No. 689,566. Patented Dec. 24, 1901.

R. ROUGÉ & G. FAGET.

APPARATUS FOR TRANSFORMING SINGLE AND MULTIPHASE ALTERNATING CURRENTS INTO CONTINUOUS CURRENTS AND INVERSELY.

(Application filed Apr. 6, 1900.)

(No Model.) 5 Sheets—Sheet I.

Fig. 1

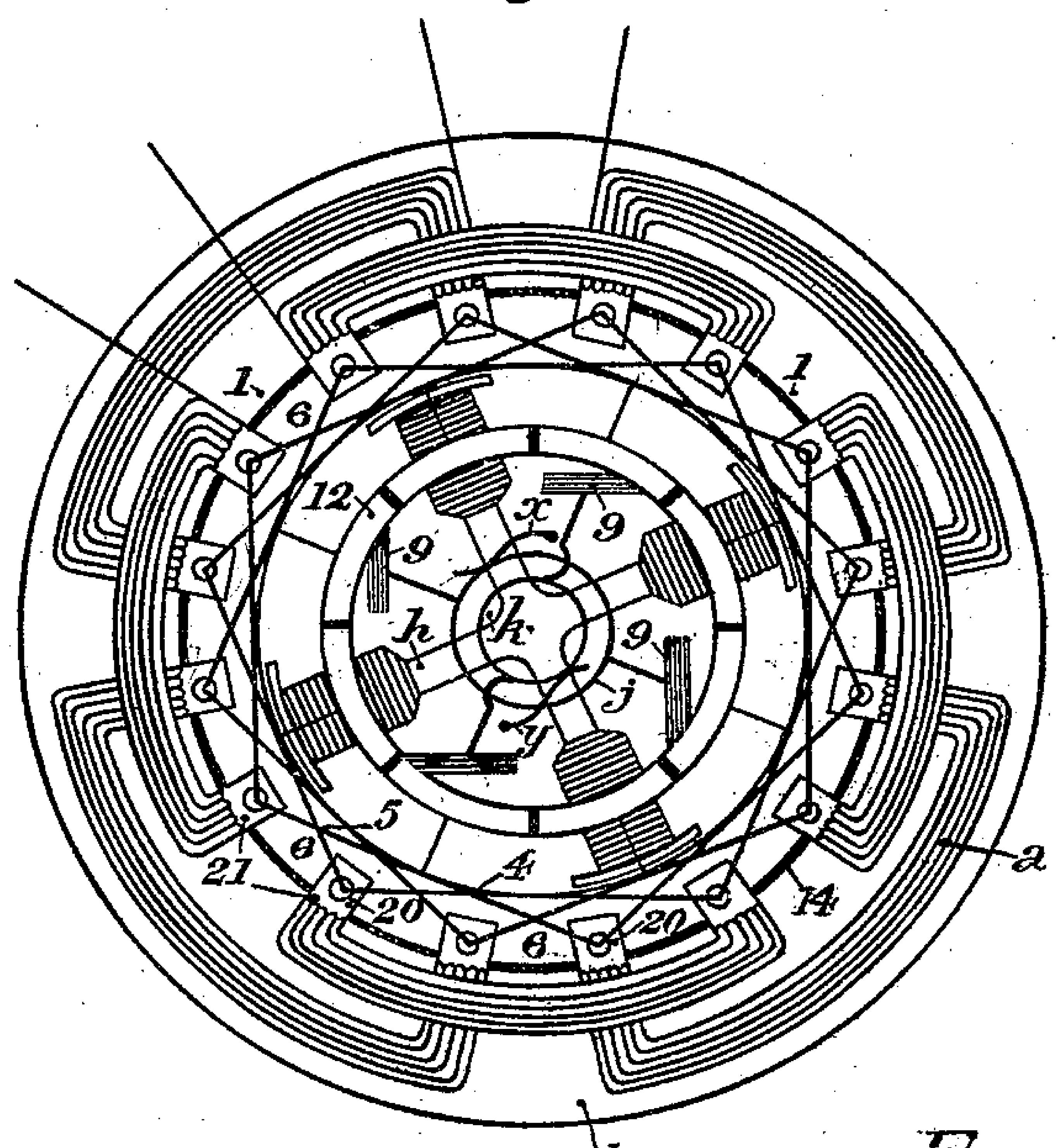

Fig. 2

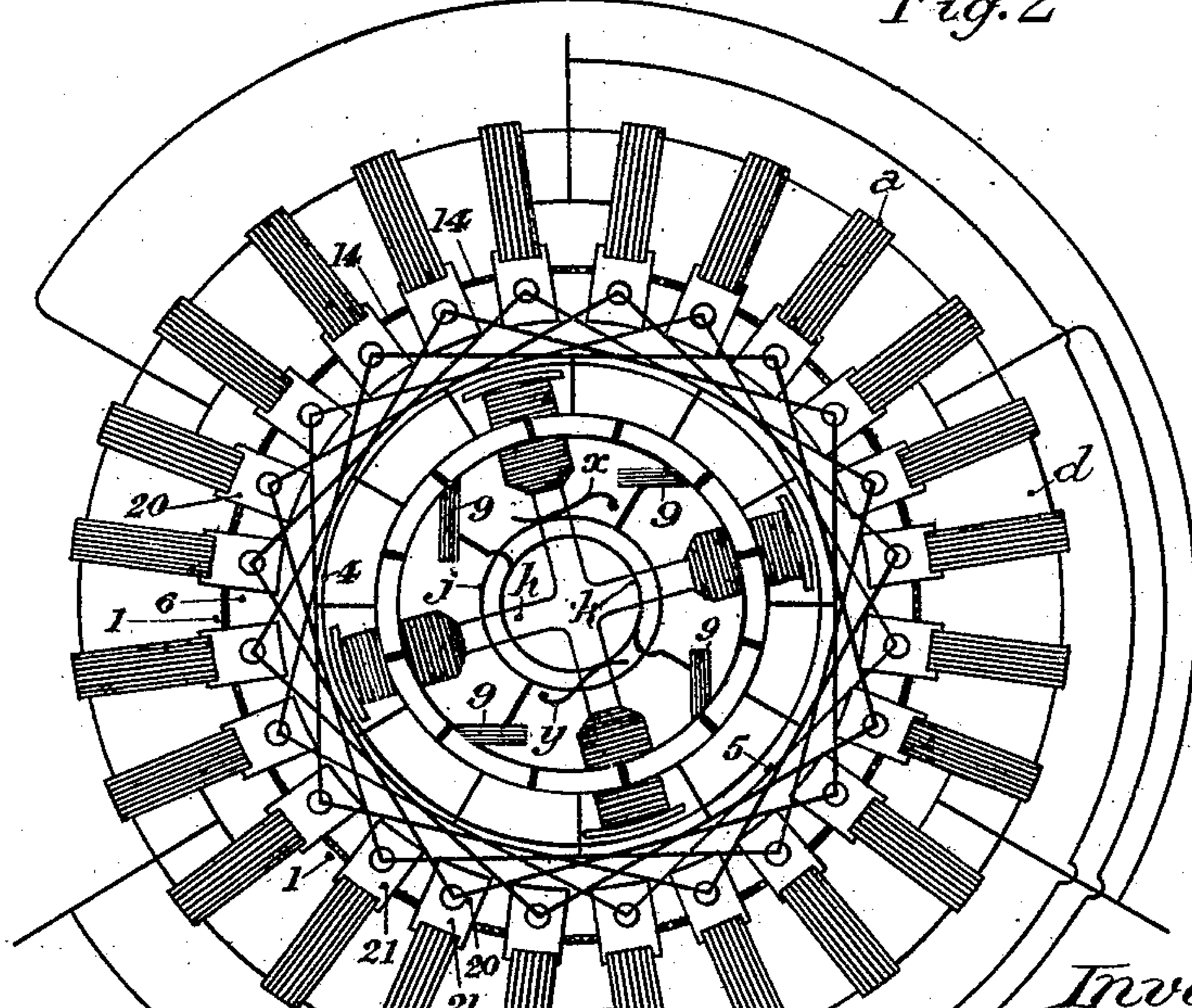

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Fig. 3

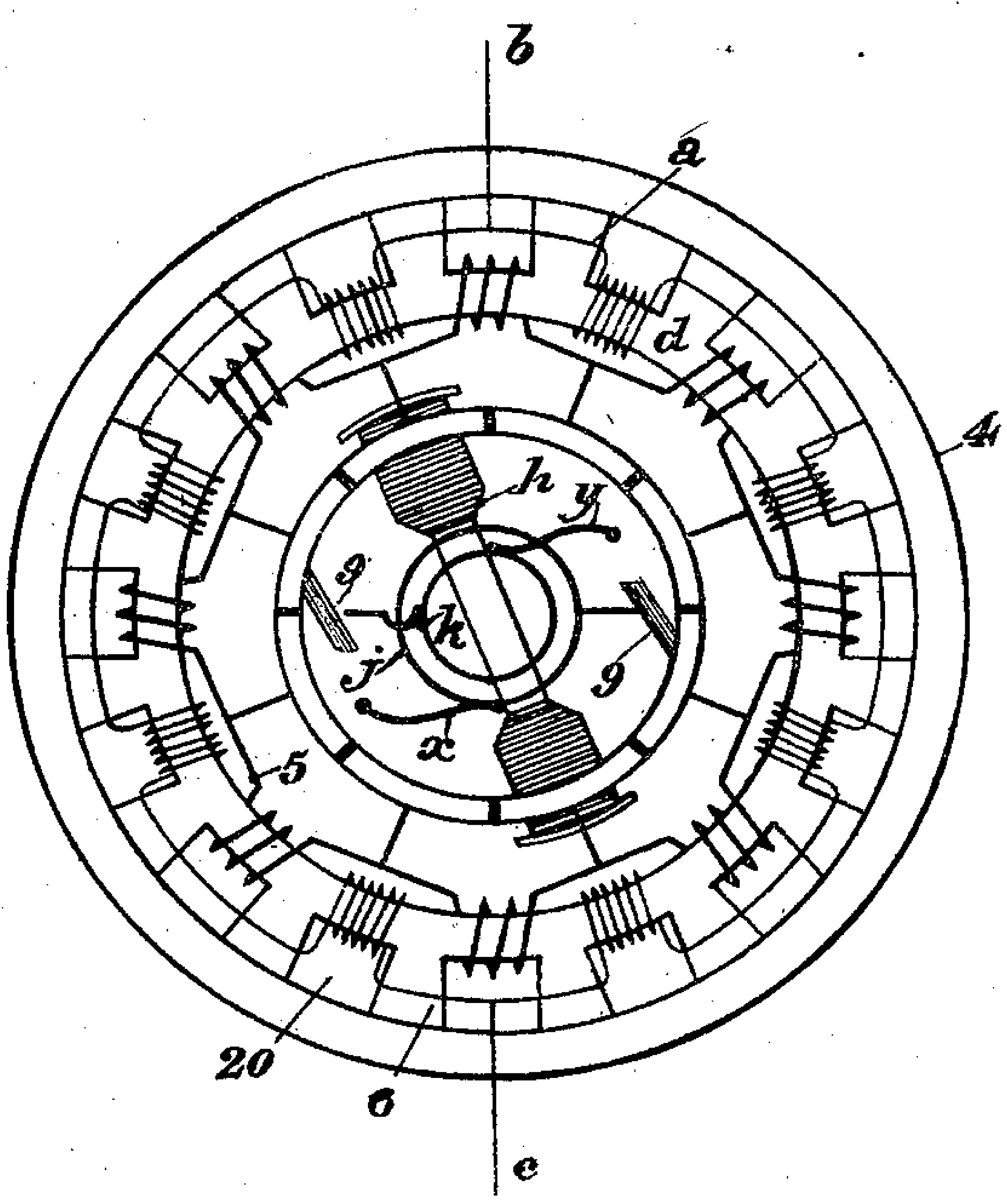

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Fig. 4

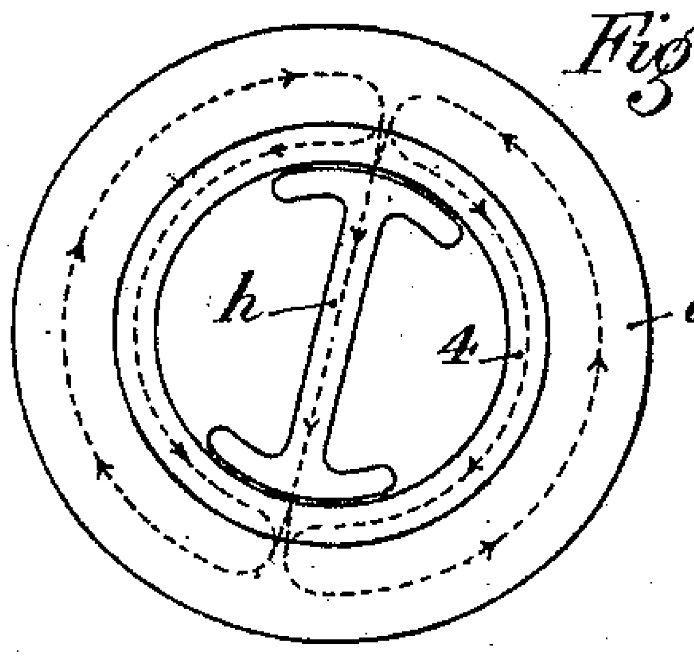


Fig. 7

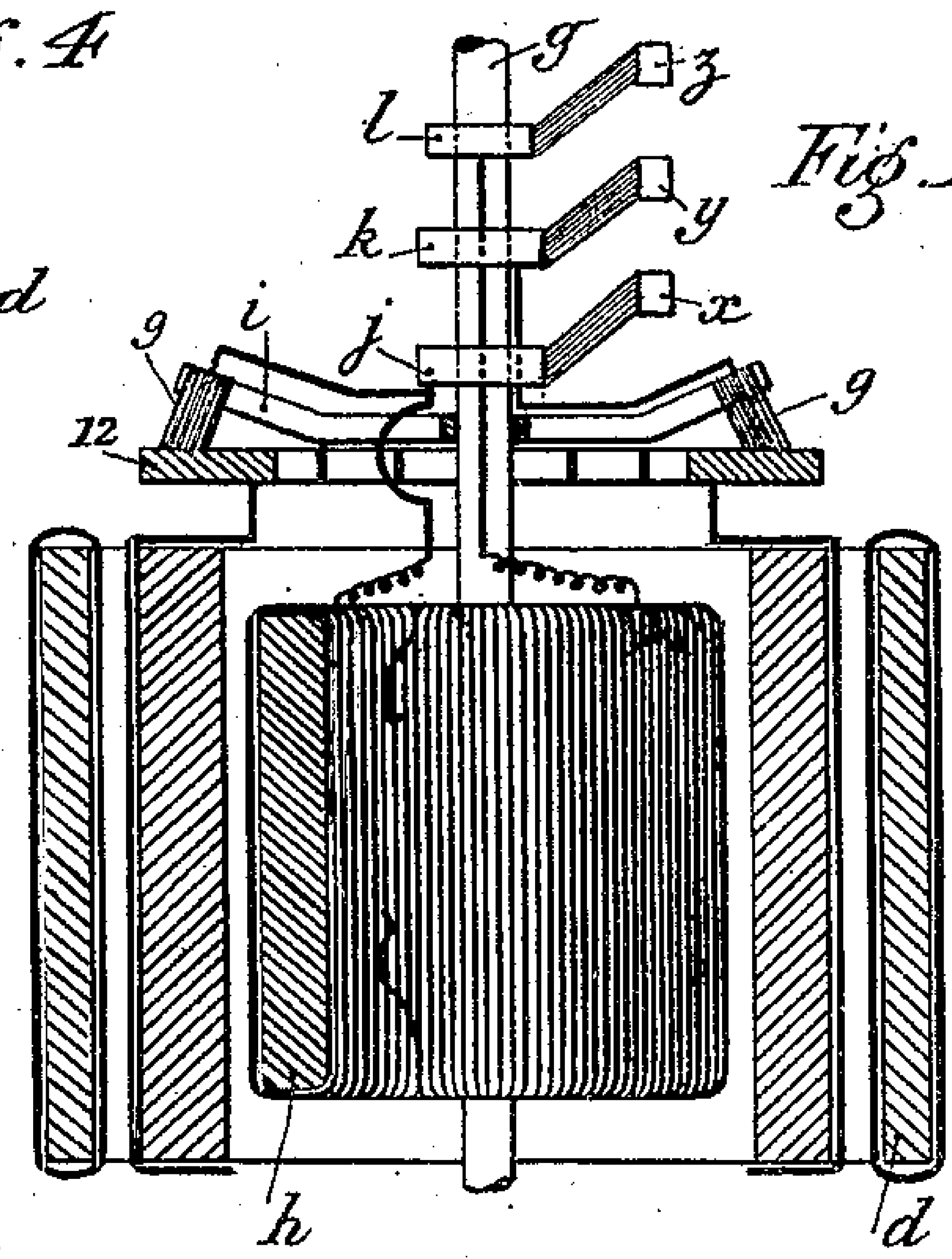


Fig. 5

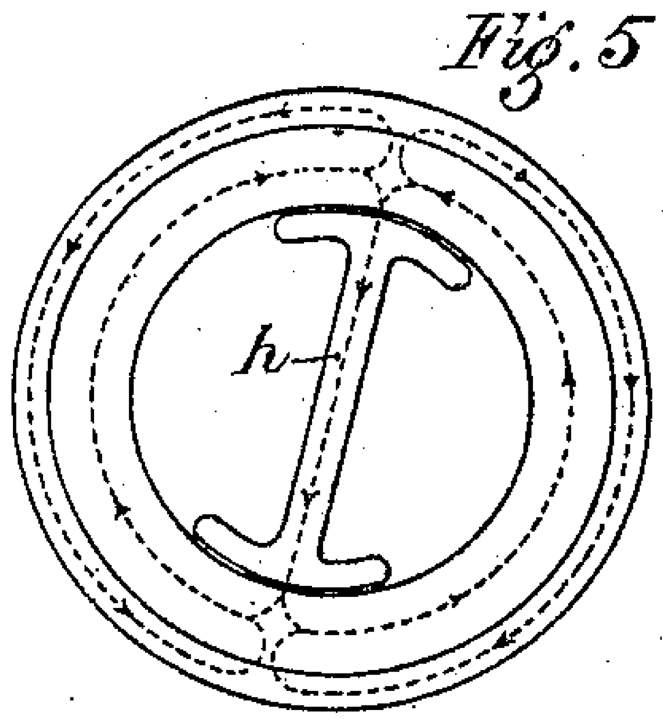


Fig. 10

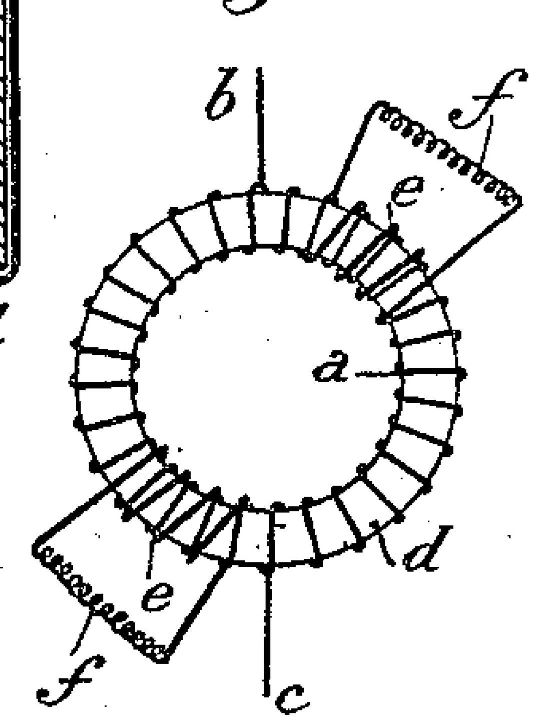


Fig. 6

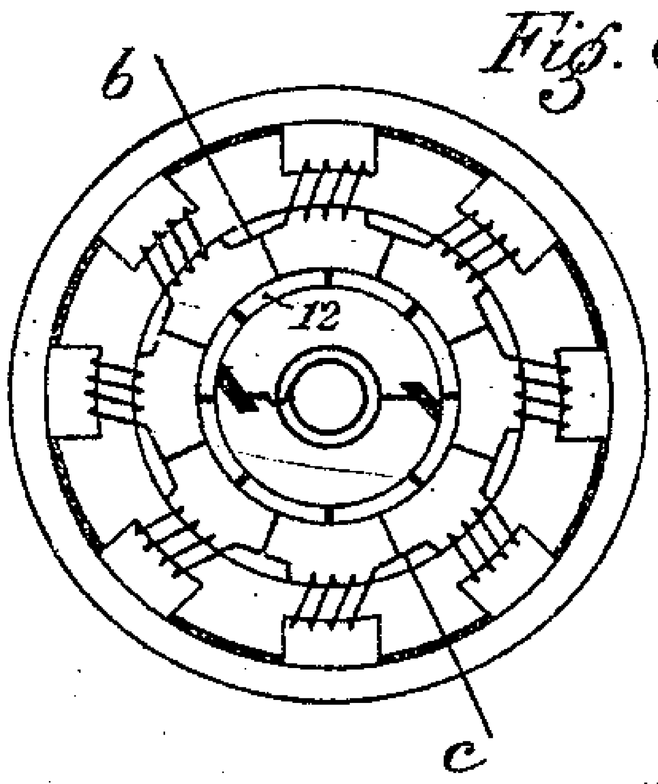


Fig. 8

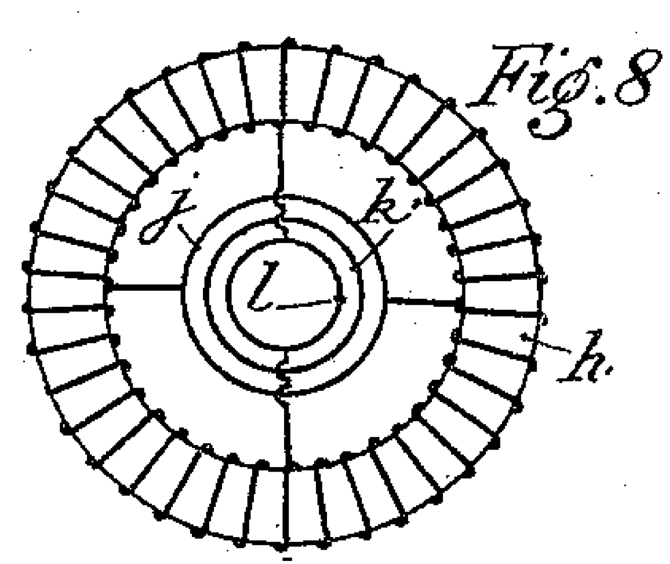
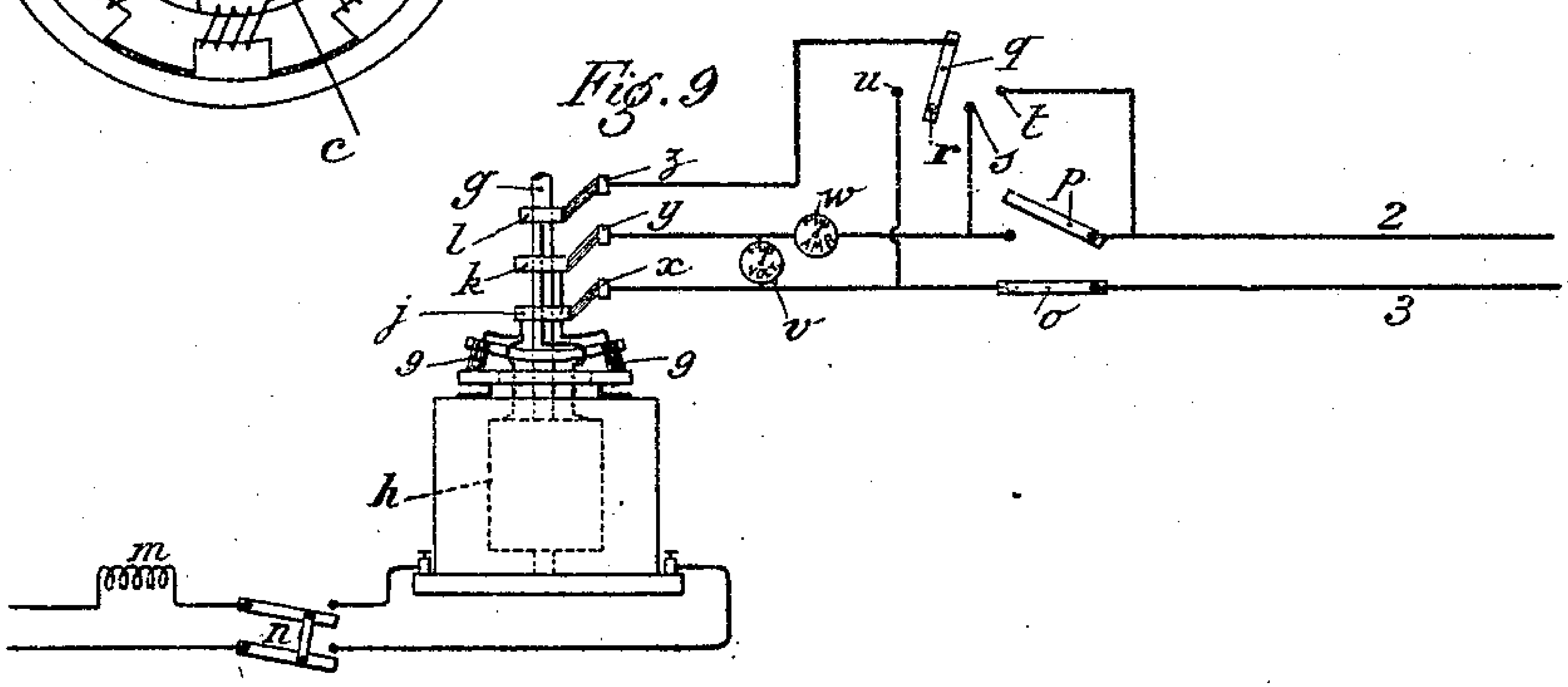


Fig. 9



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No. 689,566. Patented Dec. 24, 1901.

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Fig. 11

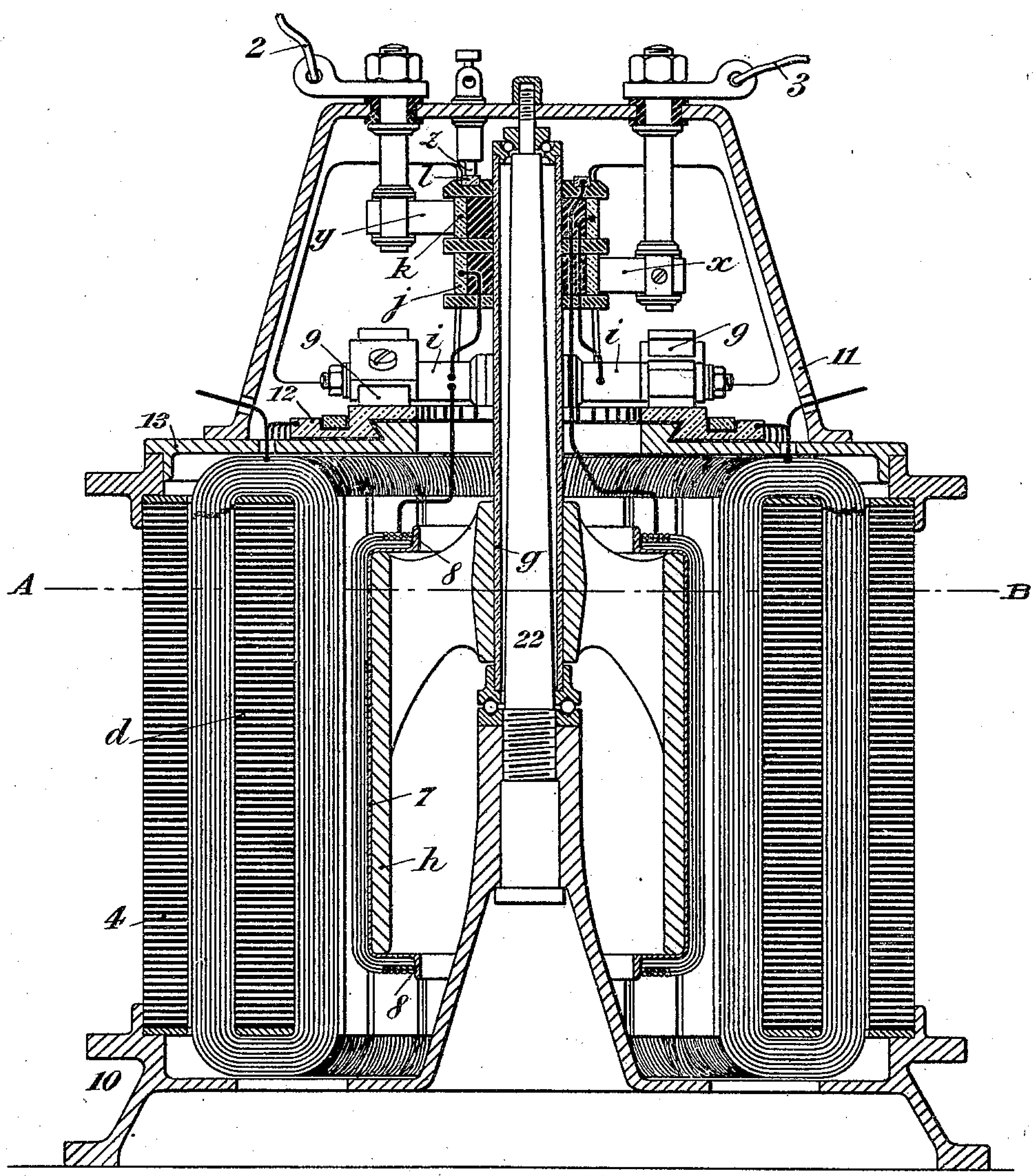

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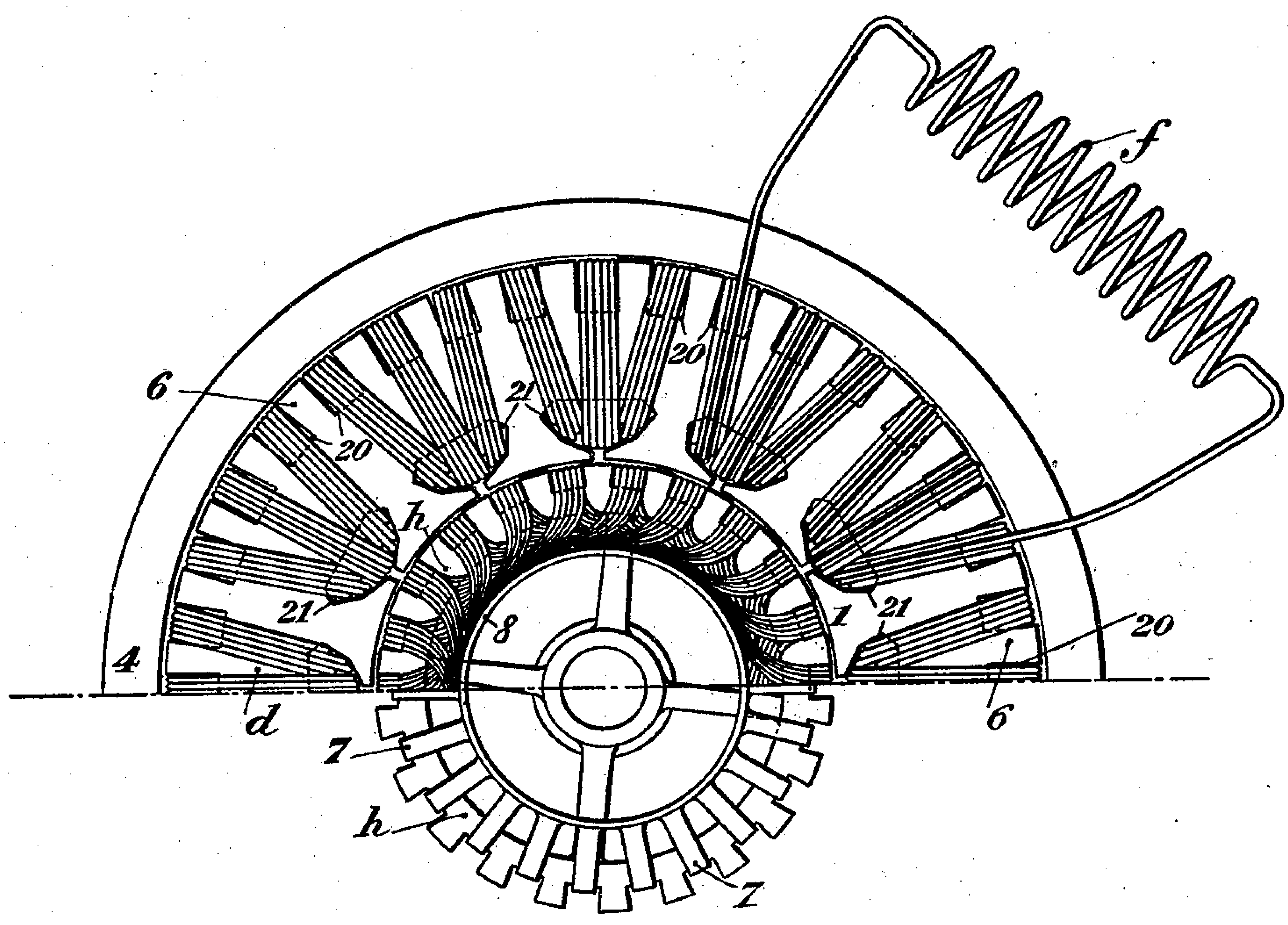
Fig. 12



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UNITED STATES PATENT OFFICE.

RAYMOND ROUGÉ AND GEORGES FAGET, OF PARIS, FRANCE.

APPARATUS FOR TRANSFORMING SINGLE AND MULTIPHASE ALTERNATING CURRENTS INTO CONTINUOUS CURRENTS AND INVERSELY.

SPECIFICATION forming part of Letters Patent No. 689,566, dated December 24, 1901.

Application filed April 6, 1900. Serial No. 11,796. (No model.)

To all whom it may concern:

Be it known that we, RAYMOND ROUGÉ and GEORGES FAGET, manufacturers, citizens of the Republic of France, and residents of 5 Rue de Stockholm, Paris, France, have invented new and useful Improvements in Apparatus for Transforming Single and Multiphase Alternating Currents into Continuous Currents, and Inversely, of which the following is a specification.

This invention relates to a system of apparatus permitting either single or multiphase alternating currents to be transformed into continuous currents of equal or different tension or continuous currents into single or multiphase alternating currents.

In order to simplify the matter, in the following description we shall in the first place consider our apparatus as applied to the transformation of alternating into continuous currents. In such application what we shall call the "inducing system or primary circuit" would become the "induced system or secondary circuit" and inversely in the case where the apparatus would be used for transforming continuous into alternating currents, as will be hereinafter more fully explained.

Our transformers comprise—

First. A stationary inducing system analogous to that of a motor with a revolving field excited by alternating currents and which we shall call the "primary circuit."

Second. A stationary induced system analogous to that of a continuous-current dynamo situated in the field of the inducing system and connected to a commutator which is also stationary. We shall call this induced system the "secondary circuit."

Third. Movable brushes sliding over the commutator to collect the induced current.

The principal characteristic of the system consists in the fact that these brushes are moved synchronously with the revolving field such as is produced by the primary and secondary currents, which renders the lead of such brushes constant no matter what may be the load in the working circuit supplied by the transformer. For this purpose these brushes are actuated by a movable magnet (either permanent or electromagnetic) placed in a derivation of the above-mentioned resulting field, so as to revolve synchronously with such field.

Figures 1, 2, and 3 are diagrams which show as examples three arrangements of this system of apparatus. Figs. 4 and 5 are diagrams showing the paths followed by the magnetic lines of force in the different cases which may present themselves. Fig. 6 shows diagrammatically an apparatus constructed according to our system of the type called "commutating." Fig. 7 is a more or less diagrammatic view, partly in elevation and partly in section, showing certain details of our apparatus. Fig. 8 is a view which is also diagrammatic and shows the electromagnet indicated in Fig. 7 in plan. Fig. 9 is a diagram showing the connections of the apparatus with the feed and working circuits. Fig. 10 is a diagram showing the connection of compensating circuits to the primary circuit. Fig. 11 shows, partly in vertical section and partly in elevation, a transformer constructed according to our system of the type called "commutating." Fig. 12 is a half-horizontal section on line A B of Fig. 11.

The same letters or numerals indicate the same or corresponding parts in all the figures.

Fig. 1 shows diagrammatically a transformer for biphase alternating currents. In this apparatus the stationary primary circuit is composed of a quadripolar drum-coil a, which is mounted upon the exterior core d. The secondary circuit, also stationary, is composed of a quadripolar drum-coil 5, which is mounted upon the interior core 4. It is provided with a commutator 12. The biphase currents flow through the stationary primary circuit, producing, as is known, a revolving field. This induces in the fixed secondary circuit a current the electromotive forces of which follow the rotation of the field. Therefore by causing the four brushes 9 which move over the commutator 12 to follow the movement of the quadripolar field a continuous current will be collected. This current is transmitted to the stationary collectors x y by the collecting-rings j k, which move with the brushes to which they are electrically connected. The brushes are actuated by a movable electromagnet h, which, like the apparatus, is quadripolar. This magnet is situated and mounted so as to be automatically rotated by and with the revolving field, such as the latter is produced by the primary and secondary currents. As a fact the best position for the electromagnet is the central space of the apparatus, because there the derivation of the field is the strongest; but we may place the magnet in any position where it will be sufficiently submitted to the influence of the resulting field.

Fig. 2 represents diagrammatically a transformer for triphase alternating currents. In this example the primary circuit *a* is wound in ring form on the outer core *d* and the secondary circuit 5 is wound in drum form on the interior core 4. These two windings are mounted so as to produce a quadripolar effect. The electromagnet *h*, which actuates the brushes 9, is itself quadripolar. The arrangements of this magnet and the operation of the apparatus are the same as in the case of Fig. 1.

In Fig. 3 a transformer for a single alternating current is represented. *a* indicates the primary and 5 the secondary circuit. They together constitute a double ring-winding, mounted upon the interior core *d*. The primary and secondary coils alternate and produce a two-pole arrangement. The electromagnet *h* is therefore here only bipolar. When once the apparatus is in motion, it produces practically continuous currents, owing to the effects of the reaction of the induced system, a reaction constituting a phenomenon analogous to that which is produced in asynchronous single alternating-current motors.

It will be readily understood that we do not limit ourselves to the three arrangements above mentioned and that the primary and secondary circuits may be wound according to any known method on either one or the other of the magnetic cores, so as to produce bi or multi polar arrangements. The cores will preferably be laminated—that is to say, formed of insulated superposed sheets or plates. They may be toothed, so as to receive the coils in the spaces between the teeth. Thus, for example, in the arrangements shown in Figs. 1 and 2 the core *d* is toothed interiorly. The coils *a* are situated in the spaces 21, formed between the teeth 1, so as to leave the greater part of the interior surface of the iron core free for the transmission of the magnetic lines of force—that is, all that part which is formed by the projecting teeth 1. Further, in the case where the tension is very high this free part may be still further increased by employing teeth which open out or expand outward, such as those shown at 1 in Fig. 12 of the accompanying drawings, which almost entirely cover the wire. In Figs. 1 and 2 the inner core 4 is also toothed, but on its outer surface, and the teeth 1 and 6 of the two cores are arranged opposite, iron opposite iron. The two cores *d* and 4 could therefore be cut out together from the same pieces of metal. These pieces would then be pierced with mortises 20 21 for the passage of the windings 5 and *a*. Nevertheless in the case of high tensions it is advisable to insulate the two cores *d* and 4 from each other by interposing between them either a sheet of mica, such as 14, or any other insulator of high resistance. This insulator may either pass through the spaces 20 21 between the successive teeth or not. The sheets of mica 14 give in effect a supplemental magnetic resistance; but in certain cases in which the primary circuit is of very high tension it may be useful to completely separate not only the primary and secondary windings, but also the cores on which these windings are made. This is why we have suggested the advisability of applying these insulations, which, however, are not claimed as essential features of the invention and are omitted from the example shown in Fig. 3, in which they would have no utility, since the two windings are upon the same core. Whatever may be the arrangement of the windings the sections of the core should be chosen or calculated so as to realize the following conditions: The saturation of the outer core should be weak enough to insure that the core does not uselessly create magnetic resistance harmful to the output. On the contrary, the saturation of the inner core should be relatively strong, so that the magnetic derivation in the central space may have sufficient importance to insure the actuating of the movable magnet. Nevertheless in order to avoid losses the saturation should at the same time be sufficiently weak to insure that the derivation is not stronger than is necessary for producing this effect. Fig. 4 of the accompanying drawings indicates in the case of a bipolar apparatus the path of the magnetic lines of force when the winding is of drum or Gramme-ring form on the outer core *d* and of drum form on the inner core 4, as in Figs. 1 and 2. It will be seen that in this case the whole of the lines of force passes through the outer core, while a portion only of the lines of force passes through the inner core. The section of the former should therefore be greater than that of the latter. Fig. 5 shows, on the contrary, that in the case where the winding is made in double Gramme-ring form on the inner core, as in Fig. 3, the whole of the lines of force passes through the latter, while a portion only of the lines of force passes through the outer core. The section of this core can therefore be less than that of the inner core.

In the preceding description we have supposed that there were two distinct circuits—a primary circuit *a* and a secondary circuit 5. This is, in fact, the case generally; but it will be noticed that when the maximum electromotive force of the source of the alternating current is the same as that of the continuous current to be produced there is no difference in potential between the corresponding coils of the two circuits. These therefore may be combined in one, connected on the one hand to the commutator and on the other hand to the terminals of the alternating current. This is shown in Fig. 6 of the accompanying drawings.

In order to finish with the stationary part of the transformer, we will again mention that in the case where it is a question of single alternating currents it is advisable to provide the apparatus, whether the secondary circuit is in one with the primary circuit or not, with supplementary compensating circuits, of which we will later on indicate the object and arrangement in dealing with the starting of the movable part. In so far as this movable part of the apparatus is concerned it will be seen by the above description that it is composed, essentially, of a magnet, preferably an electromagnet, which being carried around in the rotation of the resulting field produces the displacement of the brushes 9 on the fixed commutator 12. It is evident that this electromagnet need not necessarily have projecting poles. It may be formed and excited in any suitable manner. Thus it may have the form of a Gramme ring, which in the case of a quadripolar magnet will be excited at four points. This arrangement is illustrated in Figs. 7 and 8 of the accompanying drawings. The winding of the magnet might also be of drum form. The exciting of the magnet might therefore be made, theoretically, with a continuous current provided from any suitable source. For ordinary running the current which excites the magnet may therefore be taken either in parallel or in series from the brushes themselves of the transformer. It is further the same with regard to the starting, and this for the following reason: At this moment the alternating electromotive force on the segments of the commutator where the brushes are situated, combined with the alternating electromotive force induced in the circuit of the magnet by the derivation from the field which traverses the circuit, produces such a current in the circuit of the magnet that the latter becomes subject to a very strong couple, tending to cause it to turn in the same direction as the revolving field of the apparatus, from whence results the automatic starting.

What we have just stated applies to the case of multiphase currents, a case where the revolving field is produced as soon as the current is admitted to the apparatus. In the case where it is a question of single alternating currents the field created in the apparatus when the current is admitted is not a revolving field, but an alternating field only. It therefore results that in a general way the magnet starts automatically; but there exist, however, positions constituting dead-centers, where the starting will not be effected. This phenomenon is analogous to that which is produced in the steam-engine, in which the alternating movement of the piston has to be transformed into circular motion. The starting is only produced when the mechanism is not on the dead-center. It is for this reason that in order to insure with certainty the automatic starting in the case of a single alternating current we propose to replace the alternating field created in the apparatus at the moment of the admission of the current by a revolving or approximately-revolving field. With this object we employ the arrangement known as "diagonal circuits." (Illustrated in Fig. 10.) *a* being the stationary primary circuit, which is wound upon the core *d* and of which the terminals are at *b* and *c*, we arrange obliquely in relation to these terminals and upon the same core *d* the stationary supplementary compensating circuits *e e*, closed through the resistances *f f*. It is known that on account of this arrangement the field instead of being simply alternating will be more or less revolving, which will insure the automatic starting. It will be noticed that in apparatus constructed according to our system the great permeability of the magnetic circuits enables us to apply this arrangement of diagonal circuits without any sensible diminution in the output resulting therefrom. Thus, therefore, and it is a very important point, all apparatus constructed according to our system, whether they may be made for multiphase currents or for a single alternating current, are automatic starting. In order to more certainly insure this automatic starting, we can in all cases wind on the iron core of the electromagnet a certain number of bars of copper, forming an asynchronous motor-armature, (squirrel's cage.) An example of this arrangement is represented in Figs. 11 and 12, as will be seen further in the description of these figures. With the method of starting which we have supposed up to the present, at the moment of starting it is not a continuous current which is sent into the working circuit, but really an alternating current. Then when once running the current becomes continuous; but its polarity cannot be determined *a priori*. Now in many cases it is not desirable to thus send into the lead an alternating current or undulating current or continuous current of any polarity. We have therefore been compelled to design an arrangement which enables us to effect the starting in a manner which is suitable for each particular case. This arrangement is illustrated in Figs. 7, 8, and 9 of the accompanying drawings. It will be seen that in Fig. 7 the shaft *g*, on which are fixed the magnet *h*, movable brush-carrier *i*, and the current-collecting rings *j k*, further carries a supplementary ring *l*. One of the poles of the coil of the magnet *h* or all the poles of the same sign for a multipolar arrangement (see Fig. 8) is connected to the supplementary ring *l*, and the pole (or poles) of the opposite sign is connected to one of the collecting-rings, say *j*. The arrangement further comprises as essential elements, first, in the feed-circuit, (*a*) a variable self-induction coil *m*, enabling the voltage to be modified within the limits allowable in the installation, and (*b*) a bipolar interrupter *n*; second, in the working circuit (*a*) an interrupter *o*, inserted in the line-wire 3, leading from the brush *x* of the ring *j;* (*b*) an interrupter *p*, inserted in the line-wire 2, leading from the brush *y* of the ring *k;* (*c*) a several-way switch *q*, connected to the supplementary ring *l* and comprising a dead contact *r*, a contact *s*, connected to the brush *y*, a contact *t*, connected to the line-wire 2, and a contact *u*, connected to the brush *x*, and (*d*) an ampere-meter *w* and a voltmeter *v*, indicating the direction of the current. The interrupter *o* does not figure in the operation. It is always closed in the first instance before effecting the starting.

In order to start an apparatus arranged as just described, three principal cases may be distinguished: (*a*) the circuit is fed by a single apparatus and the polarity of the continuous current is indifferent, (*b*) the polarity is defined, (arc-lamps,) (*c*) the transformer has to be placed in parallel with a source having a fixed electromotive force—(examples, charging-accumulators, the addition of a machine to a group already running.)

Case *a:* First, if there is no inconvenience in sending for a few moments a more or less alternating current to the working apparatus which may be in circuit, the interrupters *o* and *p* are left always closed and the switch *q* is allowed to remain on the contact *s*. The operation therefore is reduced to the closing of the primary interrupter *n*. Second, if there is any inconvenience in sending an alternating current to the working apparatus, one proceeds as follows: The switch *q* is placed on the contact *u* to place the magnet-circuit in short circuit. The interrupter *n* of the feed-circuit is closed. When the speed of the movable part is considered sufficient, the switch is placed on the contact *s*. The coil of the magnet is then fed by the secondary stationary circuit, so that the movable part soon attains the asynchronous speed. It only then remains to close the interrupter *p* of the working circuit.

Case *b:* The operation is the same as in Case *a*, second; but before closing the interrupter *p* the voltage is checked. If the current is in the opposite direction to that which is desired for a short instant, the switch is turned back on the dead contact *r*, so as to allow the movable piece to lose a little of its speed and to retard it for a half-period. The switch is then turned back onto the contact *s*, and the interrupter *p* is closed.

Case *c:* The switch *q* is turned onto the short-circuit contact *u*, and the interrupter *n* of the feed-circuit is closed. When the speed is sufficient, the switch is turned on the contact *s*, which gives the synchronous speed, and then onto the contact *t*, (the outer circuit,) which determines the direction of the current. It only remains to equalize the voltages with the self-induction coil *m* and to close the interrupter *p*.

In the methods of starting *a*, *b*, and *c*, as we always begin by putting the switch *q* upon the post of the short circuit *u* it is necessary in order that the movable magnet *h* may operate as an asynchronous motor it should be furnished with a winding-in short circuit, (which we have herein referred to as "squirrel's cage.") To obtain this result, it is evidently necessary that the core of the movable magnet have a revoluble, form as in an ordinary motor.

Simplified method of starting: In the case where the movable part is not provided with the copper bars forming a cage if the interrupter *n* is supposed to be closed, the switch *q* on the dead contact *r*, and the interrupter *p* open the consumption of the apparatus is extremely low. Our transformer may therefore remain permanently in circuit as an ordinary transformer. Under these conditions for starting it is only necessary to actuate the switch *q* and the interrupter *p* in one of the methods previously indicated.

Having thus indicated in a general manner the methods of arrangement and of starting, which are suitable for apparatus constructed according to our system, we will now show by an example how these apparatus may be practically constructed. For this purpose we will refer to Figs. 11 and 12, in which we have represented a transformer made according to our system for a simple alternating current of the "commutating" type—that is to say, in which the two stationary currents—the primary and secondary—are combined together. In these figures, 4 indicates the laminated outer core, and *d* the laminated inner core upon which the single above-mentioned circuit will be wound in ring form. For this purpose the core *d* is provided with two sets of teeth—the outer set 6 and the inner set 1. The latter set open outward, with the object we have already described. The teeth are formed in such a way that for three outer spaces or gaps 20 between the teeth corresponds a single interior space 21. These spaces 20 and 21 serve to receive the windings of the single coil. They will further receive the windings of the diagonal compensating circuits *e*, Fig. 10, which have been above mentioned. The whole of the two fixed cores 4 and *d* are supported by the open base 10 of the transformer. The core *h* of the movable part is made of a cast piece. It is keyed on the sleeve *g*, which is mounted on balls around a stationary shaft 22. The core *h* is toothed or grooved exteriorly to receive the circuit of the magnet, which will be wound in drum form. At the bottom of the grooves are placed the bars 7 of the cage, the object of which has been previously described. These bars are joined above and below the core *h* to rings 8 8, which further serve to support the wires of the magnet-circuit. Upon the hollow axis are also suitably mounted the rings *j k l*, inclosed in a support of insulating material. The collectors *x y z*, corresponding to these rings, are supported by the open cap 11. The latter is fixed on the cover 13. It serves as a support to the upper part of the central rod 22, which, on the other hand, is fixed at its lower end to the base 10.

For the purpose of transforming continuous currents into alternating currents we send the continuous current to the brushes and to the movable magnet, and we collect the alternating currents in the posts of what we have termed the "primary" circuit, which then becomes the secondary circuit. Yet if the alternating current required of the apparatus were not partially "dewatted"—that is to say, a part of the alternating current is in phase with its own electromotive force while another part of the current is switched out for a quarter of a revolution with respect to this same electromotive force—we could only obtain in the apparatus a turning-field perpendicular to the line of the brushes, and consequently we should necessarily have very strong sparks and disorganization of the machine. That is why in this case to obviate these inconveniences it is necessary to maintain by the apparatus, besides the working circuit, a special circuit endowed with self-induction, the latter being intended to obtain the dewatted current necessary.

We claim—

1. A transformer of simple or multiphase alternating currents into continuous currents and inversely, comprising a stationary primary core of laminated iron, a stationary secondary annular core of laminated iron, a rotary magnetic piece, stationary primary and secondary circuits or conductors wound in uniform layers in such manner that the primary fixed core is separated both from the secondary fixed core and from said rotary magnetic piece by the two fixed conductors, a stationary collector, and movable brushes actuated by the rotary magnetic piece, substantially as herein described.

2. A transformer of simple or multiphase alternating currents into continuous currents and inversely, comprising a stationary primary core of laminated iron, a stationary secondary annular core of laminated iron, a rotary electromagnet constituted by a solid core over the whole surface of which the magnetizing-winding is distributed in a uniform manner, stationary primary and secondary circuits or conductors wound in uniform layers in such manner that the primary fixed core is separated both from the secondary fixed core and from said rotary electromagnet by the two fixed conductors, a stationary collector, and movable brushes actuated by the said electromagnet, all substantially as and for the purpose herein described.

3. A transformer of single or multiphase alternating currents into continuous currents and inversely, comprising the combination of primary and secondary stationary coils, a stationary commutator, movable brushes, a principal stationary magnetic core d, a second annular stationary magnetic part 4, a rotating magnetic part having the form of a solid of revolution and serving to actuate the brushes, and an armature of an asynchronous motor (squirrel's cage) fitted to the rotating magnetic part, the principal core d and the two magnetic parts, stationary and movable, being arranged in relation to each other and to the primary and secondary coils, in such a manner that the core d may be traversed by the whole of the resulting field created by the primary and secondary coils, while the other two stationary and movable magnetic parts are traversed by two complementary derivations of this same field, so as to together produce the closing of the latter, the whole substantially in the manner and for the purpose indicated.

4. A transformer of simple or multiphase alternating currents into continuous currents and inversely, comprising a stationary primary core of laminated iron, a stationary secondary annular core of laminated iron, a rotary magnetic piece constituted by an electromagnet, stationary primary and secondary circuits or conductors combined in a single circuit as described and wound in uniform layers in such manner that the primary fixed core is separated both from the secondary fixed core and from the electromagnet by the circuits thus combined, a stationary collector, and movable brushes actuated by the electromagnet, all substantially as and for the purpose herein described.

5. A transformer of single or multiphase alternating currents into continuous currents and inversely, comprising the combination of primary and secondary stationary coils, a stationary commutator, movable brushes, a principal stationary magnetic core d, a second annular stationary magnetic part 4, a rotating magnetic part formed by an electromagnet and serving to actuate the brushes, rings j and k movable with the electromagnet and connected to the brushes, one of these rings being further connected to one of the extremities of the winding of the electromagnet, a supplementary ring l movable with the electromagnet and connected to the other extremity of this winding, and the brushes or collectors $x\, y\, z$ for the three rings, the principal core d and the two other magnetic parts, stationary and movable, being arranged in relation to each other and to the primary and secondary coils, in such a manner that the core d may be traversed by the whole of the resulting field created by the primary and secondary coils, while the other two stationary and movable magnetic parts are traversed by two complementary derivations of this same field, so as to together produce the closing of the latter, the whole substantially in the manner and for the purpose indicated.

6. A transformer of single or multiphase alternating currents into continuous currents and inversely, comprising a combination of primary and secondary stationary coils, combined in one circuit as described, a station-

ary commutator, movable brushes, a principal stationary magnetic core *d*, a second annular stationary magnetic part 4, a rotating magnetic part formed by an electromagnet and serving to actuate the brushes, rings *j* and *k* movable with the electromagnet and connected to the brushes, one of these rings being further connected to one of the extremities of the winding of the electromagnet, a supplementary ring *l* movable with the electromagnet and connected to the other extremity of the winding, and the brushes or collectors *x y z* for the three rings, the principal cord *d* and the two other magnetic parts, stationary and movable, being arranged in relation to each other and to the so-combined primary and secondary coils, in such a manner that the core *d* may be traversed by the whole of the resulting field created by the primary and secondary coils, while the other two stationary and movable magnetic parts are traversed by two complementary derivations of this same field, so as to together produce the closing of the latter, the whole substantially in the manner and for the purpose indicated.

7. A transformer of single or multiphase alternating currents into continuous currents and inversely, comprising the combination of primary and secondary stationary coils, diagonal compensating coils *e e*, also stationary, a stationary commutator, movable brushes, a principal stationary magnetic core *d*, a second annular stationary magnetic part 4, a rotating magnetic part *h* actuating the brushes, the principal core *d* and the magnetic stationary and movable parts 4 and *h* being arranged in relation to each other and to the stationary coils in such a manner that the core *d* may be traversed by the whole of the resulting field created by the stationary coils, while the other two magnetic parts, stationary and movable, are traversed by two complementary derivations of this same field, so as to together produce the closing of this latter, the whole substantially in the manner and for the purpose indicated.

In testimony that we claim the foregoing as our invention we have signed our names, in presence of two witnesses, this 26th day of March, 1900.

RAYMOND ROUGÉ.
GEORGES FAGET.

Witnesses:
EDWARD P. MACLEAN,
ALCIDE FABE.