No. 759,967. PATENTED MAY 17, 1904.

A. J. CHURCHWARD.

ALTERNATING CURRENT MOTOR.

APPLICATION FILED MAR. 29, 1897.

NO MODEL. 3 SHEETS—SHEET 1.

Fig. 1.

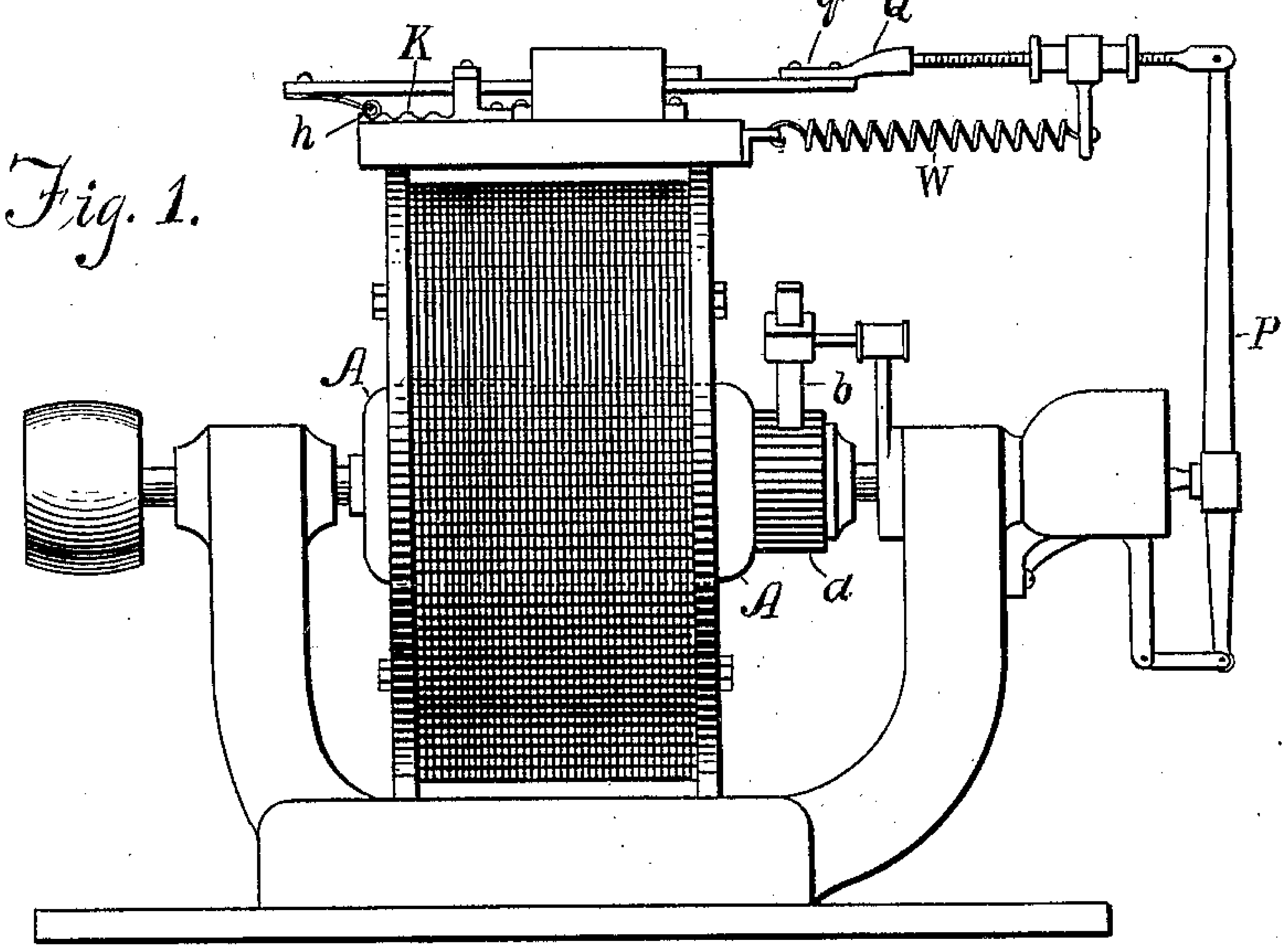


Fig. 2.

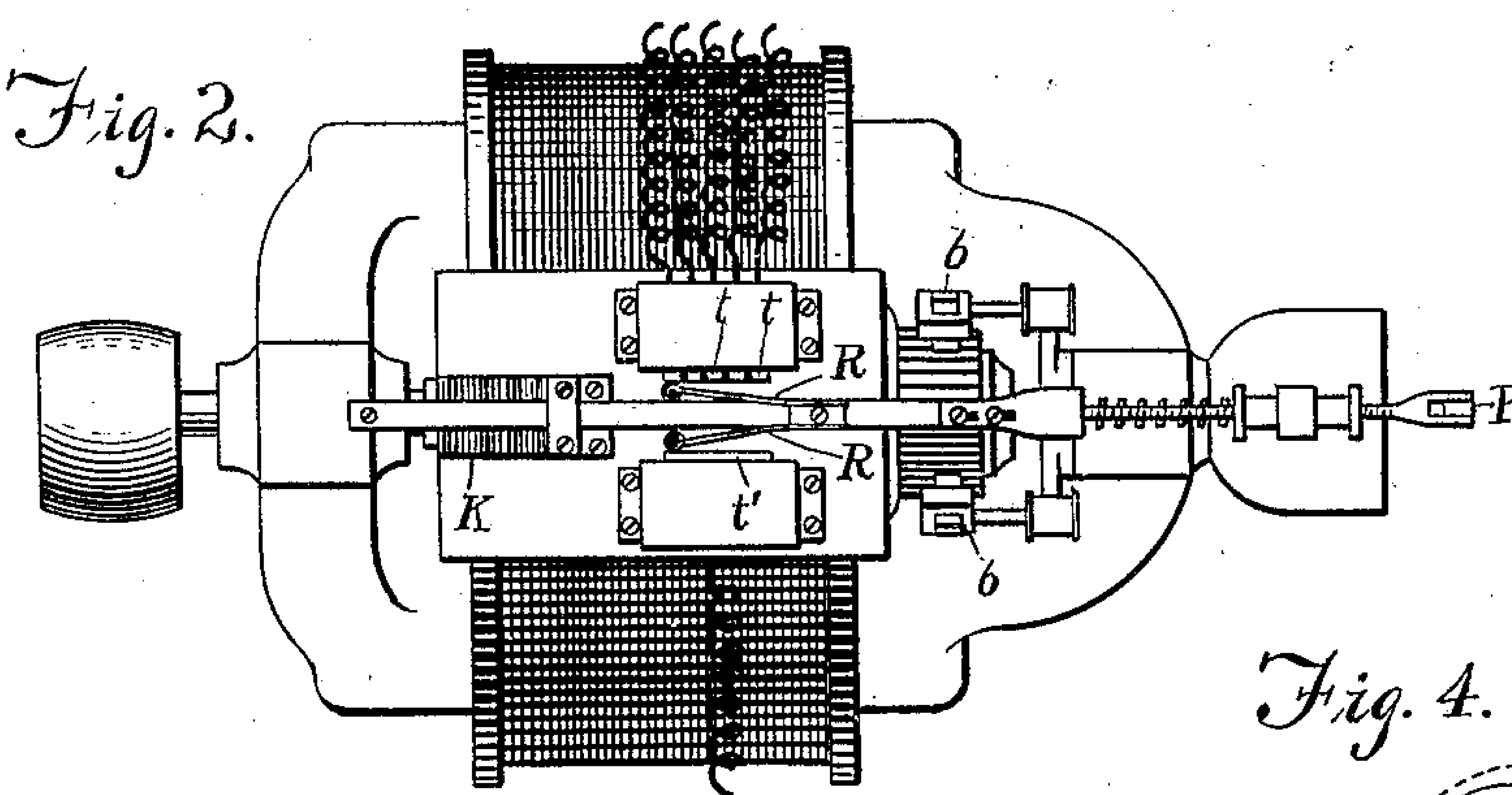


Fig. 4.

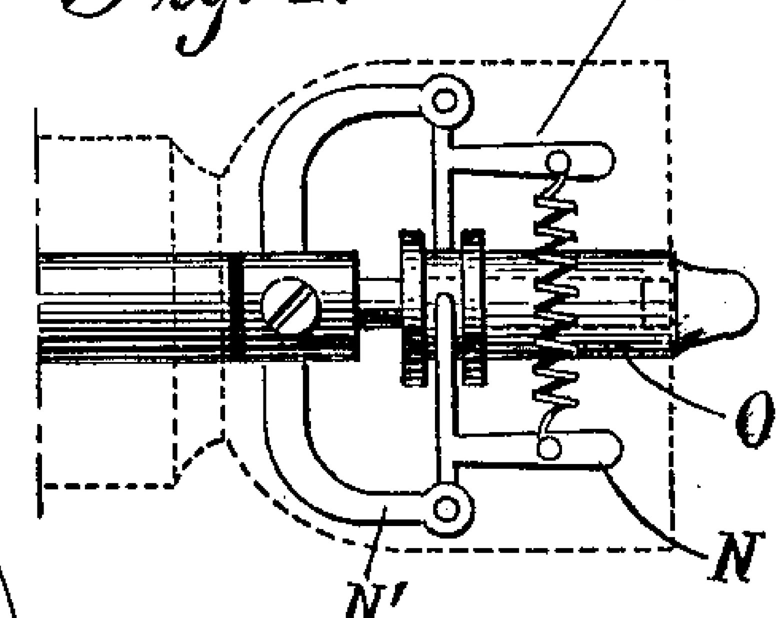
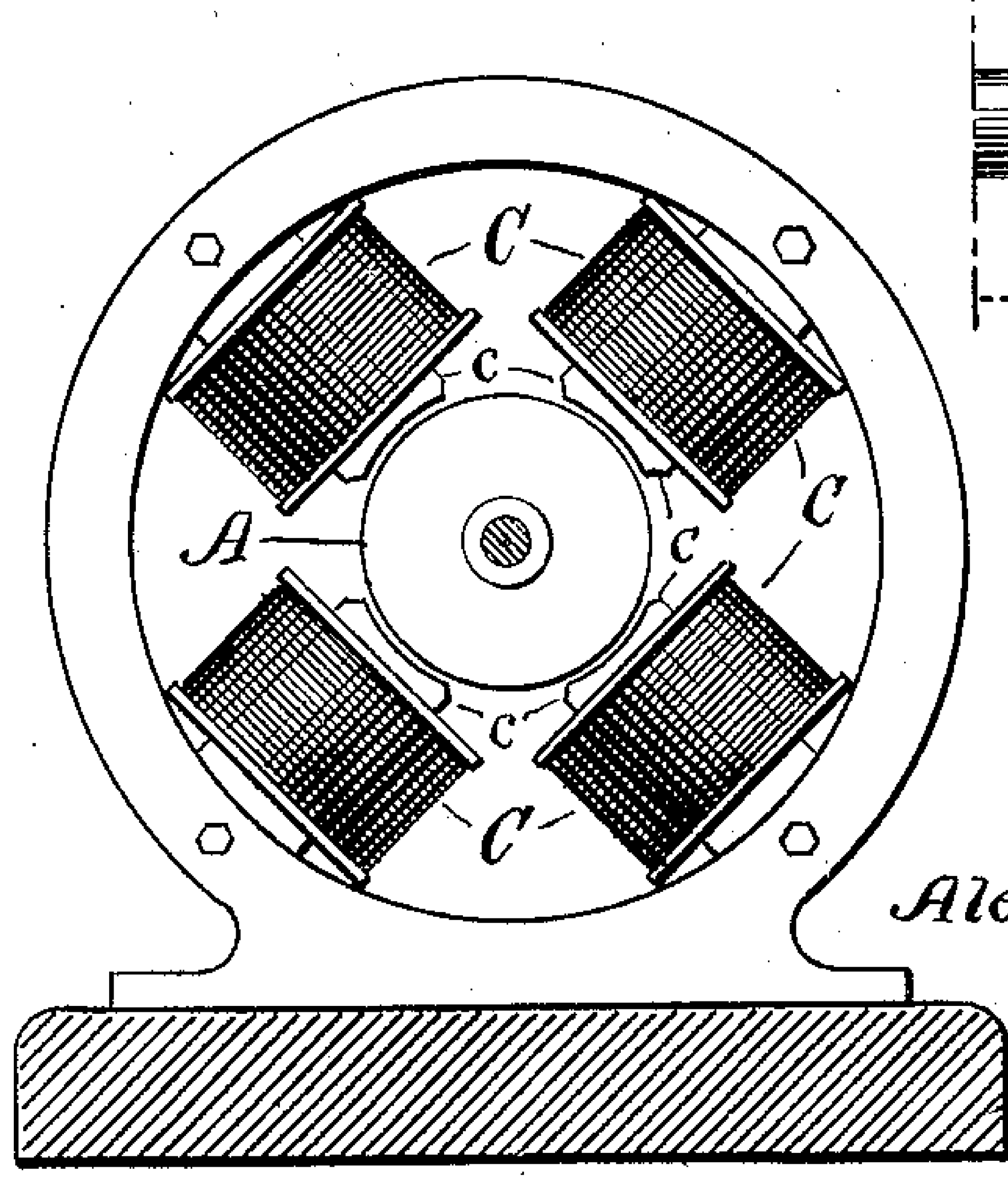


Fig. 3.



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NO MODEL. 3 SHEETS—SHEET 2.

Fig. 5.

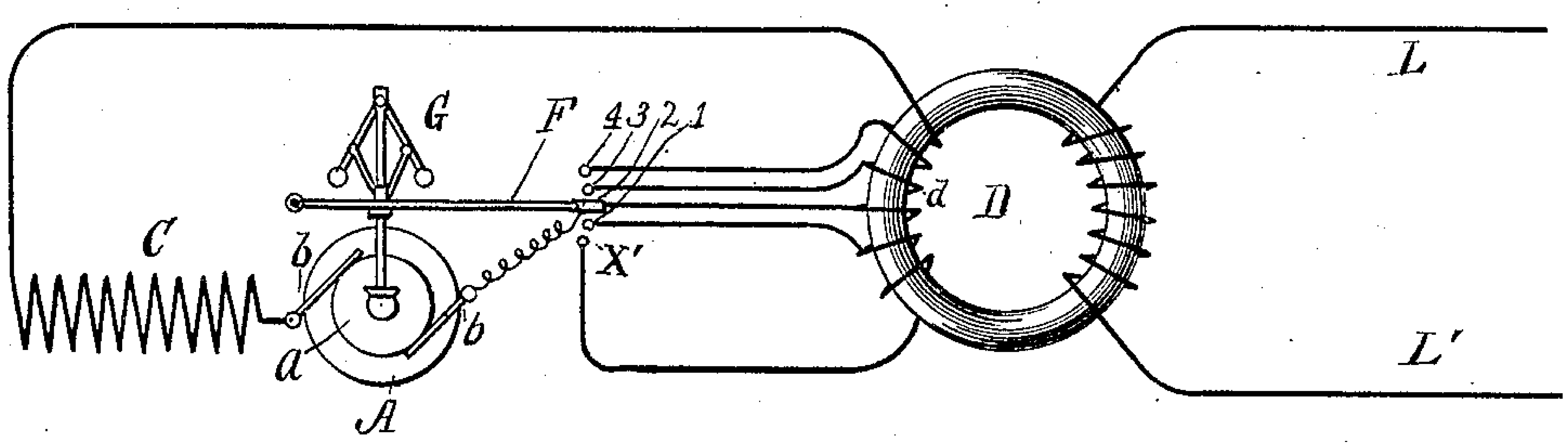


Fig. 10

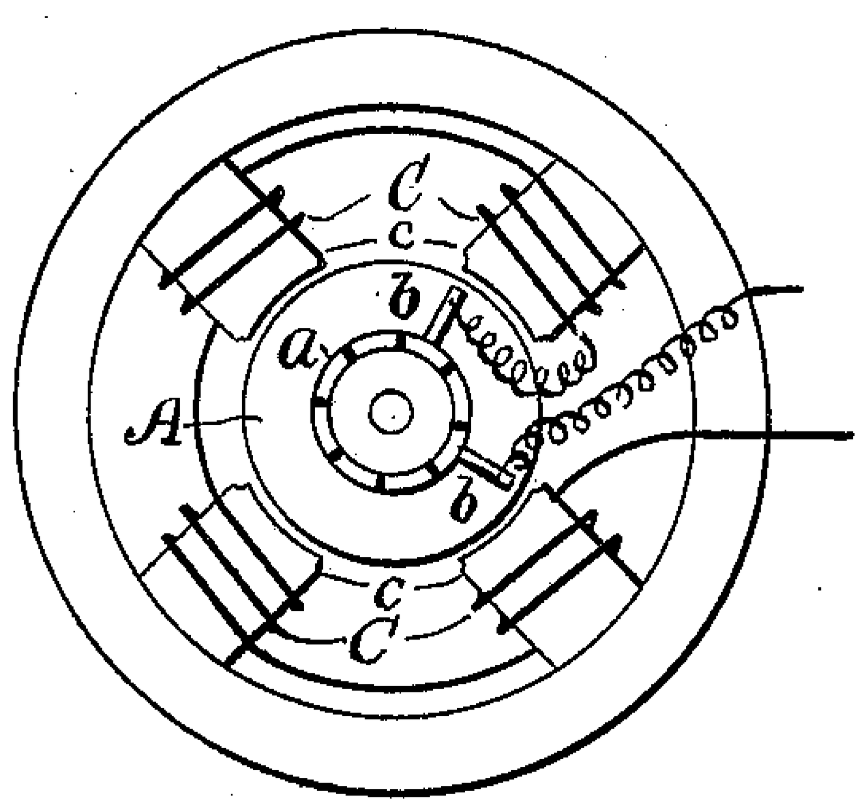


Fig. 6.

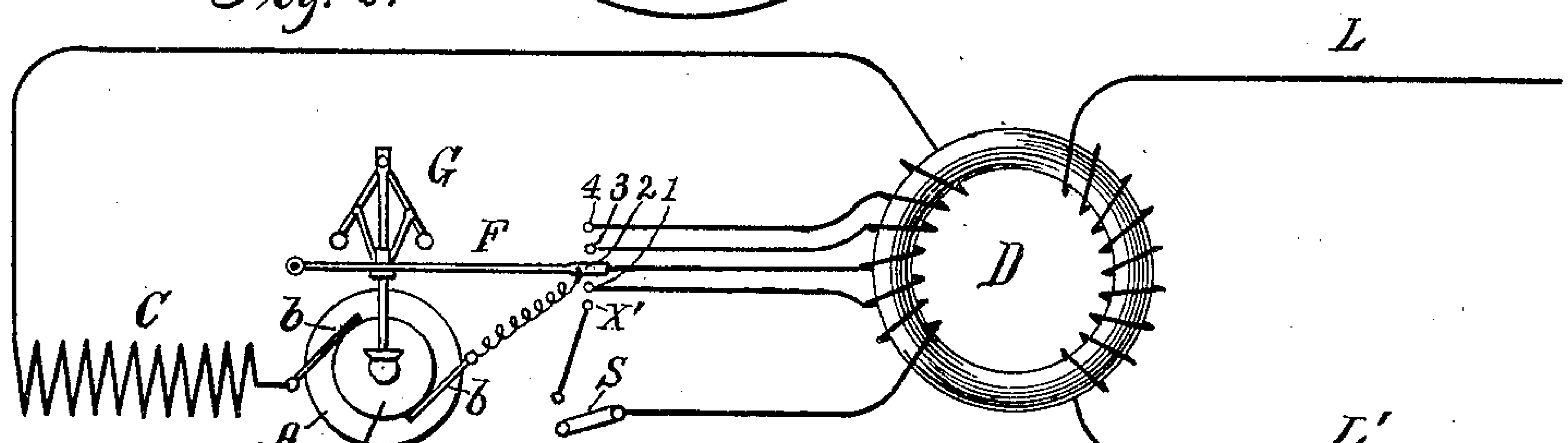
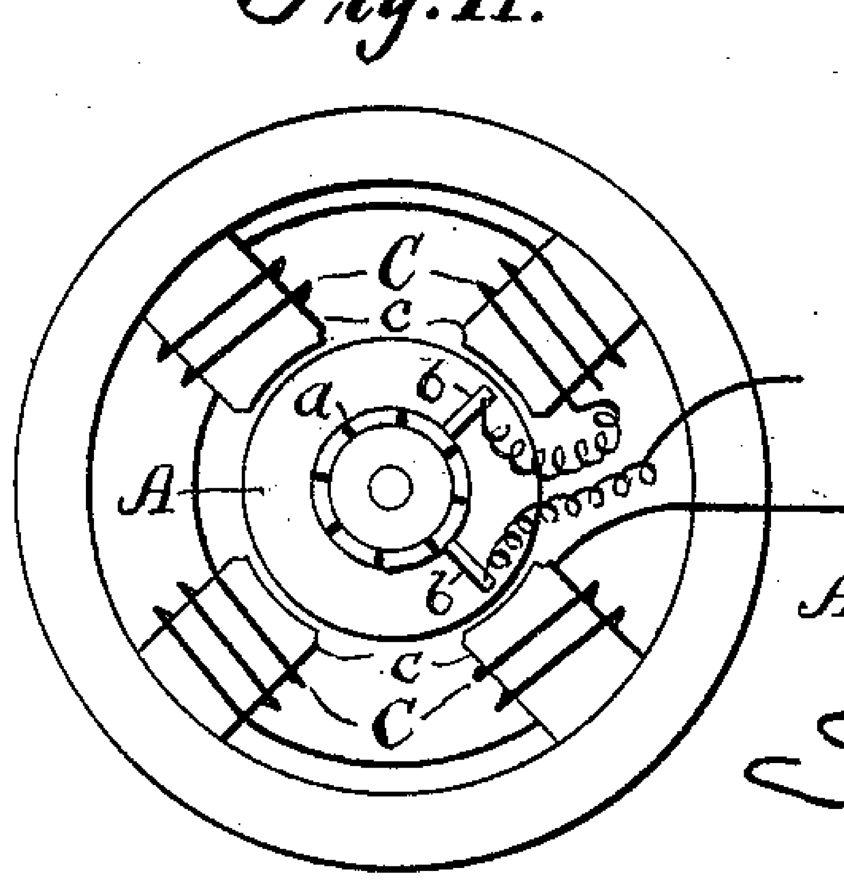


Fig. 11.



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NO MODEL. 3 SHEETS—SHEET 3.

Fig. 7.

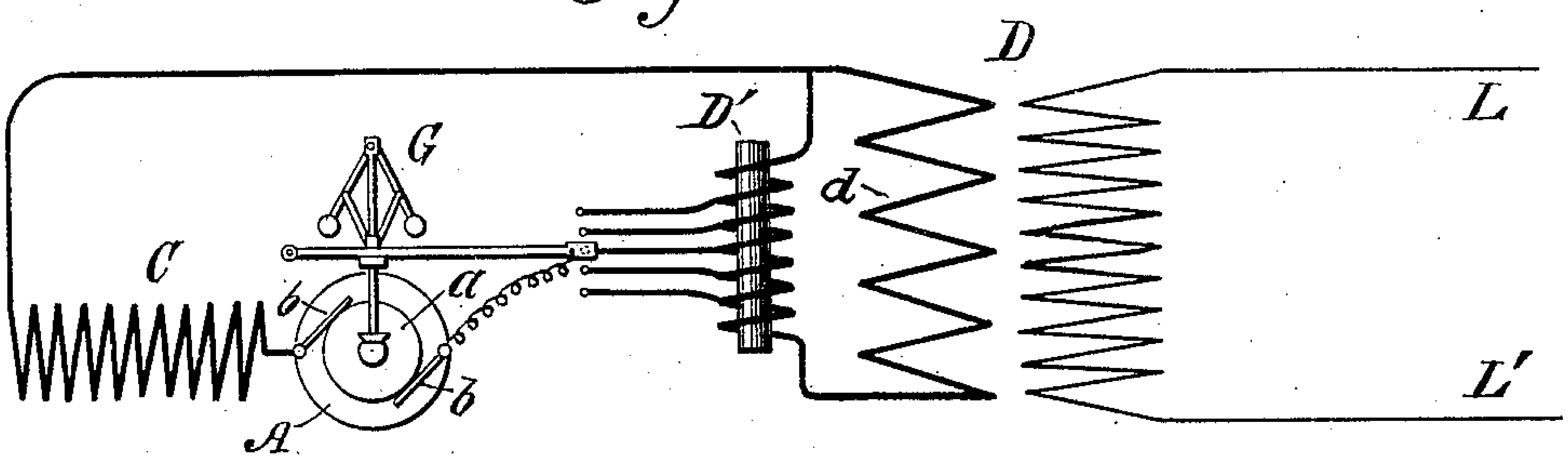


Fig. 8.

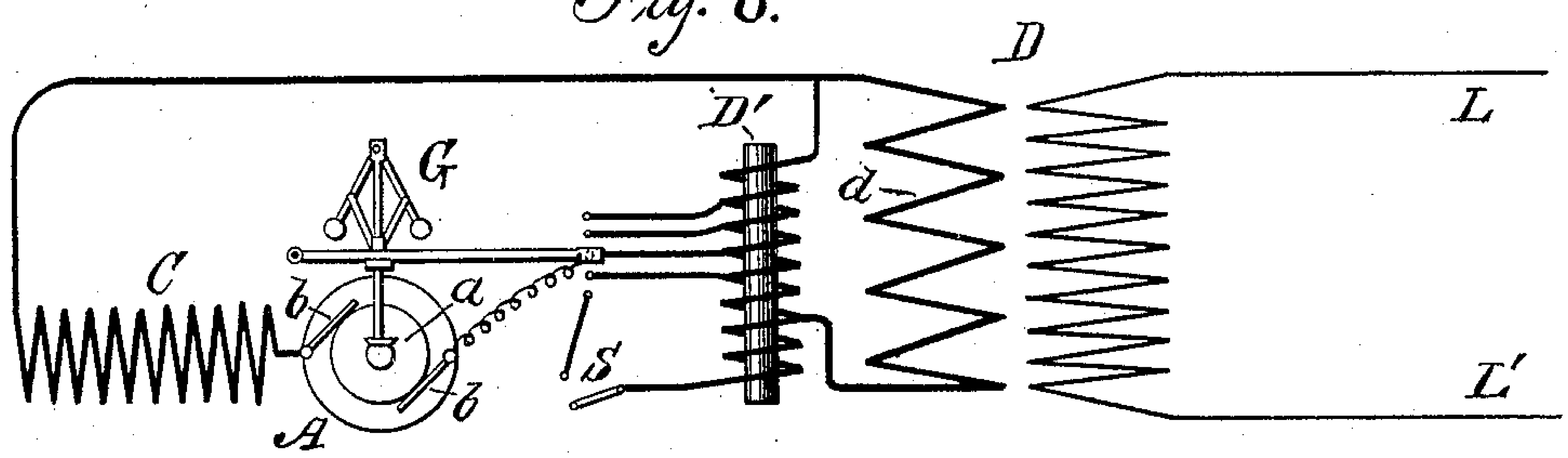
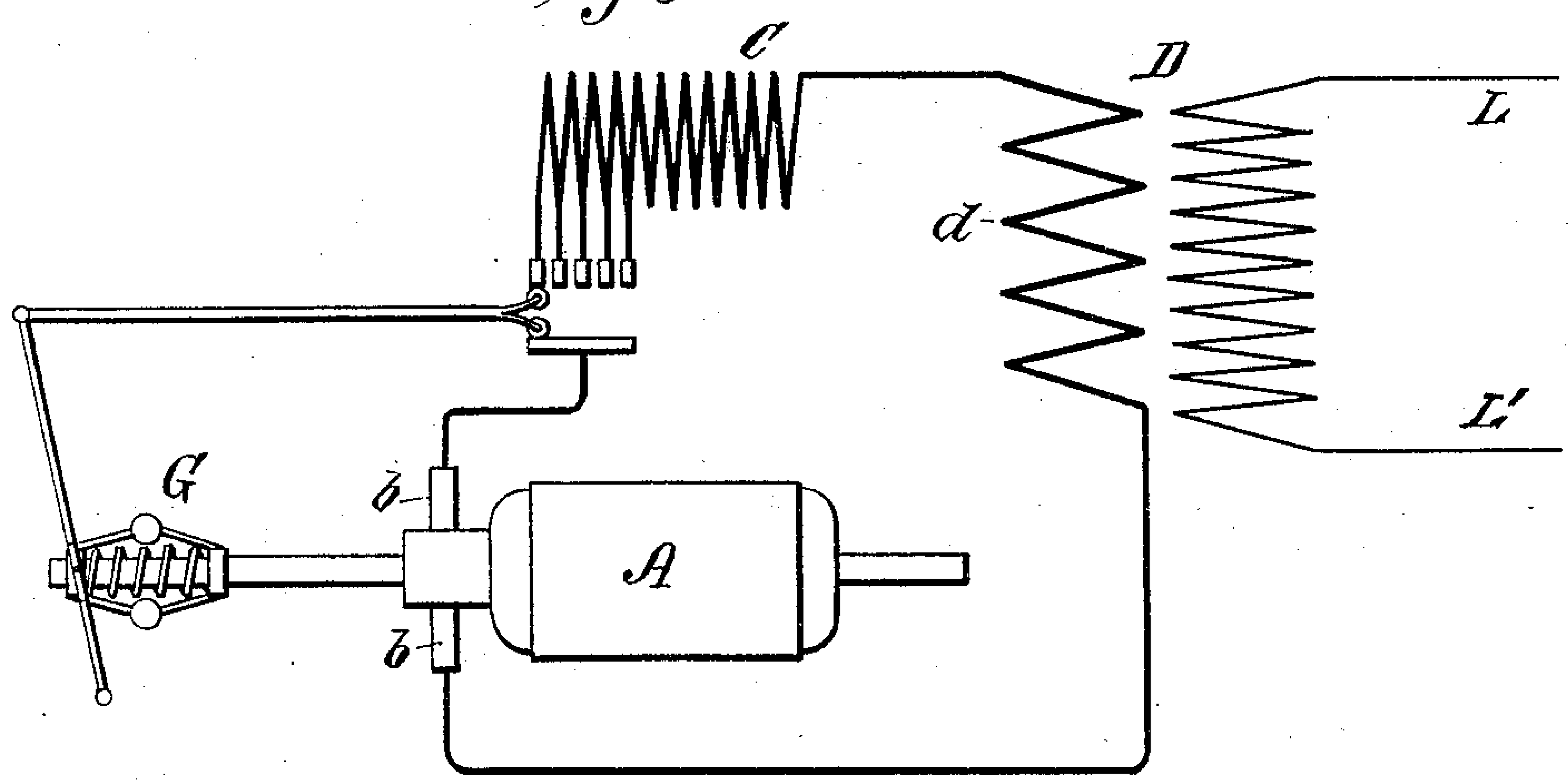


Fig. 9.



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UNITED STATES PATENT OFFICE.

ALEXANDER J. CHURCHWARD, OF BROOKLYN, NEW YORK.

ALTERNATING-CURRENT MOTOR.

SPECIFICATION forming part of Letters Patent No. 759,967, dated May 17, 1904.

Application filed March 29, 1897. Serial No. 629,849. (No model.)

To all whom it may concern:

Be it known that I, ALEXANDER J. CHURCHWARD, a citizen of the United States, and a resident of Brooklyn, in the county of Kings and State of New York, have invented a certain new and useful Alternating-Current Motor, of which the following is a specification.

My invention relates to single-phase alternating-current motors of the type in which the winding and general organization is that of any ordinary continuous or direct current motor or dynamo. As is well known, this class of machines will start and develop power when fed with alternating currents to both field and armature and will accelerate and finally reach a speed which is synchronous with the alternations; but the machine is not self-regulating and will run away under light load. Such machines, moreover, run as alternating-current motors are ordinarily very inefficient, among other things, because of the losses arising from self-induction of their parts under the action of the alternating currents—a source of loss, however, which may be largely avoided if the machine may be kept running at a speed synchronous with the rate of alternations, provided that it is so constructed as to primarily have a low self-induction. The losses from self-induction are also largely augmented, owing to the fact that such motors in order that they may have a large starting torque have been hitherto so constructed that of necessity they have also a high self-induction, which remains as a source of loss even after the motor is brought up to whatever working speed is chosen for it.

The general object of my invention is to permit machines of this class to be operated with high efficiency by alternating currents passed to the direct-current armature-winding through the direct-current commutator; and to this end the invention consists, broadly, in the combination, with said machine, of means for keeping the armature at synchronous or similar predetermined speed while so operated.

My invention consists also in the combination, with an alternating-current motor, of auxiliary means whereby an extra voltage may be produced to overcome the high self-induction of the motor at starting.

My invention consists also in the special combinations of apparatus, as hereinafter more particularly described and claimed.

The invention is particularly useful in connection with series-wound motors having a continuous-current armature-winding and commutator. When a motor of this kind is run in synchronism with the generator, the armature or revolving part becomes in reality a constant field excited by a direct current—that is, by the alternating current rectified by the continuous-current commutator, to which the armature-coils are connected and to which the alternating currents are fed. This will be readily appreciated when it is considered that the current generated by the direct-current armature is primarily an alternating current which is rectified by means of the commutator. Conversely, if an alternating current is supplied to said armature through the medium of its commutator the result will be, if the armature is in step with the alternations, that the current as it flows in the armature will be a direct current, and the armature will exhibit a field with constant poles. The poles of the field-magnet will, however, alternate and will act magnetically as a revolving field to rotate the armature. Operated under this condition there is no loss by hysteresis in the rotor, because there are no reversals of magnetism taking place and the current being continuous there is no self-induction in the wires; but to preserve this condition some regulating means must be provided for holding the motor in or about synchronism. This may be secured by various means—as, for instance, by any suitable regulating device adapted to regulate the alternating current fed to the machine, so as to diminish the current when the speed rises above the synchronous or predetermined speed and to increase it when the speed falls below such speed. This may be accomplished in various ways, as by resistance interposed in and withdrawn from the circuit, by varying the impressed electromotive force through cutting in and out the coils of a transformer or autoconverter, or in other ways regulating the voltage. The regulation might also be effected in various other ways by cutting field-coils of the machine in and out of circuit to vary the strength of the field. The regulation may be controlled either by hand or automatically by a suitable centrifugal governor or other device responsive to changes of speed. It has been shown that if the motor runs in synchronism there will be no more loss due to eddy-currents, hysteresis, or self-induction in the rotor than in the field of a direct-current motor. If we desire to run the motor at a slower speed, the loss in the rotor will be increased. If, however, we run it at half-speed, the losses will only be due to half the number of reversals of the line. For example, synchronous speed, eighteen hundred revolutions per minute, four poles, equals seven thousand two hundred alternations; half speed, nine hundred revolutions per minute, four poles, equals three thousand six hundred alternations. So, also, of any other speed which is a submultiple of the synchronous speed, so that by running at such predetermined speeds we can vary the speed within a large range without much loss in efficiency.

In the accompanying drawings, Figure 1 is an end elevation of a motor and automatic attachment suitable for carrying out my invention. Fig. 2 is a plan view. Fig. 3 is a side elevation of the field-magnet of the motor; Fig. 4, a detail of a form of centrifugal governor. Figs. 5, 6, 7, 8, and 9 are diagrams showing the circuits of the apparatus in some of its modifications. Figs. 10 and 11 show a further modification.

In the drawings I have shown the invention as carried out in connection with a four-pole machine, the armature A of which is wound like any direct or continuous current generator or motor and is provided with the usual commutator, the cylinder of which is indicated at *a* and the brushes at *b*, disposed about said cylinder in the usual manner. The four-field magnet-poles are shown at *c* and the field-magnet coils at C. By suitable connections the field-coils are in series with the armature, as indicated in the diagram, or are otherwise connected to the supply-circuits, so that alternating currents will flow to said coils in step with or at the same frequency with the alternating currents fed to the commutator-brushes and through the commutator-cylinder to the armature.

By preference I organize and operate the motor as a series motor—that is, with the armature and field coils in series with one another—and this is the condition of the machine both during starting or acceleration and when running at normal speed. The machine is fed with alternating currents from any desired source—as, for instance, from the secondary of a transformer or converter D, as indicated in the diagrams, the primary of which is supplied from mains or supply-wires L L'. In Figs. 5 and 6 the transformer supplies the motor directly, and in Figs. 7 and 8 the current from the secondary is modified by an autotransformer D'.

In Figs. 5 and 6 the means shown for regulating the speed of the motor consists of a sectional secondary *d* for the transformer and a suitable switch F, moving over a set of contacts, (numbered 1 2 3 4,) to which the sections of coil *d* are connected, as shown. The secondary feeds alternating currents through the switch, the armature, and the field C in series, and the switch by its movement increases or diminishes the number of coils *d* in action. When the speed falls from the desired synchronous or other predetermined speed, the switch is turned to increase the number of coils *d* in action, and thus increase the impressed electromotive force, and when the speed rises above the predetermined or synchronous speed the switch is turned in the opposite direction to decrease the number of coils *d* and lower the impressed electromotive force. When the machine is running at less than the full synchronous speed or in the starting operation, the alternating current flows as an alternating current in both armature and field in series with one another; but when the synchronous speed is reached the current flows as a continuous or direct current in said armature and as an alternating current in the field, but said field and armature are in series, as before. By suitable adjustment of the switches, the armature may be kept at the synchronous speed. If desired, the machine may be kept at a lower than synchronous speed in the same manner—as, for instance, at half speed or quarter speed—by proper adjustment of the regulating devices and will then work at high efficiency.

The switch or other regulator may be operated by hand or automatically by any device responsive to differences of speed—as, for instance, by a centrifugal governor, (typified at G, Figs. 5 and 6,) that may be connected with the switch or other device in any suitable way. A suitable construction of governor and switch is shown in Figs. 1, 2, and 4 and will be presently described.

The operation of the devices so far as described would be as follows: At starting or at low speed the switch would be on contact 1. The motor would then be supplied with all of the voltage due to all the coils *d* between contact 1 and the opposite end of coils *d*, connected to the field C. The high self-induction of the motor at starting would be compensated for by the large voltage thus supplied. As the motor increases in speed, the switch would be turned, decreasing the voltage of the applied current until the synchronous speed is reached, at which time the switch rests on a contact such that the voltage would keep the motor running at that speed. On further increase of speed the switch would further decrease the voltage, and the motor will drop back to the synchronous or other predetermined speed.

The sectional transformer switch and motor combined and operated as shown in Figs. 5 and 6 are not specifically claimed herein, as they form the subject of claims in another application for patent, filed by me March 29, 1897, Serial No. 629,852.

When the motor is at rest and current is turned on, there are eddy-current losses, self-induction, and losses due to hysteresis, which all tend to reduce the useful voltage of the line by increasing the self-induction of the motor, so that if the motor has to have a large starting torque the self-induction will be too great to pass sufficient current to give the necessary torque. To allow an excess of current to flow when starting the motor, I provide some auxiliary means in connection therewith for permitting or furnishing such excess current, and thereby avoid the necessity hitherto existing of using a motor which in order to get the desired starting torque has been made unnecessarily large or has been so constructed that when running at speed it will be inefficient. Such auxiliary means may be extra turns in the converter or in the autotransformer, so that if the machine is wound to run on, say, one hundred volts we can momentarily get two hundred volts. The centrifugal governor or other suitable means may be used to cut out such extra turns. These extra turns are shown as connected to an auxiliary contact X′ either directly or through a hand-switch S. The same effect could be produced by reducing the self-induction of the motor at starting by placing the brushes in relation to the field as indicated in the diagram Fig. 10, when the motor is at rest. This position will give the least self-induction, and therefore allow more current to pass at starting. As the motor gains speed the brushes are shifted to position shown in diagram Fig. 11, the position for full load, when the self-induction will be greatest, but the running efficiency will be highest. By these means the greatest starting torque and the highest running efficiency can be obtained. This method of operating single-phase alternating-current motors I do not claim herein, as it forms the subject of claims in another application for patent, filed by me March 29, 1897, Serial No. 629,853.

In Figs. 7 and 8 the sectional autotransformer D′ is used in connection with the switch as a regulator. The coil is interposed as shown in the circuit between the source D of alternating currents and the motor and switch, and the coil-sections of the autotransformer are connected to the switch, so that at low speeds the voltage will be high, but as the speed rises the number of transformer-coils in series with the motor will increase and the number in shunt diminish, thus lowering the impressed electromotive force upon the motor, but increasing the quantity of current supplied thereto from the smaller number of sections of said autotransformer remaining in shunt to the motor. Auxiliary sections on said transformer controlled by switch S may be used for starting purposes, as already stated.

Fig. 9 shows how by putting additional sectional windings on the field-magnet C and cutting the same in and out by means of the governor or other actuating or controlling device the strength of the field may be varied to keep the motor at the required synchronous speed, the number of coils being diminished should the speed increase, and thereby cutting down the strength of the field, and being at their maximum to give the maximum field at the start. The source from which the motor is supplied is supposed in this case to be adapted to give an alternating current of constant strength. The sectional winding is so proportioned that after the synchronous speed is attained further adjustment of the regulator on further increase of speed will so decrease the strength of field as to bring the motor back to synchronous speed, and a fall below synchronous speed will increase the strength of field and bring the motor up to speed again. This special method of operating single-phase self-starting alternating motors, such as described, I do not claim herein, as it forms the subject of claims in another application, filed by me March 29, 1897, Serial No. 629,851.

A suitable mechanical construction of centrifugal governor and a preferred construction of controlling-switch are illustrated more in detail in the Figs. 1, 2, and 4. The governor-balls consist of the elbow-levers N, mounted in a bracket N′, connected to the motor-shaft. The outward radial movement of the balls is resisted by a spring connecting them. The levers engage in a groove in a sleeve O, movable axially on the shaft and acting against a lever P, which is connected to a rod Q, carrying the switch-contact, composed in this case of a pair of springs R R, attached to the rod and in electrical union with one another. This contact slides in the space between the series of contact-blocks *t t*, insulated from one another in a suitable box or holder, and a continuous plate or block *t′*, mounted in a box at the opposite side of the track of the contact R R. The sections of coil or circuits to be controlled are connected to the contacts *t t* and the opposite pole of the circuit to *t′*, and the contact R R of the switch thus formed will in obvious manner as it moves to and fro under the action of the governor cut the coil-sections into and out of circuit. A retractor-spring W acts on the switch-bar Q to help reverse its movement when the speed falls. To obviate sparking as the switch-contact rides over the series of contacts, it should under ordinary conditions of use momentarily bridge successive contacts—that is, make contact with a succeeding before leaving a previous contact. This means a momentary short-circuiting of adjoining contacts, which introduces a serious difficulty when the set of coils connected to the series of contacts carries an alternating current. This difficulty arises from the fact that the section of coil short-circuited will bear the relation to others in circuit at the time of a secondary of a transformer, and heavy currents will be generated in it, which if long continued will damage the switch-contacts and will give rise to a damaging arc at the instant of break of contact. To obviate this difficulty, I provide means for giving the switch a snap action as it passes from each contact of the series to another in both directions of adjustment. This snap action may be provided by a bar K, having a series of projections or teeth and intermediate spaces, over which rides a spring-actuated catch or detent in the form, preferably, of a friction-roller h, carried by a spring attached to the switch-rod Q. At q in the rod Q or any other suitable point in the connections there is interposed a lost motion by means of a pin-and-slot connection, as indicated, to permit the switch to move freely under the operation of the spring-actuated catch or detent as the latter slips into each intermediate space between projections on bar K in obvious manner after having been forced over the summit of one of said projections. The parts are properly arranged so that this quick or snap action will cause the contact to snap from each contact-point to the next.

As will be obvious, the form of bar K and detent h, as well as the form and manner of application of the spring which forces the detent into the depressions, and thereby causes the longitudinal movement of the switch-bar Q, may be largely varied. It is also obvious that either the bar K or the detent might be attached to the rod Q and the other be fixed in position on a suitable support.

What I claim as my invention is—

1. A single-phase alternating-current motor having an armature provided with a continuous-current winding and commutator and operated by alternating current passed to its armature-coils through said commutator, in combination with an automatic regulator responsive to changes in the speed of the armature while so operated, and adjusted as described to keep the armature at a synchronous speed.

2. A single-phase alternating-current motor having any suitable direct-current armature-winding and commutator, as described, to adapt the machine for self-starting, combined with a regulator responsive to variations in speed of said motor and adjusted, as described, to keep the armature running at a speed synchronous with the alternations, as and for the purpose described.

3. The combination with a self-starting single-phase alternating-current motor having a continuous or direct current armature-winding fed with alternating current from any desired source, of auxiliary means adapted to cause an excess of current to flow when starting, as and for the purpose described.

4. The combination with a series-wound motor having an armature provided with a direct-current winding and commutator, and operated by alternating currents fed from any desired source, of an autotransformer having a sectional winding, and means for automatically increasing the length of winding in series with the motor and diminishing the length of winding in shunt thereto as the speed increases, as and for the purpose described.

5. The combination with a self-starting alternating-current motor, of an autotransformer having a sectional winding, a switch for said transformer, and means for automatically controlling said switch by the operation of the motor so as to maintain the same at constant speed, as and for the purpose described.

6. A self-starting single-phase alternating-current motor consisting of a machine having any suitable direct or continuous current winding in combination with auxiliary means for modifying the induction of the circuit to give a larger current flow at starting.

7. The combination with a centrifugal governor, of a switch having a series of contacts and connected therewith through devices permitting a lost motion, and means for giving said switch a snap or quick action as it passes from each contact of the series to the next, forward and backward.

8. The combination as a means for automatically controlling an alternating-current motor of a sectional coil carrying an alternating current, a series of contacts to which said sections are connected, a contact adapted to reciprocate over the same and to preserve connection in passing from one to the other, and means for giving to said contact a snap or quick action at the instant it short-circuits one of the coil-sections.

9. The combination as a means for automatically controlling an alternating-current motor of a reciprocating switch-contact and a series of contacts over which the same moves, a bar having a series of projections or teeth, a detent adapted to slip into the depressions between the same, an actuating-spring, and means for providing a lost motion in the actuating connections of the switch, as and for the purpose described.

Signed at New York, in the county of New York and State of New York, this 20th day of February, A. D. 1897.

ALEXANDER J. CHURCHWARD.

Witnesses:

WM. H. CAPEL,
D. H. DECKER.