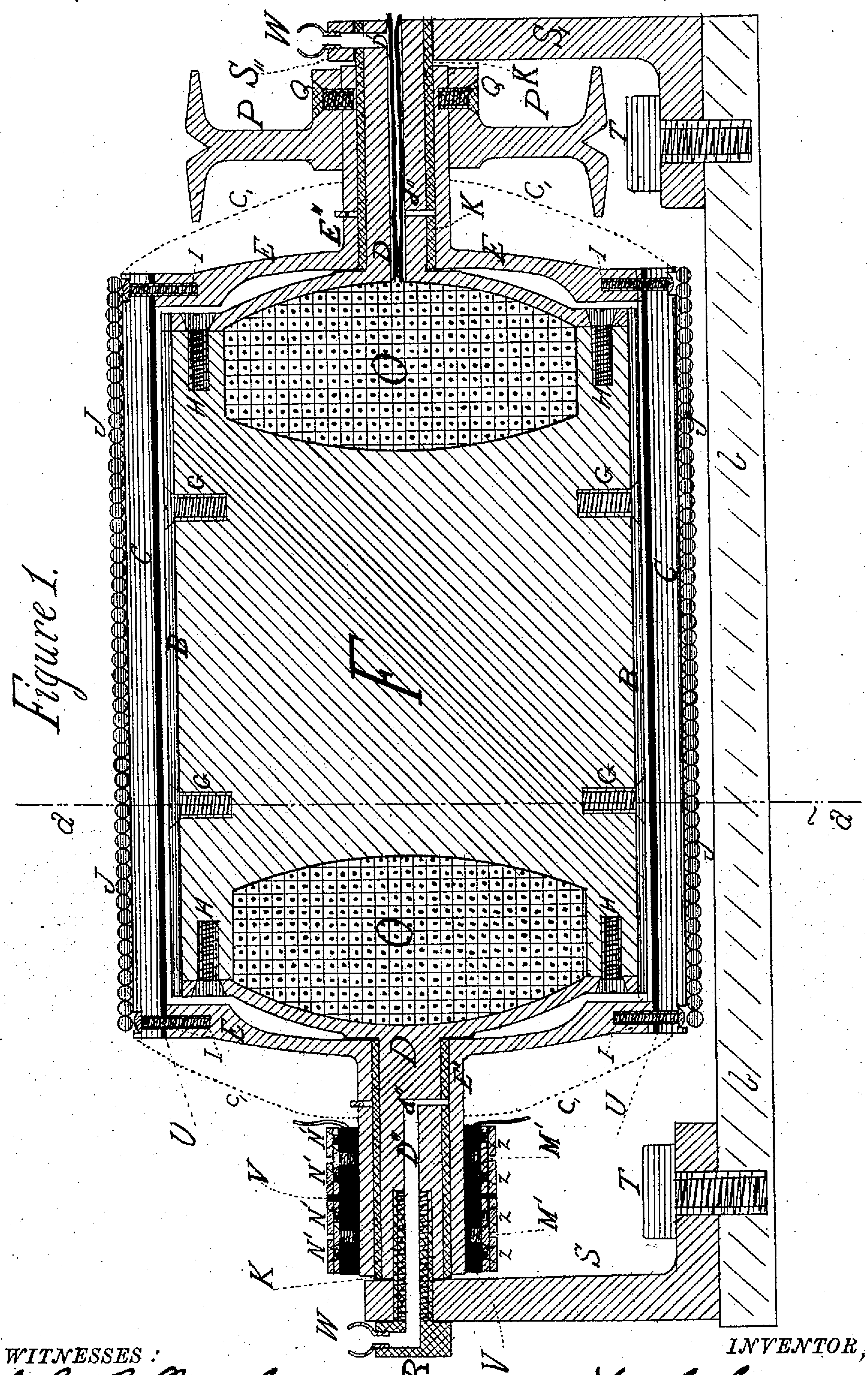
(No Model.)

4 Sheets—Sheet 1.

F. J. SPRAGUE.

DYNAMO ELECTRIC MACHINE.

No. 304,145. Patented Aug. 26, 1884.



WITNESSES:

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(No Model.)

4 Sheets—Sheet 2.

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DYNAMO ELECTRIC MACHINE.

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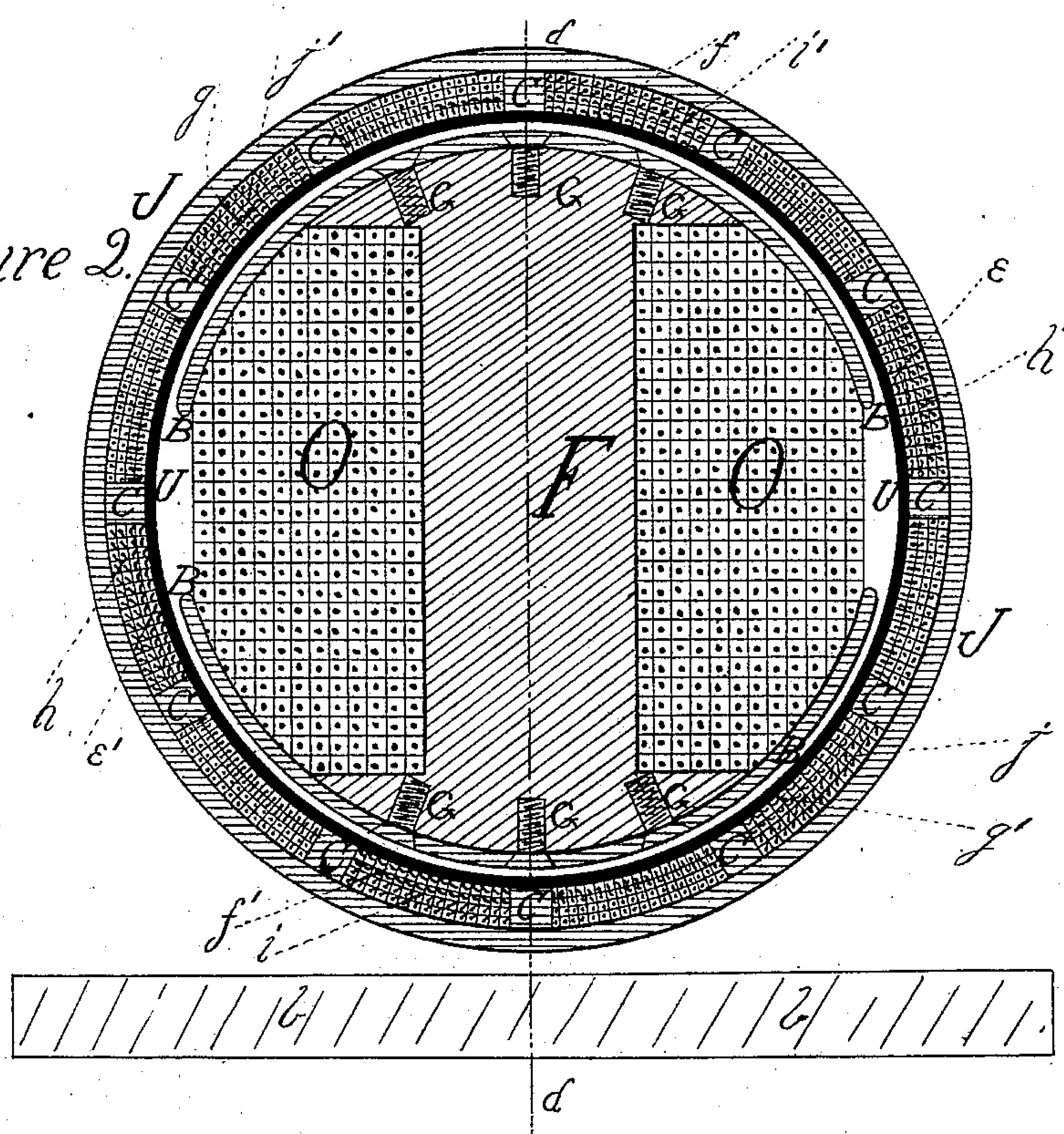
Figure 2.



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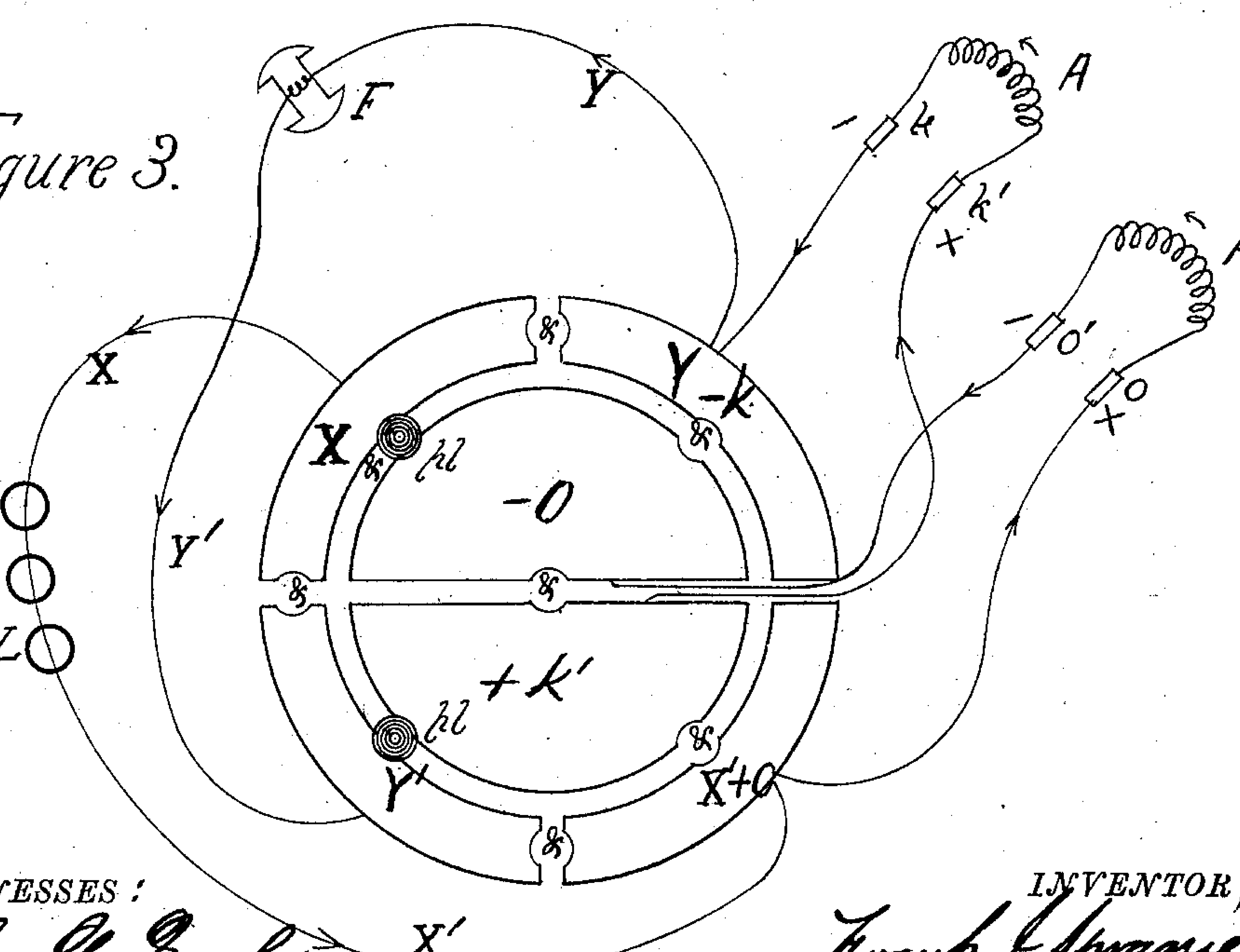

WITNESSES:

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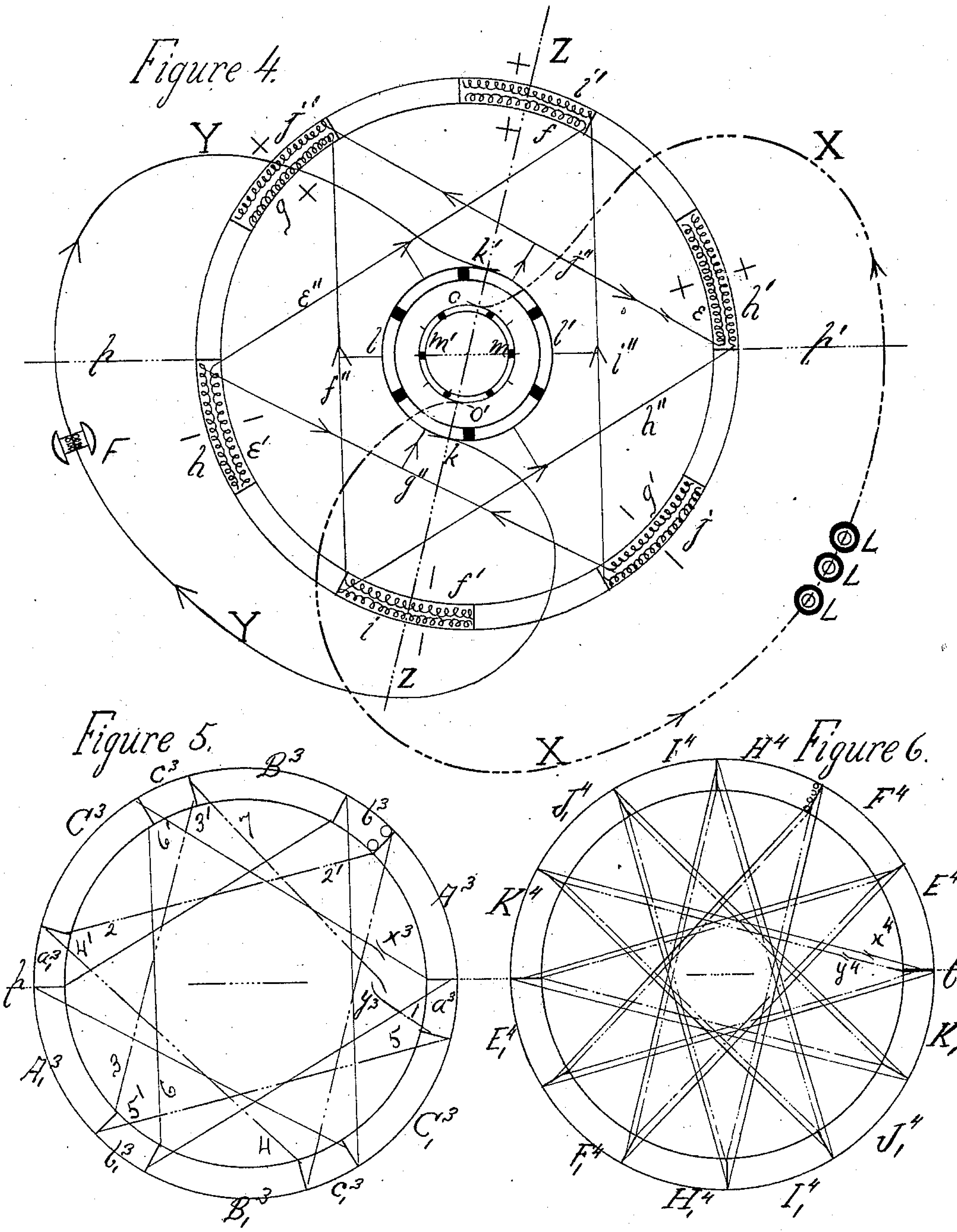
(No Model.)

4 Sheets—Sheet 3.

F. J. SPRAGUE.

DYNAMO ELECTRIC MACHINE.

No. 304,145. Patented Aug. 26, 1884.



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(No Model.) 4 Sheets—Sheet 4.

F. J. SPRAGUE.

DYNAMO ELECTRIC MACHINE.

No. 304,145. Patented Aug. 26, 1884.

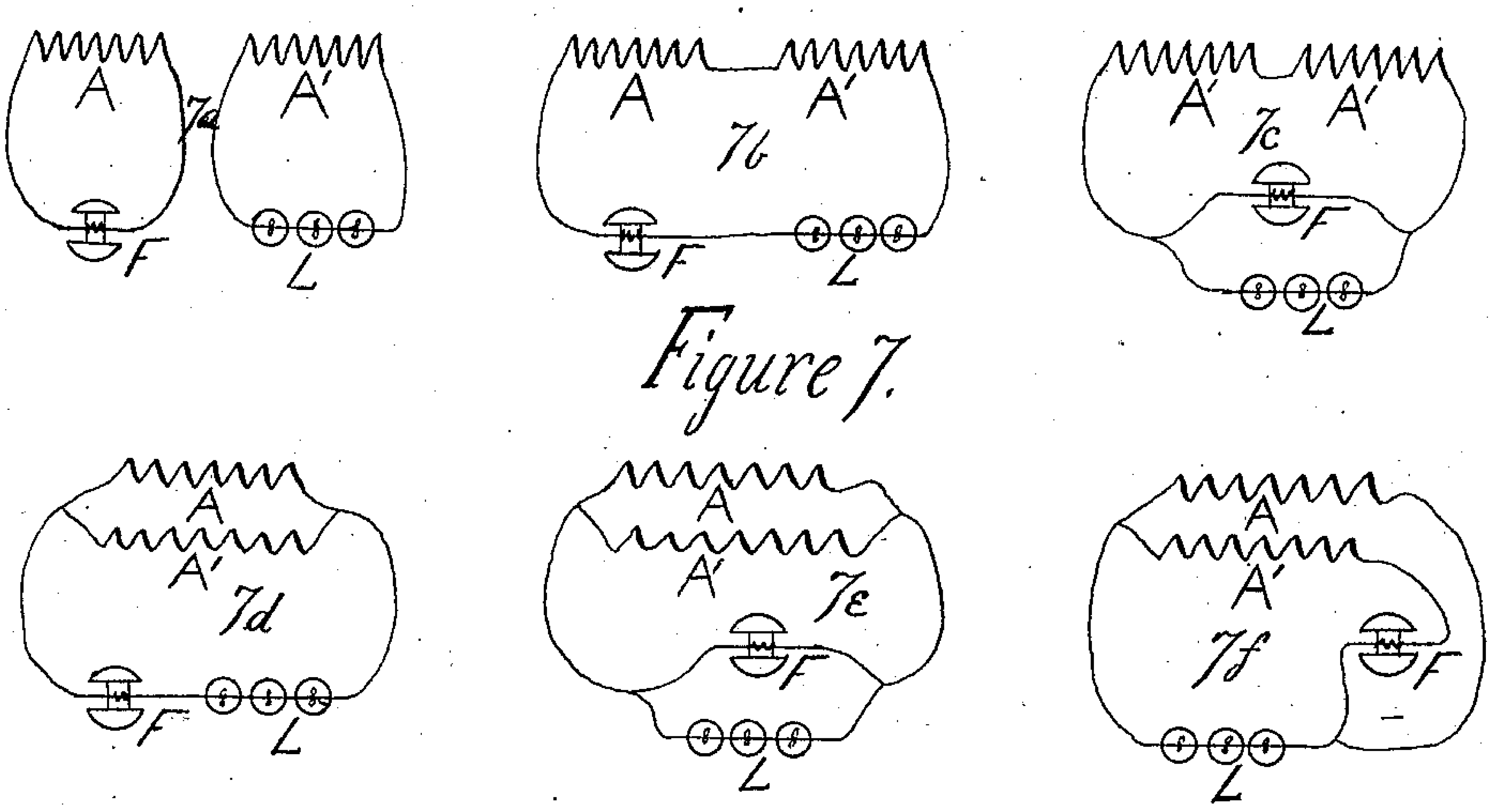


Figure 7.

Figure 8.

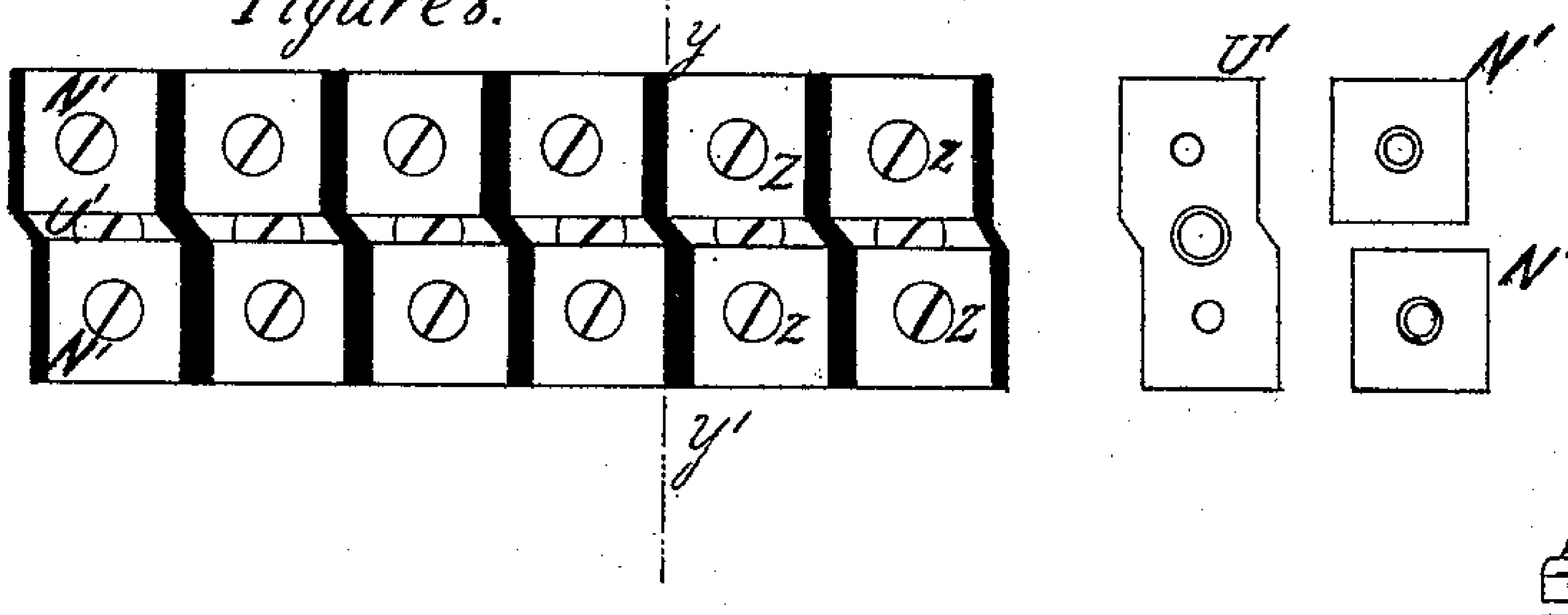


Figure 9.

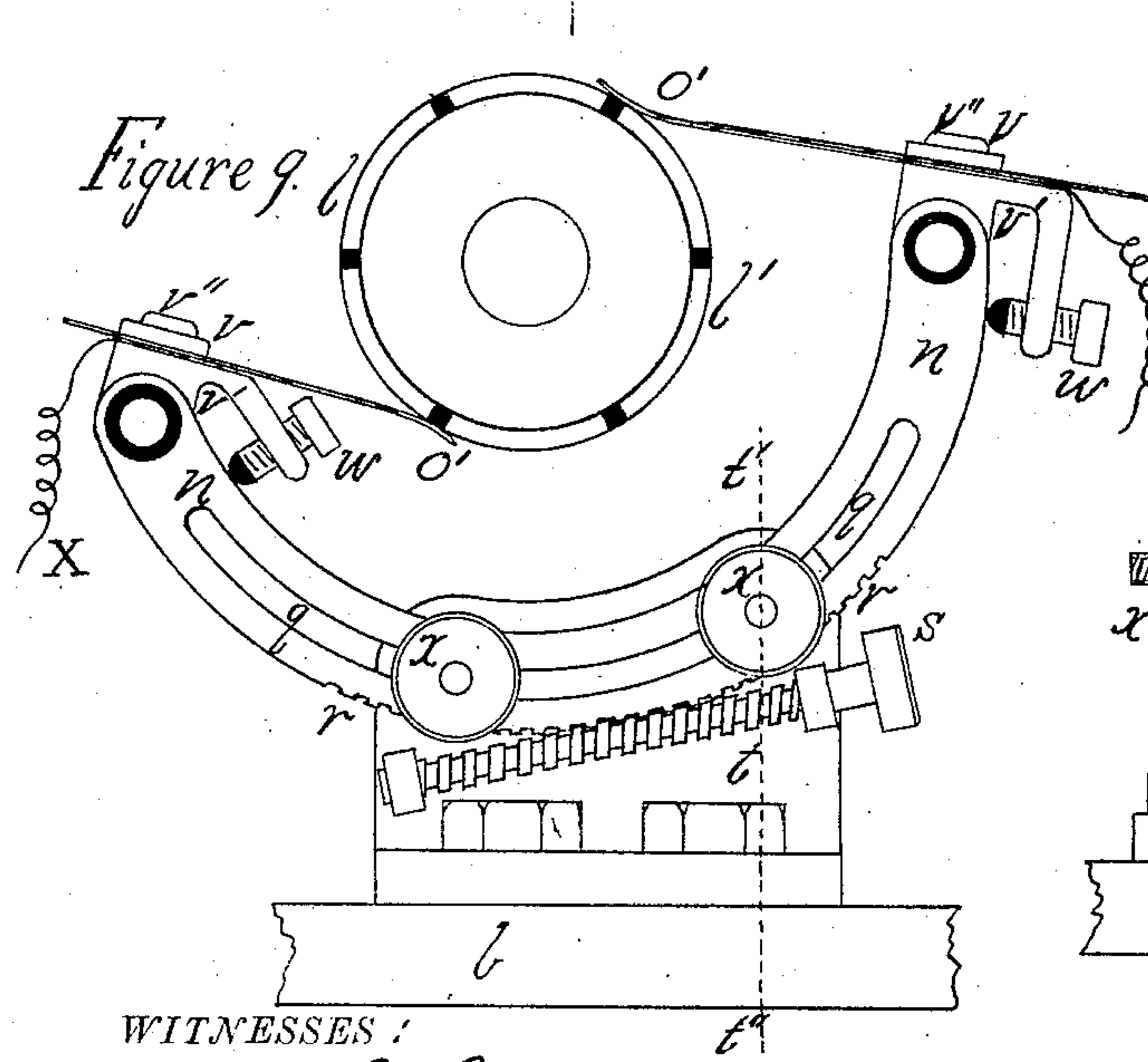


Figure 10.

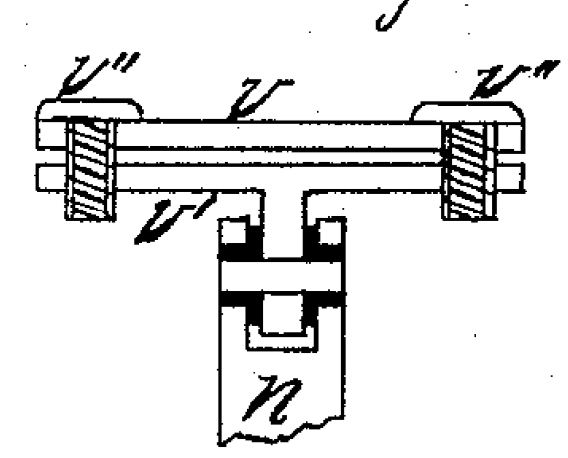
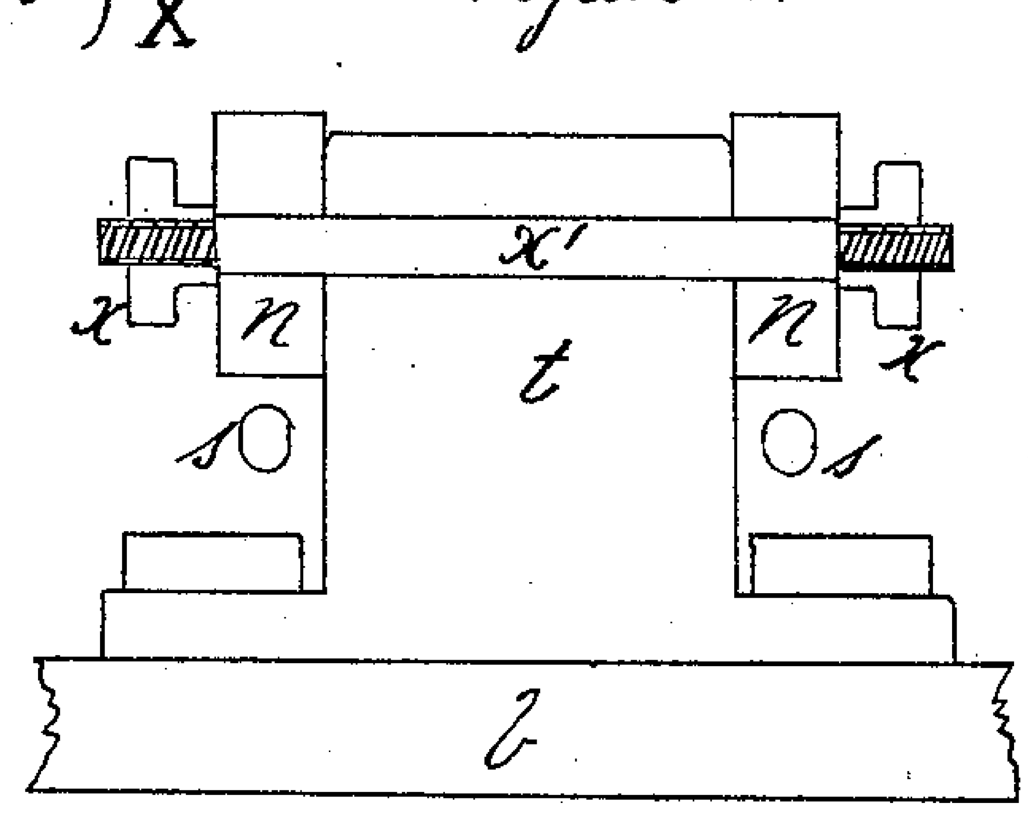


Figure 11.



WITNESSES: John G. Quimby, Harry R. Cohen

INVENTOR: Frank J. Sprague

UNITED STATES PATENT OFFICE.

FRANK J. SPRAGUE, OF THE UNITED STATES NAVY.

DYNAMO-ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 304,145, dated August 26, 1884.

Application filed October 4, 1881. (No model.)

To all whom it may concern:

Be it known that I, FRANK J. SPRAGUE, midshipman, United States Navy, a citizen of the United States of America, residing at North Adams, in the county of Berkshire and State of Massachusetts, have invented certain new and useful Improvements in Dynamo-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, reference being had to the accompanying drawings, and to letters or figures of reference marked thereon, which form a part of this specification.

My improvement relates to that class of dynamo-electric machines in which a system or systems of coils of wire longitudinally traverse an armature which rotates in a magnetic field in close proximity to the poles of one or more electro-magnets, and I aim generally at compactness, efficiency, economy, and steadiness of the current generated.

Although the general working of dynamo-electric machines is well understood, I will collate a few facts which will render the objects of my invention more plain. If a bar of iron has a single coil of wire around it through which a current is sent to magnetize the iron, such coil would be placed at the neutral point of the bar—that is, at the center—such that it would occupy a symmetrical position with regard to the two ends. Then, bearing in mind also that the distance of a turn of wire from the inclosed iron also affects its magnetic influence, I hold that the best distribution of wire on a magnet will be with the maximum amount around the center of the magnet. In support of this theory I cite Sir William Thompson's galvanometer, and the opinion of other leading electricians can be adduced. In the system of winding I adopt I desire wide magnetic fields, and since the end parts of the coils are practically useless, save for the conveyance of the currents, I prefer to have the length of the armature greater than the diameter.

In the form of machine here described the first part of my invention relates to the field-magnets, for which I use a magnet of double T-shaped section with very wide polar extensions, its length greater than its diameter, and so supported by face-plates that the entire space between the polar extensions can be wound full of wire, thus securing the largest amount of wire and the greatest magnetic effect in the least possible space. This cannot be done when the magnet is supported by a bar passing through its center.

The second part of my invention relates to the system of winding, which is a modification of the well-known Alteneck system, and also to the exciting of the field-magnets.

There are in common use two general systems of winding the coils of continuous-current machines where there are but two reversals of the current in any particular coil in one revolution. In the first, each end of a diameter of the armature intercepts two parts of one of a series of coils which are continuously wound around and inclose a magnetic ring or cylinder, and form a closed circuit. The bights of the wire between the coils are joined to separate pieces of a commutator, and brushes connected by an outside circuit and placed in contact with the commutator at the so-called "neutral points," or points of highest and lowest potential, afford a path for the current generated in the two halves of the armature. This is the Gramme system. In the second, each end of a diameter of the armature intercepts one part in each of two coils which form part of a series of continuously-connected coils longitudinally traversing the exterior of a cylinder either magnetic or non-magnetic, and inclosing a magnetic cylinder. The bights of the wire are connected to the separate pieces of a commutator in such order as to allow for the successive changes of polarity, and the currents taken off as before by commutator-brushes. This is the Alteneck system commonly illustrated in the Siemens machine, and is used in several others. A modification of this last is adopted for the armature of my machine, to which I shall again refer.

It is the customary practice to excite the field-magnets by putting the coils of the field-magnet in series with the outside circuit, and sending the whole current through or in arc with the outside circuit, and sending a branch current through. To both systems there is a decided objection in this that the strength of the field-magnet is made, not dependent, as it should be, solely upon the velocity of the armature, but varies with every variation in the resistance of the outside circuit, thus making the current subject to reactionary changes when the outside circuit changes its resistance. To the series arrangement another objection becomes prominent, because, with the proper distribution of wire, but twenty per cent. to twenty-five per cent. of the power put into a machine is needed to well saturate the field-magnets, and when an unnecessarily strong current is sent through the coils their resistance appears as an additional circuit-resistance and energy is wasted in heating the coils.

To obtain a constant field in machines wound on the Alteneck system, separate exciting-machines have been used, and an attempt has been made in other longitudinal coil-machines to lessen the change by having two operative circuits, each of which includes part of the coils of the field-magnets and part of the outside circuit; but two machines are objectionable, yet to get the best result the electro-motive force of a machine must be constant, with a constant velocity, and independent of the resistance of the outside circuit. To obtain this result, the field of the machine and the outside circuit must be perfectly independent. Again, if one machine be used for running both arc and incandescent lights, the absolute need of independent circuits becomes very evident, and in this case there would be three—one for the field, one for the arc lights, and one for the incandescent lights. Finally, while being independent, it may be sometimes desirable with machines having variable work to connect up the independent armature systems, the field, and outside circuits in different arrangements of arc or series. I propose to attain the ends indicated by winding an armature with two or more modified systems of Alteneck coils, each perfectly complete and independent, and connected to its own commutator, and to connect the brushes of the commutators, the field, and outside circuits to a switch in such a manner that the field and lights may be put in independent circuits, thus getting a field independent of outside changes, and securing a steadier main current, and also so that they, with the armature systems, may be thrown into such arrangements of arc or series as may be desired.

In the diagrams, Figs. 4, 5, and 6, I illustrate three methods of winding two independent systems of coils. In Figs. 4 and 6 the divisions of the armature are equal, in Fig. 5, the alternate divisions unequal. In Figs. 4 and 5 each system has six coils—two in each set—of diametrically separate divisions, and the coils in the alternate divisions are continuously connected, and also connected to its commutator. Each of the two commutators would then have six divisions and one set one-half of a division ahead of the other. In Fig. 6 each set of diametrically separate divisions has four coils, one half being continuously connected and joined to its commutator, and the other half likewise continuously connected and joined to its commutator. Similar windings would be made if three systems were used. It is evident that the result is the same whether one, two, or four wires are used in winding, and also that the size of the wire and the number of turns in each system may be different from that in the other. Further explanation of the system of winding will be given with particular reference to the drawings. I do not limit this system or practice of using two or more independent systems of modified Alteneck coils to the form of machine I here describe, but claim, broadly, its application to any number or form of field-magnets, whether internal or external, and such use is evident without further illustration.

The third feature of my invention relates to the switch aforementioned and its connections, which is so constructed and its parts put into such juxtaposition that, by the insertion of plugs, such connections as are desired may be made.

The fourth feature in my present invention consists in providing a combination of magnetic and non-magnetic substances to give support to my rotating system of coils, to concentrate the magnetic field, and to afford a free radiation for any heat caused by changes of polarity in my armature. The ends of this frame-work are disk-shaped, and have projecting from the center hollow shafts, which are supported by the arms which project from the magnet face-plates, the diameter of the disk to be slightly greater than the diameter of the field-magnets. These disks support a cylinder of hard rubber or stiffened paper, to keep the bights of the wire free from the polar extensions, and yet allow close proximity. To stiffen this system, afford walls to separate the coils, and to intensify the magnetic field, as many soft-iron ribs as there are coils extend longitudinally along the cylinder, and are secured to the disks by screws. These ribs may be at equal or unequal distances, as circumstances may require. After the coils are wound on this machine the outside of the armature is wrapped with soft-iron wire or surrounded with iron rings, continuous or non-continuous, which afford a close magnetic contact with the iron ribs, and a path from pole to pole for the magnetic field, this metallic wrapping to revolve with the coils.

It will be seen that in the machine I am describing I propose to use a stationary internal magnet, which gives the most natural field of force—a radiating field from a cylindrical surface—in combination with a rotating system or systems of coils and armature, which armature shall be outside of the coils, and having one surface entirely exposed to the free action of the air.

In all machines having a continuous change in the magnetic state of iron there is, when the change is sufficiently rapid, a heating of the armature, and this heating is due to the induced currents in the iron. This has been to a certain extent lessened by breaking up the iron of the armature, and by affording paths for the air to circulate through it; but the results have not been entirely satisfactory, partly because the iron of the armature is usually to a great extent covered up or inclosed by the coils, so that it is not only heated by the self-induced currents, but also, by conduction from the surrounding coils, which are themselves heated by their own current. By putting the iron of the armature outside of the coils, which armature may be broken up or divided as much as desired, and rotating this armature, I obtain the freest possible radiation from its surface, and the displacement of heated air by centrifugal force, thus being able to attain a higher velocity, and consequently greater efficiency, with a machine of any given size.

The fifth feature of my invention relates to the commutators. These are carried on the hollow shaft of the armature-disks, and insulated therefrom by a bushing of paper, wood, or hard rubber. I desire to have a commutator which will allow the brush to make good contact with any section before breaking contact with the one it is leaving, to have the double contact for the shortest angular distance and time, and to be able to readily replace the wearing parts. To this end each section is composed of three parts—one of the shape shown in drawings, which is secured by screws to the insulating-bushing, and the two others segments of cylinders of the same width as the ends of the first-mentioned piece, and a little less than one-half its length screwed onto the inner piece, so that the advance edge of the inner piece shall be in nearly the same line as the rear edge of the outer piece of the next division of the commutator. In this way, while in contact, less than nearly one-half the brush is never used, and the period of double contact is made as small as possible. Each inner section has an independent wire secured to the outer end, and led through holes in the insulating-bushing, thus allowing the free ends to be handled without danger of breaking away. The commutators can be placed on the same or opposite ends of the armature-cylinder. When on the same end the wires from the outer commutator are led through holes in the bushing of the inner ones.

The sixth feature of my invention consists in an adjustable brush-carrier which shall allow a change in the position and pressure of the commutator-brushes. The carrier for each pair of brushes consists of metal or an insulating material, or a combination of the two, and is in the form of the arc of a circle of about one hundred and twenty degrees, with a groove or slot extending about three-fourths its length. This arc is held against the plain face of a support, from which project two screws set in the arc of a circle of the same radius as that of the slot, and may be clamped in any limited position by two clamp-screws. On the lower edge are cut several teeth, which engage the threads of a screw held in a fixed position by two lugs projecting from the support, thus affording a convenient means of changing the position of the brushes. At each end of the arc are two small clamps supported by a pin, and capable of limited rotation in the plane of the arc. These are provided with clamp-pieces to hold the brushes in their angular position, and consequently the pressure of the brushes, which, being of rolled and hammered copper, have an elasticity of their own, may be regulated by thumb-screws acting against the arc.

Dynamo-machines are used ordinarily on two kinds of circuits—one where the lamps are in series and the other where the lamps or motors are in derived circuits, practically in multiple arc. In the first the currents should be always maintained the same in quantity, and the electro-motive force must be increased in a somewhat less rapid ratio than the external resistance, depending upon the relation of the internal and external resistance. In the other the difference of potential at the terminals of the machine should be very nearly constant, and this requires an increased electro-motive force, with the decrease of external resistance caused by adding derived circuits. There are two ways of increasing the electro-motive force—one by increasing the strength of the current in the field-magnet, the other by increasing the velocity of the armature. Both methods may be advantageously used with the lamps in series; but in the multiple-arc arrangement it is better to have a high constant velocity, a low internal resistance, and to regulate by regulating the field-current. I am aware that this has been done and in the following methods: a regulator, a mechanical arrangement to turn the brushes, set in action by a controlling-magnet has been attached to the machine, and the magnet being put in the main current or a derived circuit, or the current increased or decreased from the normal, the brushes have been moved one way or the other to change the strength of the field-current. In this plan a part of the main current set in motion the brushes collecting the same, a great objection to which is that this change is too marked, and much sparking and wear result because of the whole current being involved. Since practice has shown the great advantage of an independent field-circuit, this has led to the use of a regulator on one machine, which supplies the field controlled by a part of the current from the main machine. Another method is that shown by patent to Maxim, No. 228,543, June 8, 1880, in which two armatures, each with its own separate field, have been mounted on the same shaft, and the current from the main armature controlled the brushes in the auxiliary. To both arrangements there is the great objection of practically two machines, two plants, and increased space required, to say nothing of the cost. I propose to obviate this difficulty or objection by my multiple-circuit armature.

The accompanying drawings are as follows: Figure 1 is a longitudinal section of the machine, with the armature-wire shown only in outline, and leaving out the commutator-brushes. Fig. 2 is a transverse section at the line *a a* in Fig. 1; Fig. 3, a diagram of the switch, the connection with the field, lights, and two systems of armature-coils, with plugs in to connect up in independent circuits; Fig. 4, a diagram of one end of the armature-cylinder and commutators, with an illustration of the method of winding the system of coils, which supply the field when the divisions are equal. The other system is wound in precisely the same manner and supplies the outside operative circuit. Its commutator is shown in its relative angular position only. Fig. 5 is a diagram of the end of the cylinder for both coils when the divisions are unequal, with the commutator-connections left out; Fig. 6, a diagram of the end of the cylinder for both coils when divisions are equal, and both systems—that is, four coils—wound in the same division; Fig. 7, *a*, *b*, *c*, *d*, *e*, and *f*, diagrams of the different arrangements of the independent systems of armature-coils, the field-coils, and the outside lamp or motor-circuits, afforded by varying the switch-connections; Fig. 8, a development of the commutator, with separate pieces at one side; Fig. 9, elevation of commutator and adjustable brush-carrier; Fig. 10, brush-holder; Fig. 11, section of carrier at *t′ t″*.

The present machine consists of a large **I**-shaped casting or forging, F, with the exterior faces forming segments of a circle. On this is shrunk a smooth-turned wrought-iron cylinder, which is secured by screws G G, after which the parts half-way between the faces are cut away, leaving wide polar extensions B B. These polar extensions being removed, the whole space is wound full of wire O, and the polar extensions restored to their places. A current being passed through the wire O, produces an electro-magnet with wide polar extensions. To support this magnet, two cup-disk faces with projecting arms D D are secured to the ends of the magnet F by screws H H. The arms D D are supported and held rigid at one end by a slotted standard, S′, with cap S″, and at the other end by a standard, S, and screw R. The arms D D are surrounded by steel sleeves K, shrunk on. Outside of the arms D D are hollow composition sleeves E′ E″, forming projecting arms to the exterior disks, E E, the diameter of these disks being slightly greater than the diameter of the field-magnet. These disks fit in the ends of a rubber or stiffened paper cylinder U, and are rigidly secured together by a number of soft-iron bars, C C—in this case twelve—held to the periphery of the disks by countersunk screws I I. In each of the diametrically-opposite divisions are wound two coils, *e e′* and *h h′*, *f f′* and *i i′*, *g g′* and *j j′*, &c., and the coils in the alternate divisions are connected to each other and to the divisions of the commutators, as will be indicated in the explanation of Fig. 4.

In the machine here illustrated there are two commutators, M′ M′, and two independent sets of coils, which will be called A A′. Three sets of coils can be wound and connected in a similar manner. In Fig. 1 the external contour of the coils is indicated by the dotted lines *c c*. The method of winding will be described farther on. Outside of the coils and ribs is a soft-iron shell, J, in metallic contact with the ribs C C. This may be formed by wrapping with iron wire, or of a series of iron rings, continuous or non-continuous, or perforated, or otherwise broken up for the purpose of ventilation. This shell with the ribs serves to make a powerful radial magnetic field, and is, in fact, an external cylindrical iron armature with the armature-coils wound upon the inside. This armature, while performing the usual function of producing a more available magnetic field, has the external surface entirely exposed to the air, so that any heat produced by induced currents will have the freest possible radiation, and its dissipation facilitated by the displacement of heated air by centrifugal force.

On one arm E″ is the driving-pulley P, secured by screws Q Q; on the other, E′, as many commutators M′ M′ as there are independent systems of coils, insulated from the arm by a rubber, wood, or paper bushing, V. Fig. 8 is a development of one of the commutators, which is intended to allow continuous contact by the brushes, the shortest double contact, and for replacing when worn. Each section is composed of an under part, U′, which is secured to the insulating bushing, and is electrically connected to the proper bights of the armature-coils, and two other parts, N′ N′, which are held by screws *z z* to the part U′, and may be easily replaced. The line of brush-contact being *y y′*, it is evident how the ends desired are secured.

Fig. 3 illustrates the switch for varying the arrangement of armature systems, light-circuit, and field-circuit. It consists of two semi-circles of composition, —O and +*k′*, outside of which are four quadrants, X, Y—*k*, X′+O, and Y′, which are lettered according to the circuits to which they are connected, as indicated. The different sections are cut to receive composition plugs *pl pl* to form electrical connection between any two parts. In the diagram the plugs are inserted to form independent circuits—one of the primary objects of my invention. This arrangement is also shown as 7*a* in Fig. 7. In the same figure, 7*b* shows the arrangement of all in series; 7*c*, armature systems in series, field and lights in arc; 7*d*, armature systems in arc, field and lights in series; 7*e*, armature systems in arc, field and lights in arc; 7*f*, one armature system in series with field, both systems in arc with lights. This freedom of arrangement enables a very varied field of work to be performed in the best possible way with this machine.

The commutator-brushes *o o'* are held by clamp *v* and screws *v'' v''* to the arm *v'*, held by pins to and insulated from the arc-shaped carrier *n*. These arms are moved in a vertical plane by screws *w w*. The carriers *n* have a slot, *q*, and are held against the face of a support, *t*, by clamp-screws *x x* engaging the threads of screws on the end of stationary pin *x'*. On the lower edge are cut several teeth, which engage the threads of a tangent screw, *s*, held by lugs on face of support *t*. The leading wires of the field-magnet are led out through an axial hole in one arm, D', and both sleeves are oiled by feeders W W, supplying oil, which passes into axial holes in the arms D'' D'', and out of radial holes *d'' d''*, being forced outward along spiral grooves cut in the direction of rotation around the arms D D.

To resume the winding and connections of the independent systems of coils to their commutators, let us refer to Fig. 4, which illustrates the coils of one series, the connection between the coils on the end of the armature next to the commutators, the connections of the coils of that system to its commutator, the field-circuit Y F Y, and the angular position of the second commutator and its connection with the lamp-circuit X L X. The spaces for the coils for the lamp-circuit system are left vacant for clearness; but the coils of this system are wound in precisely the same manner as the other. The winding is illustrated by one continuous wire, but the result is the same whether a single or double wire is used, and afterward connected up. To wind, start at *e* and wind down *e*, up *e'*, until a sufficient number of turns have been taken; then take the last turn *e''* and carry it to the second division following, and wind down *f* and up *f'*, as before; then carry last end *f''* to second division following last, and wind down *g* and up *g'*, as before; then pass to the divisions first wound and wind over the first coil in the reverse direction—that is, down *h* and up *h'*; then down *i* and up *i'*; then down *j* and up *j'*, bringing the last turn *j''* to join the first turn *e*. Now, connect the bights *e''*, *f''*, *g''*, *h''*, *i''*, and *j''* to the nearest division of the commutator. Let *p p'* be the neutral magnetic line half-way between the poles of the field-magnet. Then when the armature-coils are revolved in the proper direction + currents are induced in the coils above the neutral line, and — currents in those below, making the currents in any coil complete. The neutral commutator-line Z Z is nearly at right angles to the neutral magnetic line. The brushes *k k'* in contact with the commutator at the points of highest and lowest potential take off the current for the field-circuit Y F Y. The current for the lamp-circuit X L X is taken off from its commutator by the brushes *o o'*.

Fig. 5 represents the end connections of both systems of coils when the divisions are of different widths, but the winding is precisely the same as in the preceding case. Fig. 6 represents the end connections when both systems are wound in the same division—that is, with four distinct coils in each pair of diametrically-opposite divisions, and each set of coils are connected to the coils in the next adjacent pair of divisions, as in the ordinary Alteneck system of single circuit.

It is evident that the size of the wire and the number of turns in the two systems may be unlike as well as that the number of systems of coils may be more than two.

It is evident that the machine when put in circuit with a suitable source of electrical energy becomes an electro-dynamic motor, and that the invention possesses advantages similar to those before set forth when the machine is given its reversible function.

Having thus described my invention, I claim as new and pray that Letters Patent may be granted for the following:

1. The combination, with a field-magnet, of a rotating cylinder inclosing the same, said cylinder including longitudinal armature-coils and an external magnetic shell secured together, substantially as set forth.

2. The combination, with a field-magnet, of a rotating cylinder inclosing the same, said cylinder including longitudinal armature-coils and an external magnetic shell, composed of a wrapping of iron wire secured upon said armature-coils, substantially as set forth.

3. A rotating duplex cylinder composed of an inner non-magnetic shell, an outer magnetic shell, with intermediate magnetic ribs, the whole rigidly secured together and supported by face-plates, and adapted to give support to one or more systems of rotating coils wound between the ribs, substantially as set forth.

4. The combination, with a field-magnet having centrally-projecting arms, of a rotating cylinder inclosing such magnet, and having sleeves turning upon said magnet-arms, said cylinder including longitudinal armature-coils and an external magnetic shell secured together, substantially as set forth.

5. The combination of a field-magnet of H form, with fixed poles, and a rotating cylinder inclosing such magnet, and including longitudinal armature-coils and an external magnetic shell secured together, substantially as set forth.

6. The field-magnet supported by end plates, and having its winding within said plates, in combination with a rotating cylin-

der inclosing such magnet, and including longitudinal armature-coils and an external magnetic shell, substantially as set forth.

7. The field-magnet supported by end plates and central arms, and having its winding within said plates, in combination with a rotating cylinder inclosing such magnet, and having end plates provided with sleeves which turn upon the magnet-arms, substantially as set forth.

8. The cylindrical field-magnet of H form, composed of a central web, extended pole-pieces secured to the central web, end plates and central supporting-arms, and a winding wholly within the end plates, substantially as set forth.

9. The combination, with an armature having two or more independent windings connected to separate commutators, of a field-magnet, one or more external circuits, and a switch for permitting the connection of the armature, field-magnet and external circuits in any desired arrangement of arc or series, substantially as set forth.

10. The switch composed of the six contiguous parts, in combination with the two armature-circuits, the field-magnet circuit and the external circuit connected to such parts as described, and means for making and breaking connection between the parts of the switch to produce any desired arrangement of series or arc between the said four circuits, substantially as set forth.

11. In a commutator, the combination of the sections, each composed of three parts, U′ and N′ N′, the parts N′ N′ being removably secured upon U′, and projecting laterally therefrom in opposite directions, substantially as set forth.

12. In a commutator brush-holder, a slotted arc-shaped carrier having a curved slot for adjustment concentric with the commutator, a worm for adjusting said carrier, rocking brush-holder supported by said carrier, and screws for adjusting said rocking brush-holder upon said carrier, substantially as set forth.

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

FRANK J. SPRAGUE.

Witnesses:

JOHN G. QUINBY,
HARRY R. COHEN.