my invention, commutation of a coil is facilitated by the automatic introduction into the leads of the armature coils which are undergoing commutation, of an inductance so great as to prevent the development of currents of any considerable volume in the said coils undergoing commutation.

The reasons why the neutralizing coil-wound core C^{11} neutralizes the inductance of the main armature circuit, and not of the short circuited armature coil, will be made clear by the following explanation. The currents that flow from the armature coils to the commutator to be delivered to the brushes and returned to the generating circuit develop magnetic fields in the cores P, which oppose one another, thereby causing the flux set up by said current to complete its path through the coil C^{12} of the core C^{13}. On the other hand, the currents that circulate in an armature coil, when it is short circuited by a brush bridging its adjacent commutator bar terminals, so magnetizes the cores P as to produce magnetic poles in them that attract one another, and the flux from these poles finds a return path through the ends of the core C^{13} without the necessity of passing through the coil C^{12}. In other words, the current collected by the brushes flows in the same direction through the coils B, while the currents that circulate in a short circuited armature coil pass through adjacent sets of the coils B in opposite directions. In the first case, therefore, currents are induced in the coil C^{12}, whereas, in the second case, no currents are induced in the coil C^{12}. In the first case, the coil C^{12} exerts a neutralizing effect upon the inductance of the coils B^2, while in the second case, it does not have this effect. The short-circuited coils C^{11} perform their function in neutralizing the impedance of the impedance coils when the said impedance coils are permeated by commutated currents, on account of the fact that the induction set up in the cores of the impedance coils by commutated currents permeates through from pole to pole of the cores of the coils C^{11}, and, thereby, in passing through these coils, develops reactive currents in them which neutralize the inductance of the impedance coils. When commutating currents are flowing through the impedance coils, the flux set up in the cores of the impedance coils by the commutating currents passes up into the pole pieces of the cores C^{13}; but this flux does not pass through the cores, and, consequently, no reactive currents are set up in the short-circuited coils C^{11}. The flux developed in the cores of the impedance coils by the commutating currents, accordingly, simply passes up into the pole pieces or ends of the cores C^{13}, from the pole of the core of one impedance coil to the pole of the core of the next impedance coil; thereby the return path of the flux set up by the commutating currents is greatly facilitated, and, therefore, the inductance of the impedance coils to commutating currents is actually increased above its normal value.

As shown, the inductance neutralizing coil-wound cores embrace but two of the commutating impedance coils. They may, however, embrace a greater number of these coils with equal effectiveness. The inductance neutralizing coil-wound cores may be in advance of or lagging behind the neutral plane, if conditions so require, instead of being in direct line with the neutral plane.

In Fig. 5, R indicates the core of the primary element, J the field coils of said element, and N and S the pole pieces. O indicates the armature of the secondary element, P the impedance coil core of said secondary element, E the commutator, and F, F^2 the brushes resting on said commutator. C^{11} indicates one of four inductance neutralizing coil-wound cores, which are placed over the impedance coils B^2 at the points of commutation and act to neutralize the inductance of the impedance coils B, placed between the armature coils A and the commutator bars E, to the passage of commutated currents, without affecting the impedance of said coils B with reference to the currents induced in the coils A during the time the terminals of the said commutator coils are short-circuited by the brushes F, F^2. The inductance neutralizing coil-wound cores are represented as being positioned slightly in advance of mid-position between the pole tips, but said electro-magnets may be given an advance or lag, or be placed immediately in line with the central points between the pole tips, and thereby made more effective in assisting commutation, as the case may require.

In Fig. 6, P indicates the core over which the impedance coils are wound, C^{13} the core of the inductance neutralizing coil-wound core, and C^{12} the short-circuited winding thereon. In this construction, formed coils placed in longitudinal slots are employed in positioning the impedance coils in the commutator leads.

In Figs. 5 and 6, the arrangement of the commutating impedance coils and the inductance neutralizing coil-wound cores in such as to produce the same results with the same efficiency and effect that are produced by the combination and arrangement which has been shown and discussed in Figs. 2, 3, 3ª, 4, and 4ª. Q designates any suitable source of power.

In Fig. 7, a combination of parts with the armature of a commutating electric machine is shown, in which the combined effect of the parts that have been described in detail, more particularly in connection with Figs. 1 and 2, is made use of to facilitate and promote the act of commutation. The commutating impedance coils B are wound over the slotted core P, and connected in between the junction points of the armature coils A (which are wound over the armature core O) and the commutator bars E. The industance neutralizing coils C are so placed and adjusted as to neutralize the inductance of the armature coils A during commutation, while the inductance neutralizing coils C^{11} are so placed as to neutralize the inductance of the commutating impedance coils B to the passage of the currents to or from the armature coils A and the brushes F. On the other hand, the inductance neutralizing coils C^{11} have no effect whatever in diminishing the impedance of the commutating impedance coils B in their function of reactance coils connected in series with the local circuit through the commutating coils A^2, the brushes F and the other elements linked therewith, as diagrammatically shown.

By the arrangement of parts shown in Fig. 7, the counter electromotive force which would ordinarily be developed in the coil A^2 by the current variations taking place in it during the period of commutation is, in the present case, largely wiped out by the presence of the inductance neutralizing coil C in intimate relation with the said coil A^2, and the effectiveness of such portion of the said counter electromotive force of self-induction that still remains, in setting up a rush of current around through itself, the commutator bars E and the brush F, is greatly diminished by the automatic introduction of the commutating impedance coils B^2 in the circuit through which the coil A^2 is short-circuited by the brushes F.

In Figs 8 and 9, the arrangement of parts and the combinations there presented provide for the carrying out of the functions which have been accredited to the commutating impedance coils and the inductance neutralizing coil-wound cores of Fig. 7 without the necessity of providing an additional core, over which to wind the commutating impedance coils, or of bringing into play more than one inductance neutralizing coil-wound core at each point of commutation. As in the construction shown in Fig. 7, the commutating impedance coils B are wound over the slotted core P and connect the junction points of the armature coils to the commutator segments. Core P also carries the armature coils A, so that only one neutralizing magnet C is required in acting upon the inductance of the armature coils and impedance commutating coils at each of the junction points. In Fig. 8, the two sets of coils alternate in the slots of core P, an armature coil occupying one slot and an impedance commutating coil the next. The winding in Fig. 9 combines, therefore, two windings of the type shown in Fig. 8, superposed upon one another in such manner as to bring the conductors of an armature coil of one winding in the same slot with the conductors of a commutating impedance coil of the other winding, the said commutating impedance coils connecting in each case the junction points of the armature coils of their respective windings to commutator bars in such manner that every other commutator-bar is connected in with the same set of armature and impedance coils. Accordingly, the brushes must be sufficiently wide to touch upon at least three commutator bars. Figs. 8 and 9 are inserted chiefly to show the ease with which the system of inductance neutralizing coil-wound cores and commutating impedance coils herein described can be adjusted to and made an effective part of various and complex types of dynamo and motor windings.

As diagrammatically shown in Fig. 9, the commutating impedance coils B so act magnetically when they are permeated with currents flowing either to or from the armature coils A and the brushes F as to set up reactive currents in the short-circuited coil of the inductance neutralizing coil-wound core C, which reactive currents set up in the coil C have the effect of neutralizing the inductance of the coils B to the passage of current to or from the armature coils A and the brush F. When, on the other hand, we consider the currents which permeate the coil A^2 during the time when its terminal bars E are bridged by the brush F, we find that the coil A^2 is brought into such inductive relation to the inductance neutralizing coil C as to induce in the said coil C currents which react magnetically to neutralize the inductance of the coil A^2. Again, the presence of the coil C has no effect upon the inductance of the coils B, considered as acting in series with the coil A^2 during the time of its commutation, all for and on account of reasons that have been made plain in the foregoing discussion. The number of coils embraced by the inductance neutralizing coil-wound core C varies under different conditions.

It must be apparent that, in the figures herewith presented from 1 to 9, only a small number of the possible applications of my invention have been shown. Where desirable, the inductance neutralizing electromagnets or coils may be wound on extension of the pole tips, or may be made to bridge the interval between pole tips, or may be incorporated with and made to form part of the field ring when the said ring is given the form common to induction motors. The latter construction is diagrammatically shown in Fig. 10, which forms a part of this specification. It will further be seen that my invention applies to various types of electric machines, among others of which may be mentioned direct current generators and motors of all types, and commutating alternating current motors. In the employment of the expression "commutating machine" with reference to my invention, it is to be understood, therefore, that this term is intended to include all types of commutating machines, such as direct-current generators, direct current motors, alternating current commutating-motors, and other electro-magnetic devices in which it is desirable to arbitrarily change the direction of flow of a current induced in a coil thereof, when such coil bears a certain pre-determined relation to the other and related electro-magnetic parts of said devices.

My invention may be arranged in combination with all types of magnetic circuits, whether they be of the internal multi-polar type common in direct current machinery, or the continuous field ring multi-polar type common in alternating current induction motors.

Although not specified in the drawings herewith submitted, it is to be understood that the armatures may be placed in series or parallel or other common form of connection with their field circuits and with the source of supply of electric energy, whether it be a direct current or alternating current source.

As explanatory of the terms "commutated currents" and "commutating currents," which will be encountered in the following claims, it may be observed that the former are those currents that flow to or from a source of electricity and sets of the armature coils not undergoing commutation, while the latter are those currents that circulate locally in an armature coil during the period of the commutation of said coil.

Having thus fully described my invention, what I claim as new and desire to secure by Letters-Patent of the United States, is:

1. In an electric machine, the combination with the field coils and armature coils, of a commutator, independent iron cores disposed within the influence of the armature and having short-circuited windings arranged in inductive relation to the armature coils so as to reduce the inductance thereof at commutation, without being in inductive relation to the field coils.

2. In an electric commutating machine, the combination with a commutator, of induction coils connected in series with the commutator leads of the armature coils, and short-circuited core-wound coils adapted to be placed in inductive relation to said induction coils.

3. In an armature, the combination with a commutator, of commutator leads having self-induction, and independent short-circuited core-wound coils adapted to increase or diminish the self-induction of the said commutator leads, as set forth.

4. In an electric commutating machine, the combination with a commutator, of induction coils connected in series with the commutator leads of the coils of the armature of said commutating machine, independent short-circuited elements adapted to be placed in inductive relation to the said induction coils in series with the commutator leads, as set forth.

5. The combination with a commutator, of impedance coils connected in the commutator leads of a commutating machine, and of iron cores having short-circuited windings, the said short-circuited windings being adapted to be brought into inductive relation to said impedance coils, when said impedance coils are carrying electric currents, as set forth.

6. The combination with a source of electric currents, and a circuit from the same, of a commutating machine, a commutator, and commutator leads having self-induction, and of short-circuited elements, said short-circuited elements being adapted to be brought into inductive relation to such of said commutator leads as complete said circuit through said commutating machine, as set forth.

7. The combination of a commutating machine, a commutator, and impedance coils connected in commutator leads of said commutating machine and cores having short-circuited windings, said cores and windings being adapted to be brought into inductive relation to said impedance coils when they form part of the working circuits through said commutating machine, as set forth.

8. In a commutating machine, the combination with a commutator, of armature coils, and of commutator leads having self-induction, and of independent short-circuited coils adapted to be brought into such relation with the commutator leads as to diminish the self-induction of said leads to commutated currents, while not diminishing the self-induction of said leads to commutating-currents, as set forth.

9. The combination of an electric circuit, and of a commutating machine, a commutator, and of impedance coils connected in series with the commutator leads of the armature coils of said machine, and of means for making the inductance of said impedance coils ineffective in obstructing the flow of current from or to the said electric circuit and said armature coils when they are not

commutated without reducing the effectiveness of said inductance in cutting down the currents induced in the armature coils when they are commutated.

10. In an electric machine, the combination with a commutator, of armature coils, and commutation leads having self-induction, and of means comprising independent short-circuited elements for changing the self-induction of the armature coils and the commutation leads, as set forth.

11. In a commutating machine, the combination with a commutator, of armature coils and commutator leads having self-induction, and of independent magnetic elements with short-circuited coils arranged in inductive relation to the armature coils, and of other independent magnetic elements with short-circuited coils, arranged in inductive relation to the commutator leads, whereby the self-induction of the said armature coils and commutator leads is changed, as set forth.

12. In an electric machine, the combination with a commutator, of armature coils and commutation leads having self-induction, and of short-circuited elements within the influence of said armature coils, and of other short-circuited elements within the influence of said commutation leads, as set forth.

13. The combination in an electric machine with a commutator, of armature coils and of impedance coils connected in the commutation leads of said armature coils, and of induction coils having short-circuited windings adapted to neutralize the self-induction of the armature coils, and of other induction coils having short-circuited windings adapted to change the self-induction of the impedance coils, during the time of the commutation of said armature coils, as set forth.

14. In a commutating machine, the combination with a commutator, of armature coils and of leads having self-induction connecting said armature coils to commutator segments, and of iron cores wound with short-circuited coils placed in inductive relation to the armature coils, and of other iron cores wound with short-circuited coils placed in inductive relation to the leads, all adapted to diminish the volume of the currents induced in the armature coils during the period of commutation, as set forth.

15. In a commutating machine, the combination with a commutator, of armature coils and of commutator leads having self-induction, and of cores having short-circuited windings and placed in inductive relation to the armature coils, and of cores having short-circuited windings and placed in inductive relation to the commutator leads, and all adapted to reduce the inductance of the armature coils, while increasing the impedance of the closed circuits through the armature coils, during their commutation: and all adapted to reduce the impedance of the armature circuits between the brushes, as set forth.

16. The combination of an electric circuit, and of a commutating machine, a commutator, and of armature coils and of impedance coils connected in series with the commutator leads of the armature coils of said machine, and of means for making the inductance of said armature coils of less effect in inducing currents in said armature coils when they are commutated, and of means for making the inductance of said impedance coils effective in cutting down the currents induced in said armature coils when they are commutated, and for making the inductance of said impedance coils ineffective in obstructing the flow of current between the said electric circuit and said armature coils when they are not commutated, as set forth.

17. In a commutating machine, the combination with a commutator, of armature coils and commutator leads having self-induction, and of means within the influence of the armature coils and the commutation leads for inductively affecting said armature coils and commutation leads and consisting of short-circuited induction coils, as set forth.

18. The combination in a commutating machine, with a commutator, of armature coils, and impedance coils connected in the commutator leads of the armature coils, and of means consisting of short-circuited elements for effectively reacting upon the armature coils and the impedance coils during the time of commutation of said armature coils, as set forth.

19. In a commutating machine, the combination with a commutator, of commutator segments, armature coils, leads having self-induction connecting said armature coils to said commutator segments, and iron cores wound with short-circuited coils adapted to diminish the volume of the currents induced in the armature coils during the period of their individual commutation, as set forth.

20. In a commutating machine, the combination with a commutator, of armature coils and commutator leads having self-induction, and of means comprising cores having short-circuited windings for neutralizing the inductance of the armature coils while increasing the impedance of their individual circuits during commutation and for reducing the effective impedance of the armature circuits between brushes, as set forth.

21. The combination of an electric circuit and of a commutating machine, a commutator, and of armature coils and commutator leads having self-induction, and of means

for making the self-induction of the armature coils less effective in inducing currents, and of means for making the self-induction of said commutator leads effective in cutting down the currents induced in said armature coils, when they are commutated, and for making the self-induction of said commutator leads ineffective in obstructing the flow of current between the said electric circuit and said armature coils when they are not commutated, as set forth.

22. In an electric motor, the combination with a magnetic field ring, of a commutator, an armature having longitudinally extending slots containing the armature coils, of connected polar projections overlying said longitudinally extending slots and arranged between the unlike poles of the normal magnetic circuit, said connected polar projections being provided with a short-circuited winding adapted to neutralize the effects of armature reaction.

23. In an electric machine, the combination with the field circuit, a commutator, of an armature circuit and of armature coils and of means for making the self-induction of any armature coil ineffective in inducing in its circuit electric currents when the said coil is short-circuited during the period of its commutation and of means for increasing the inductive resistance of the circuit through the said armature coil when the same is undergoing commutation without increasing the inductive resistance of the circuit through the armature, as set forth.

24. In an electric machine, the combination with a commutator, of an armature and armature coils, of impedance elements arranged in commutation leads from the armature coils and of short-circuited elements arranged in inductive relation to said impedance elements, as set forth.

25. In an electric machine, the combination with a commutator, of an armature and armature coils, of inductance elements arranged in leads from the armature coils, and of inductance neutralizing elements distinct from the leads arranged in inductive relation to said inductance elements, as set forth.

26. The combination with a source of electric currents and a circuit from the same, of an electric machine having a commutator, armature coils arranged in a closed winding, tapped circuits having self-induction brought out from said closed winding at equidistant points, and short-circuited elements arranged in inductive relation to the self-inductive portions of such of said tapped circuits as complete the active working circuits through said closed winding, as set forth.

27. In an electric machine, the combination with a commutator, of armature coils and commutation leads having reactance elements, and of short-circuited elements within the influence of said armature coils, and of reactance neutralizing elements within the influence of said reactance elements, as set forth.

28. In an electric machine, the combination with a commutator, of armature and armature coils, of impedance coils arranged in the leads from the armature coils and of short-circuited elements arranged in inductive relation to said armature coils, and of other short-circuited elements arranged in inductive relation to said impedance coils, as set forth.

29. In an electric machine, the combination with a commutator, of armature and armature coils, of impedance coils, of means arranged in inductive relation to said armature coils, and means arranged in inductive relation to said impedance coils for inductively affecting the said armature coils and impedance coils and consisting of short-circuited elements.

30. In a commutating machine, the combination with a commutator, of armature coils, and commutator leads having self-induction, of means within the influence of the armature coils, and means within the influence of the commutator leads for inductively affecting said armature coils and commutator leads, and consisting of short-circuited elements.

31. In an armature, the combination with a commutator, of commutator leads having reactance, and of independent short-circuited elements adapted to neutralize or augment the reactance of said commutator leads, as set forth.

32. In an armature, the combination with a commutator, of commutator leads having self-induction and of short-circuited means adapted automatically to increase or diminish the self-induction of said commutation leads, as set forth.

33. In an armature, the combination with a commutator, of armature coils and of leads from the same containing reactance, and of short-circuited means adapted to automatically neutralize or augment the reactance of said leads, as set forth.

34. The combination in an electric commutating machine, of a commutator, of an armature and of armature coils, and of reactance elements connected in the commutator leads of said armature coils, and of short-circuited means whereby the inherent inductance of said elements is increased for the purpose of reducing sparking during the time when the armature coils are successively undergoing individual commutation, as set forth.

35. In a commutating machine, the combination with a commutator, of armature coils, and of commutator leads having self-induction, and of independent short-circuited elements adapted to neutralize the

self-induction of said leads to commutated currents while increasing the self-induction of said leads to commutating currents, as set forth.

36. In an electric machine, the combination with a commutator, of armature coils, and of commutation leads having reactance, and of means adapted to neutralize the reactance of said leads to commutated currents, while increasing the reactance of said leads to commutating currents, as set forth.

37. In a commutating machine, the combination with a commutator, of armature coils, and of leads having reactance connecting said armature coils to commutator segments; and of short-circuited means whereby the inherent reactance of said leads is increased for the purpose of diminishing the volume of currents induced in the armature coils during the period of their individual commutation, as set forth.

38. The combination in an electric machine, with a commutator, of armature coils, and impedance coils connected in the commutation leads of the armature coils, and of means whereby the self-induction of the armature coils and impedance coils is neutralized to current passing in the circuit between brushes during the time of the commutation of said armature coils, as set forth.

39. In an electric machine, the combination with a commutator, of armature coils and commutation leads having self-induction, and of means for neutralizing the inductance of the armature coils while increasing the impedance of their individual circuits during commutation, and for reducing the effective impedance of the armature circuits between brushes, as set forth.

In testimony whereof, I affix my signature, in the presence of two subscribing witnesses.

WINDER ELWELL GOLDSBOROUGH.

Witnesses:

CHARLOTTE CUMBERSON,

W. D. HESTON.