(No Model.) 6 Sheets—Sheet 1.

W. MAIN.

ELECTROMOTOR AND DYNAMO ELECTRIC MACHINE.

No. 373,146. Patented Nov. 15, 1887.

Fig. 1.

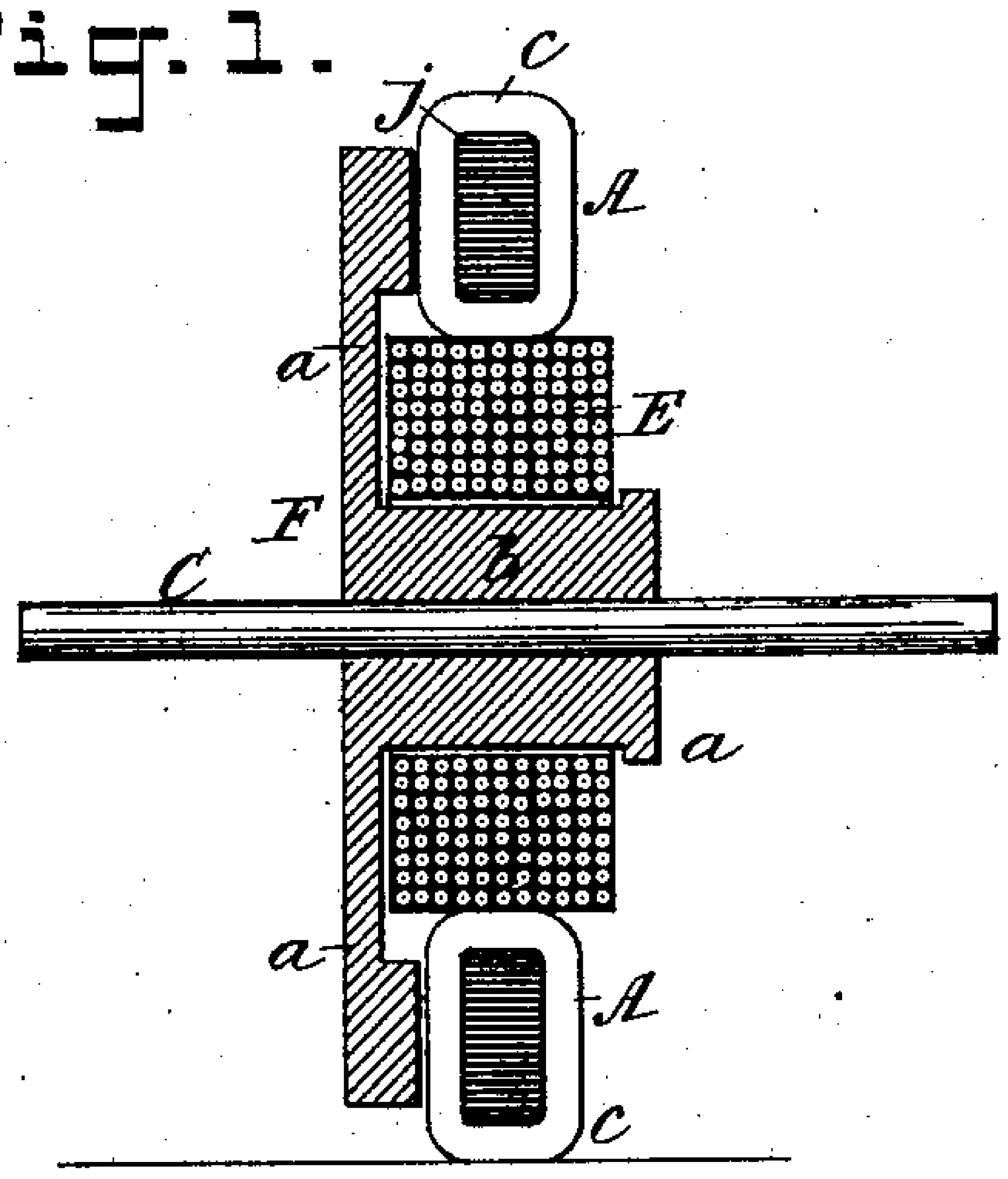

Fig. 2.

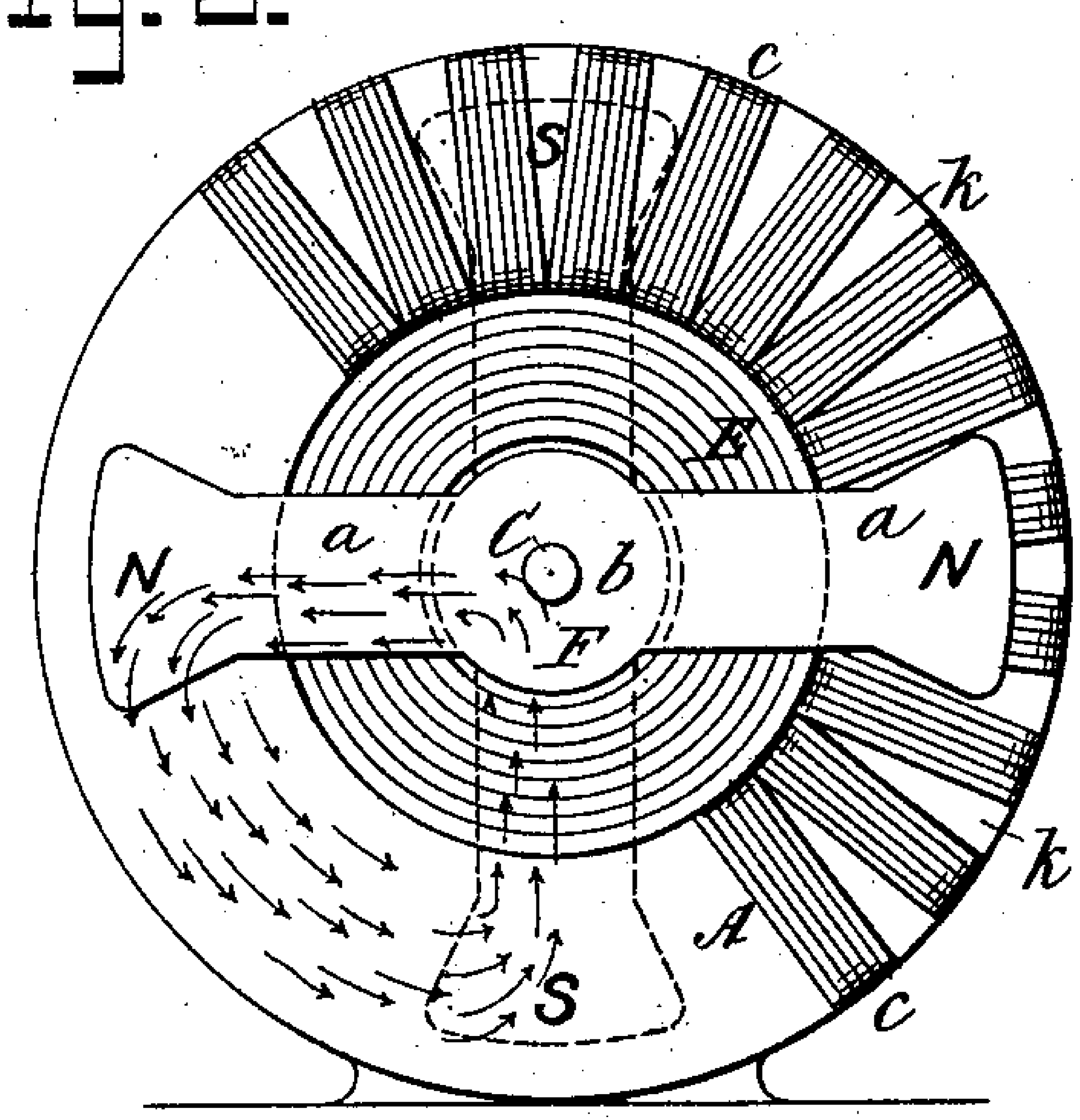

Fig. 3.

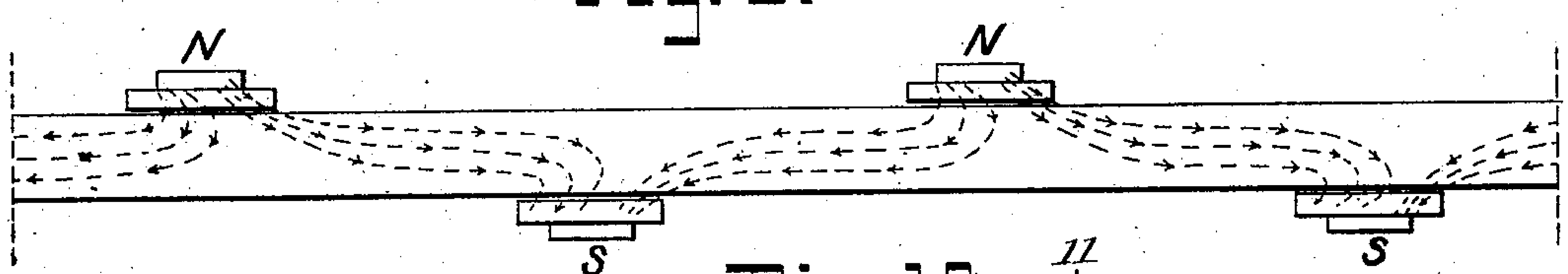

Fig. 11.

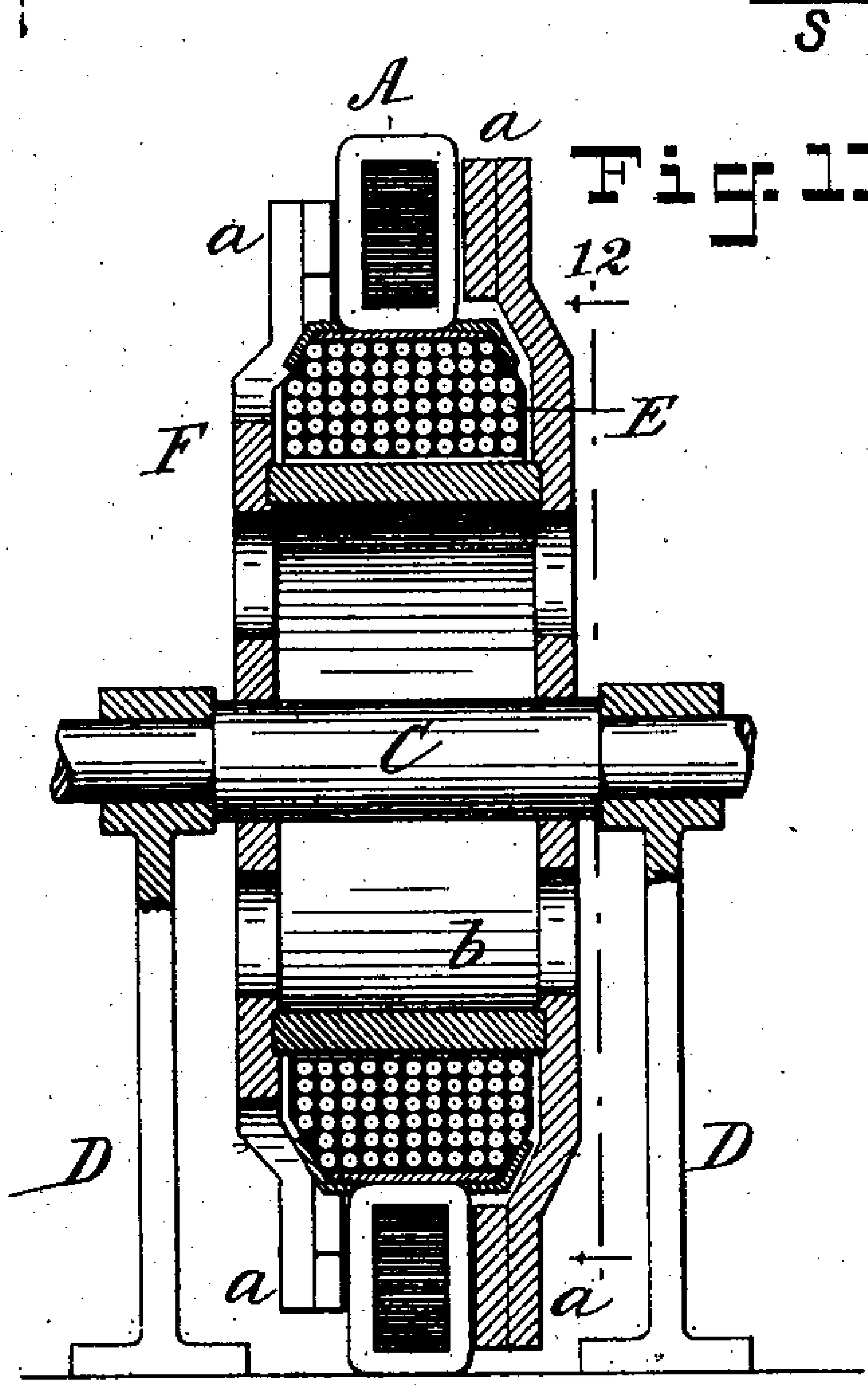

Fig. 12.

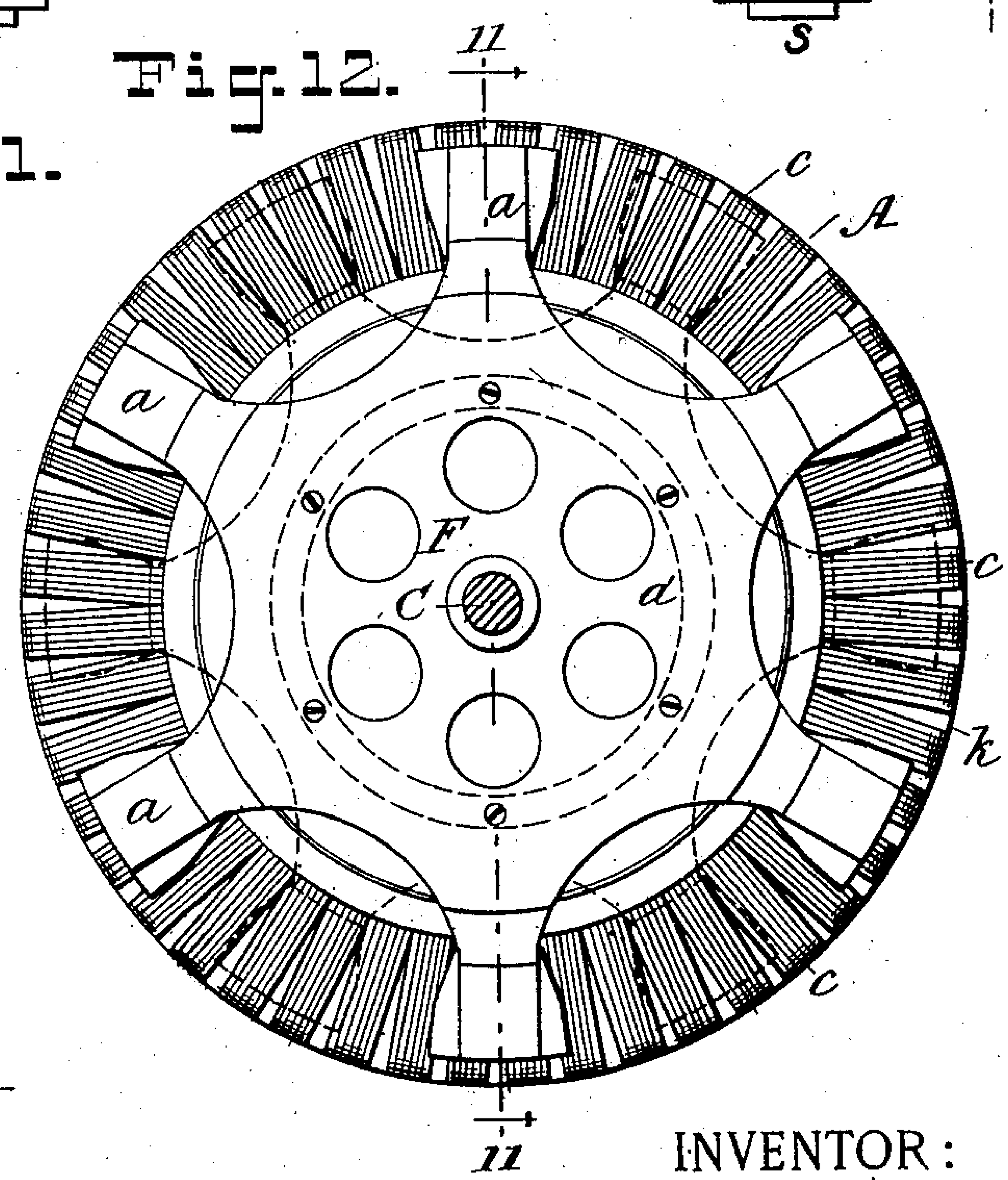

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Fig. 4.

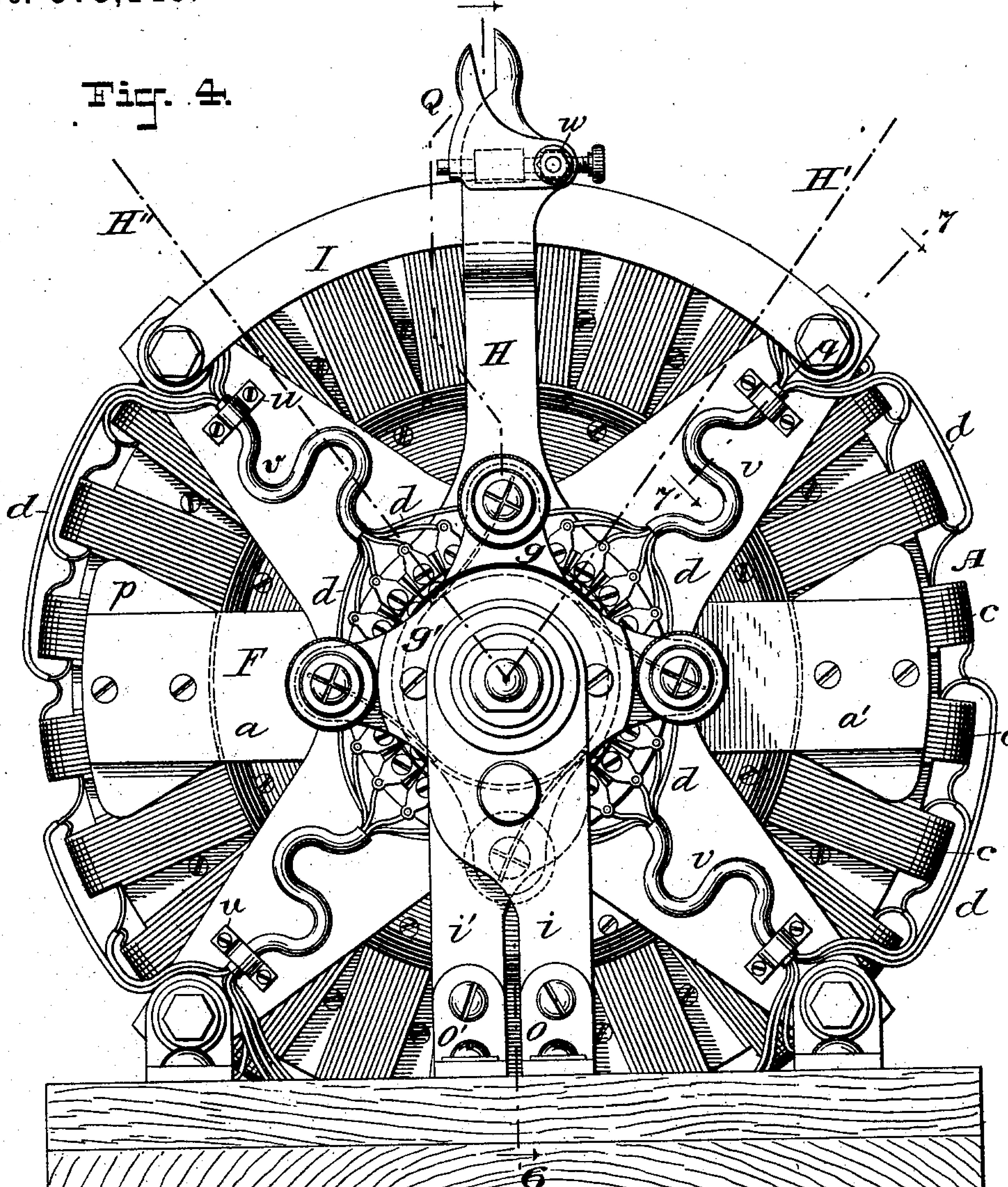

Fig. 10.

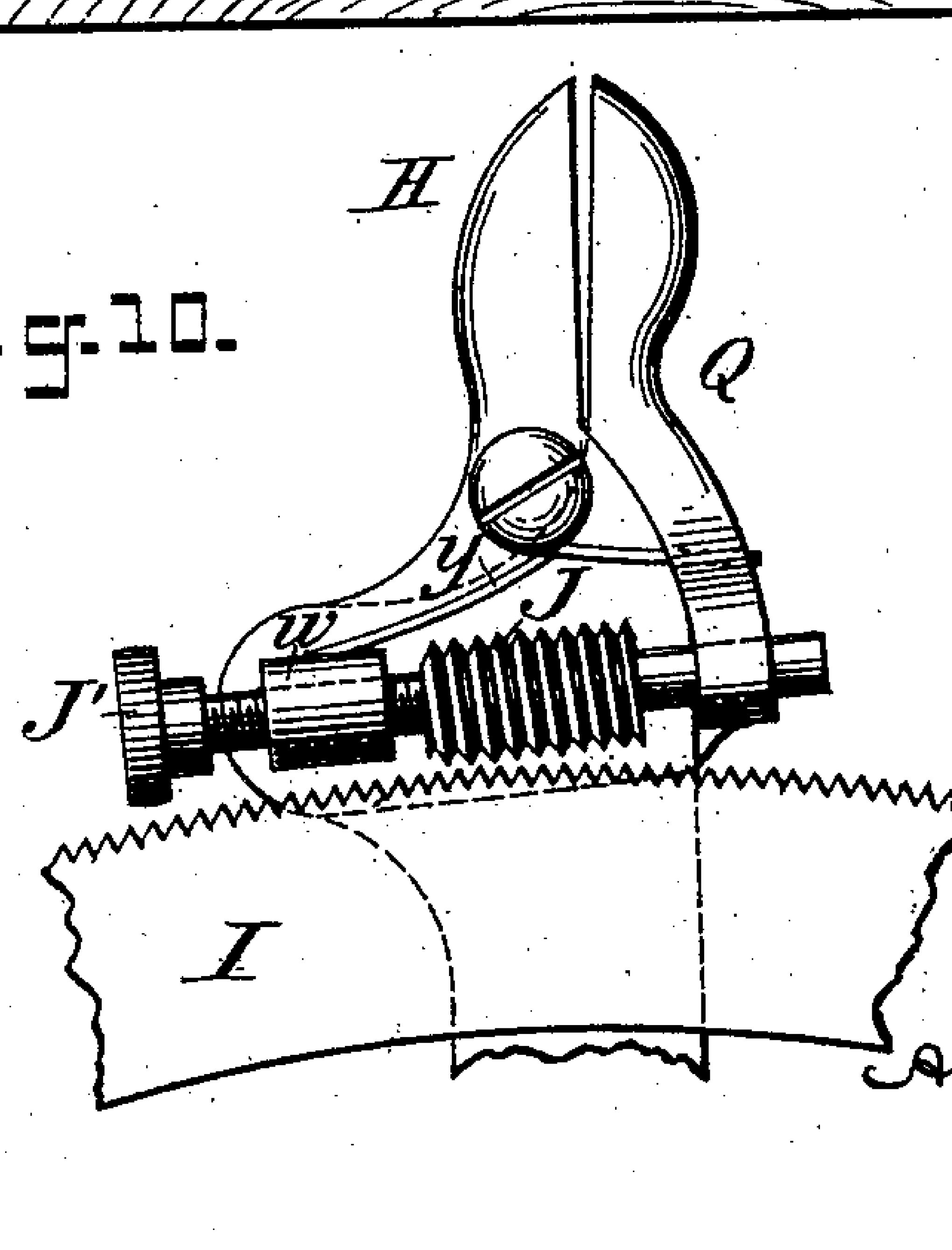

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Fig. 5.

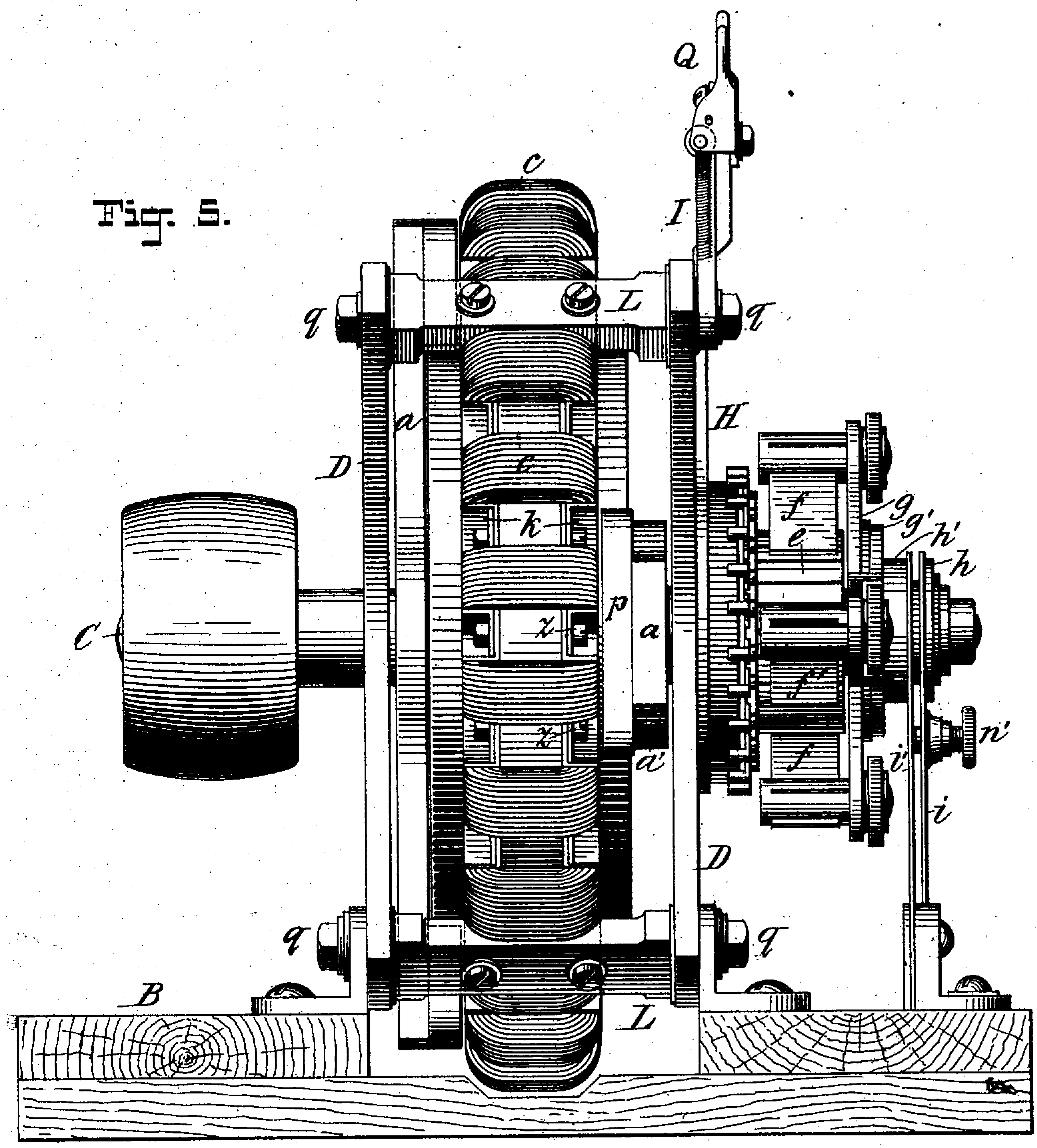

Fig. 14.

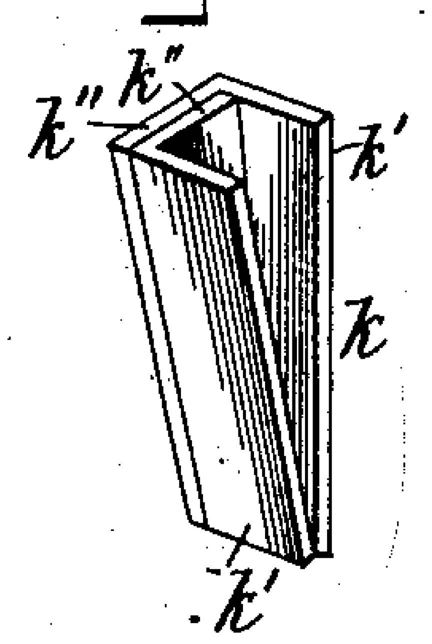

Fig. 15.

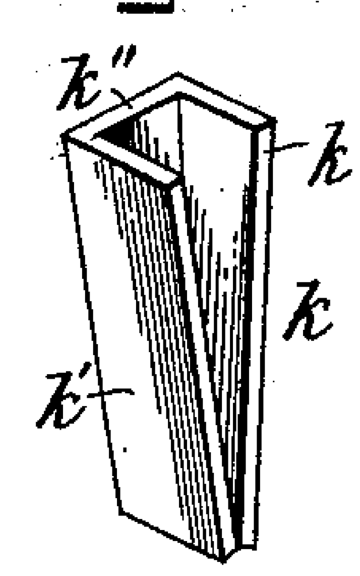

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Fig. 8.

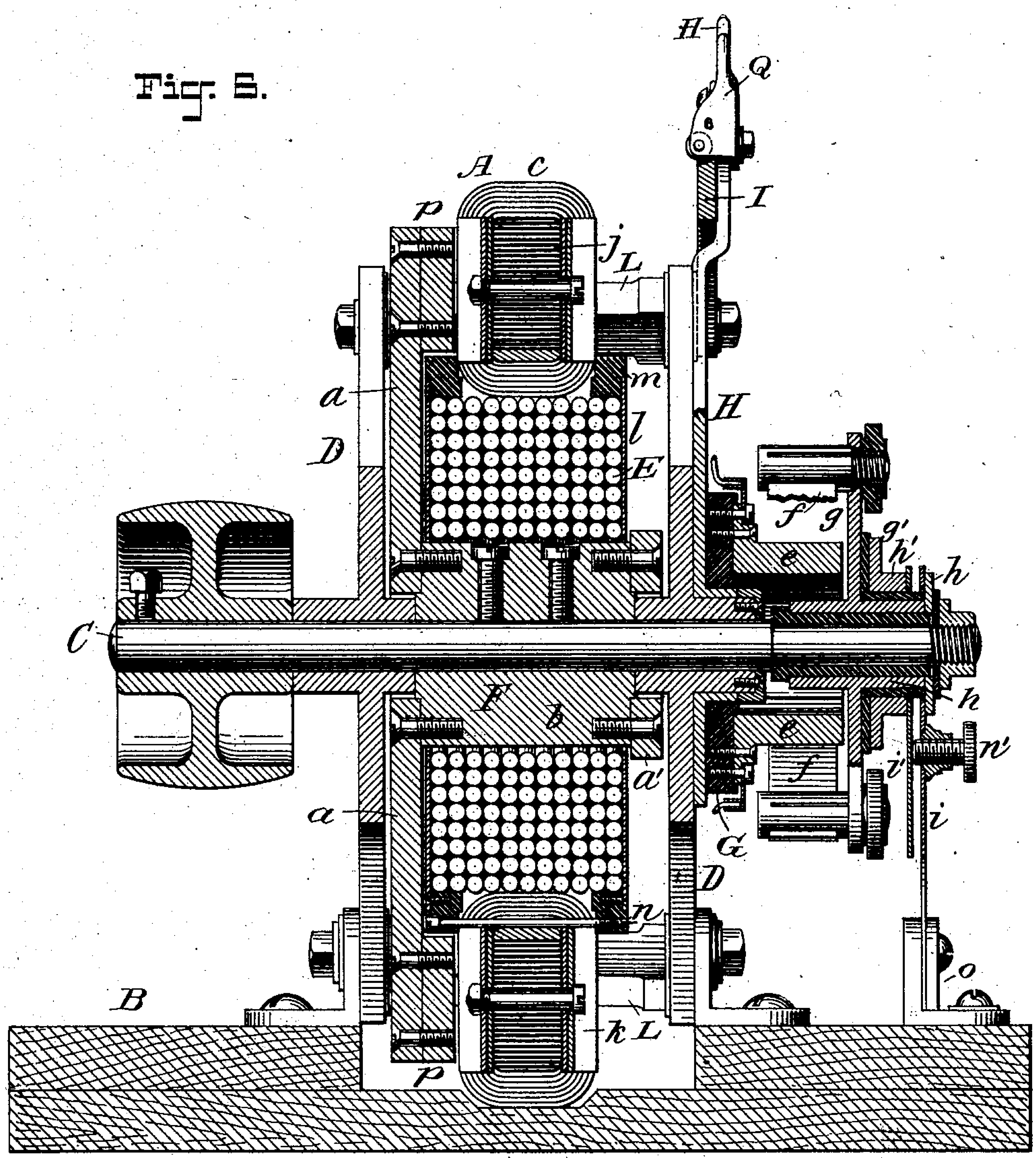

Fig. 16.

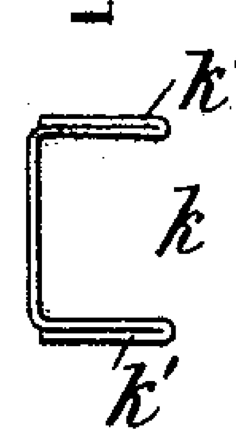

Fig. 17.

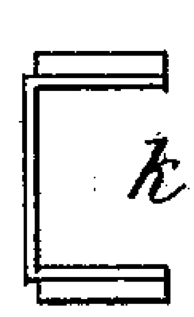

Fig. 18.

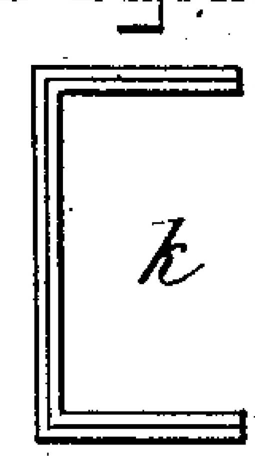

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Fig. 7.

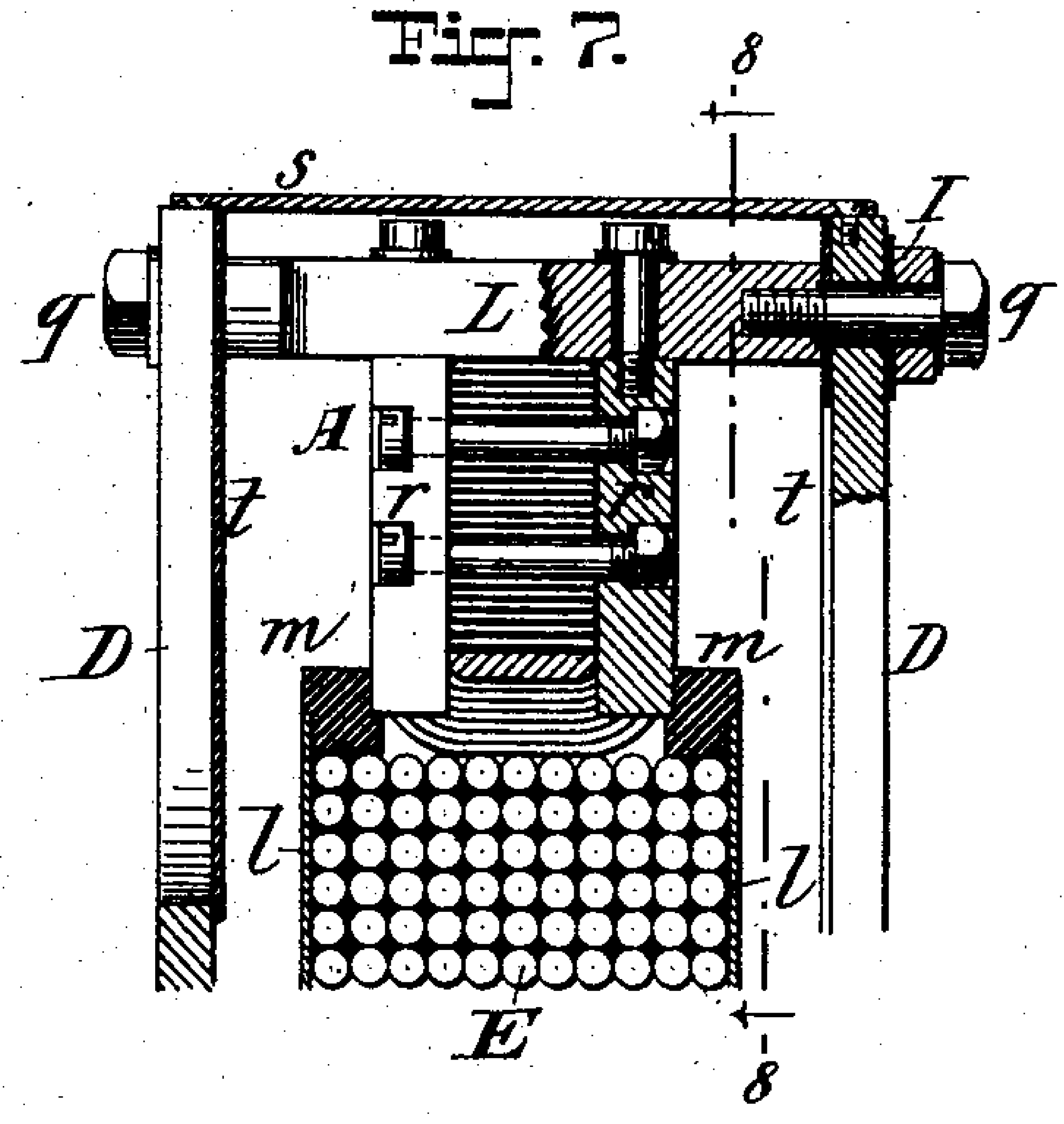

Fig. 8.

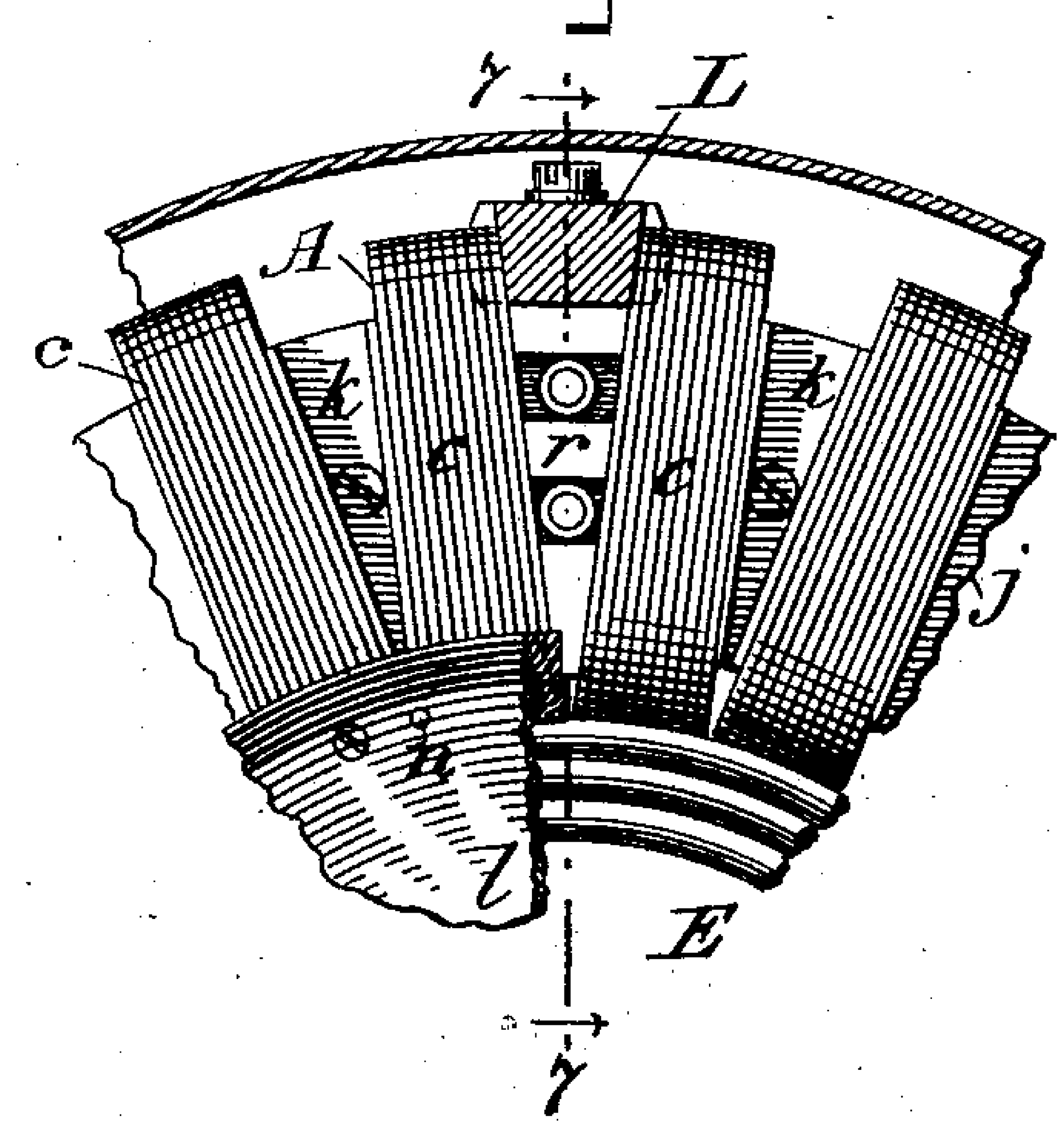

Fig. 9.

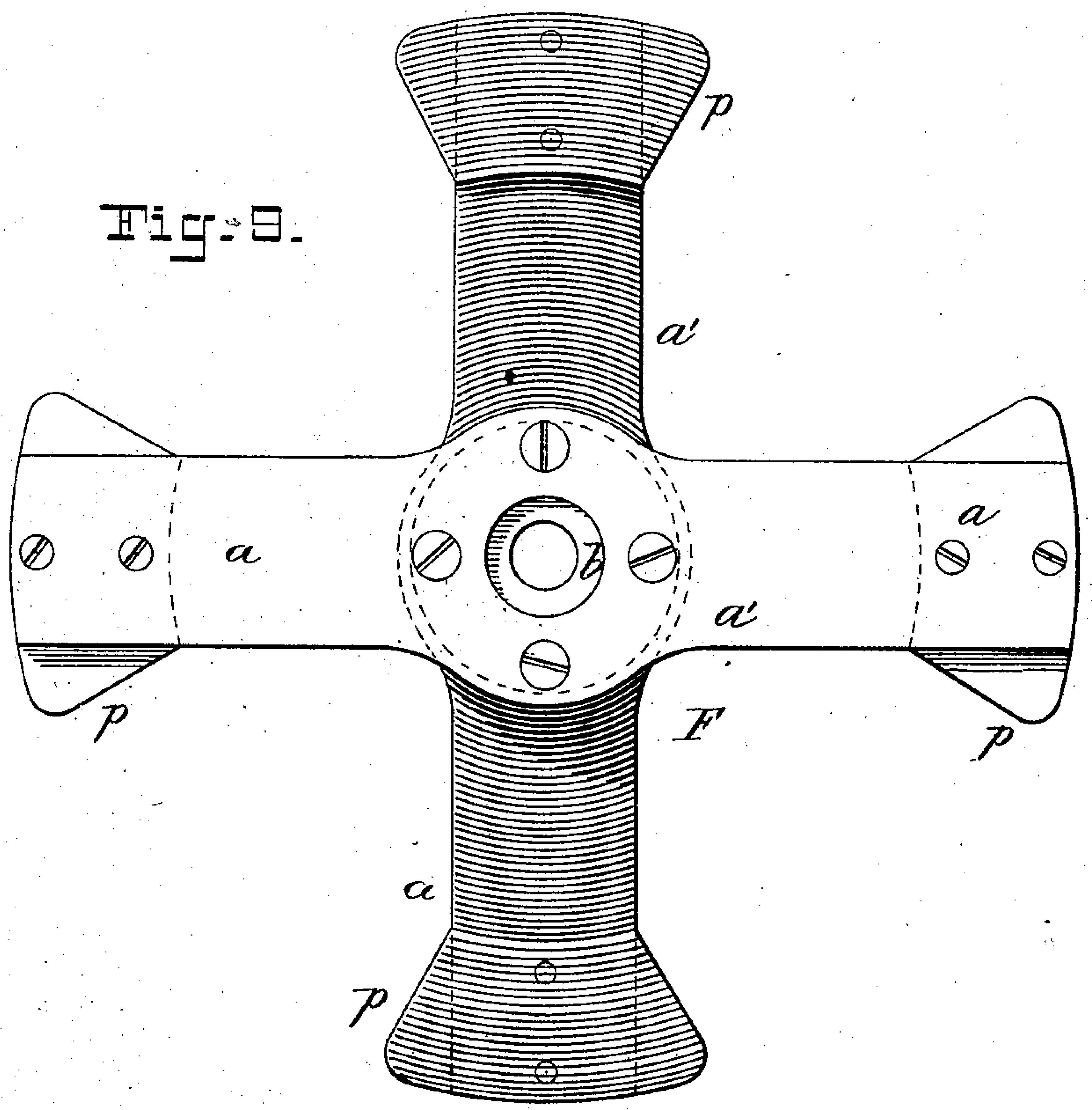

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Fig. 19.

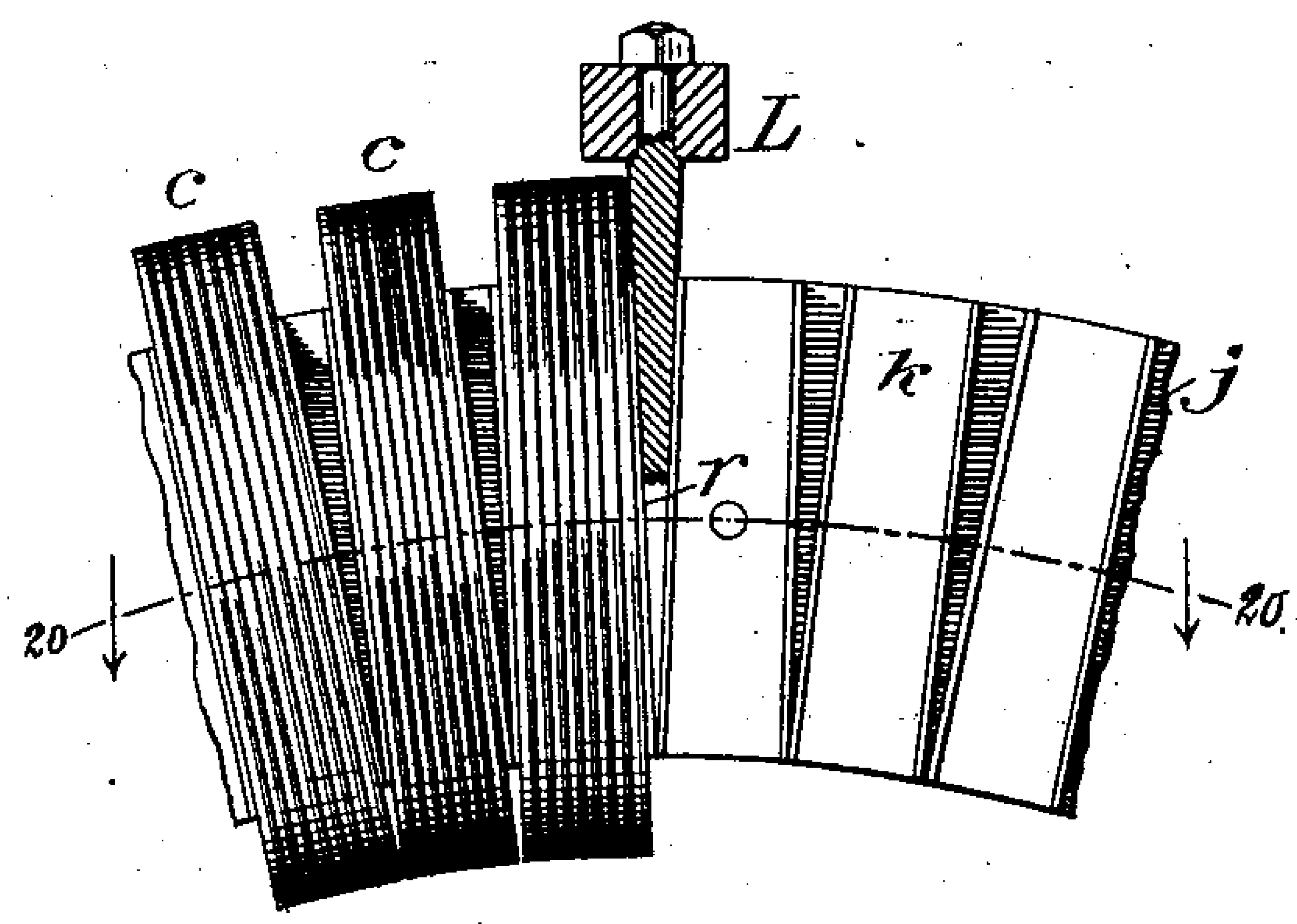


Fig. 13.

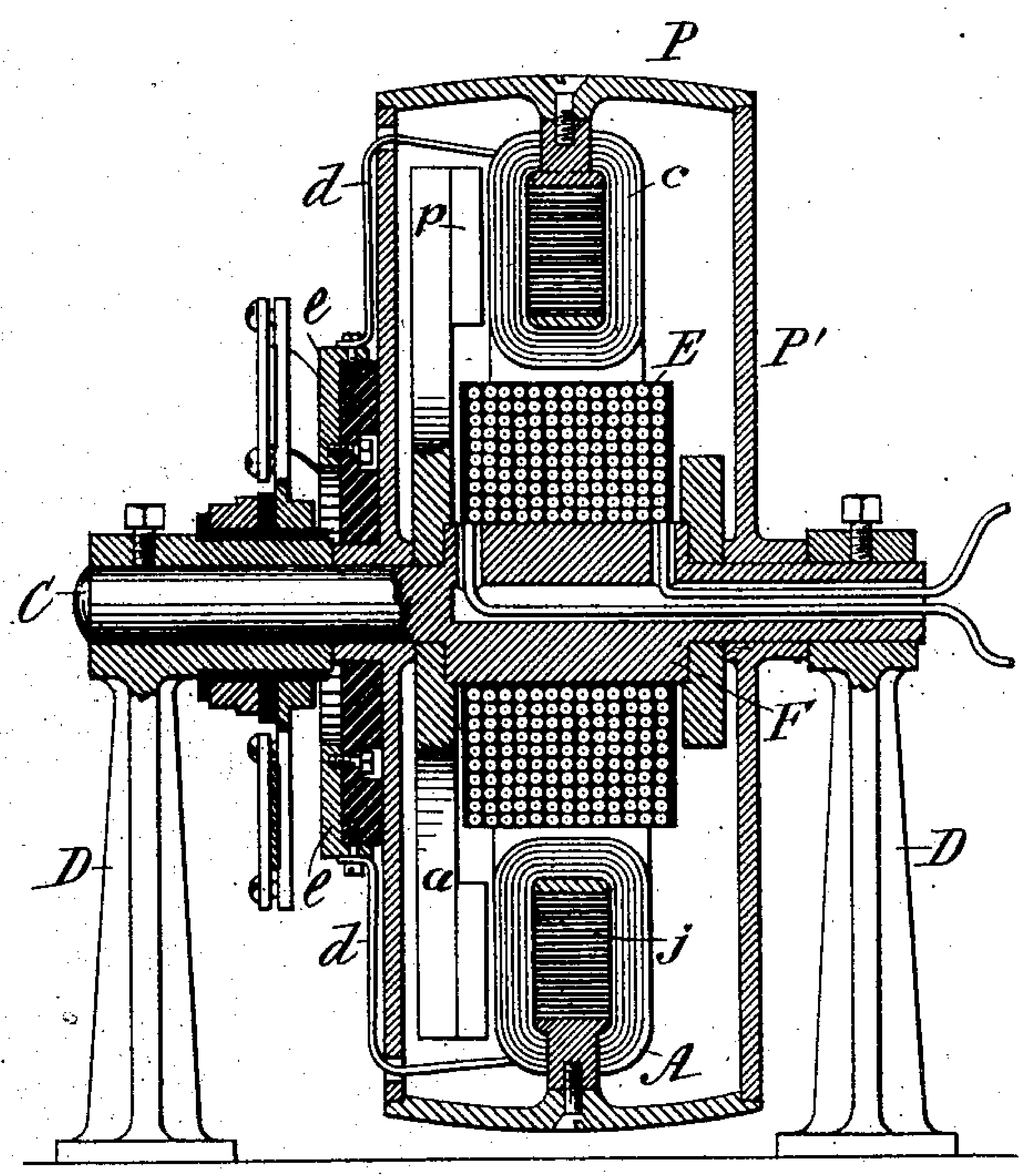


Fig. 20.

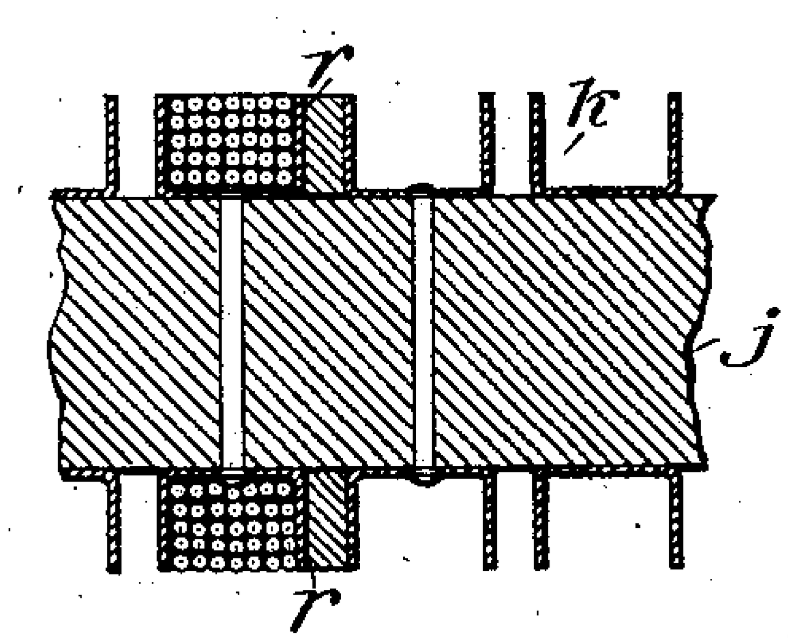
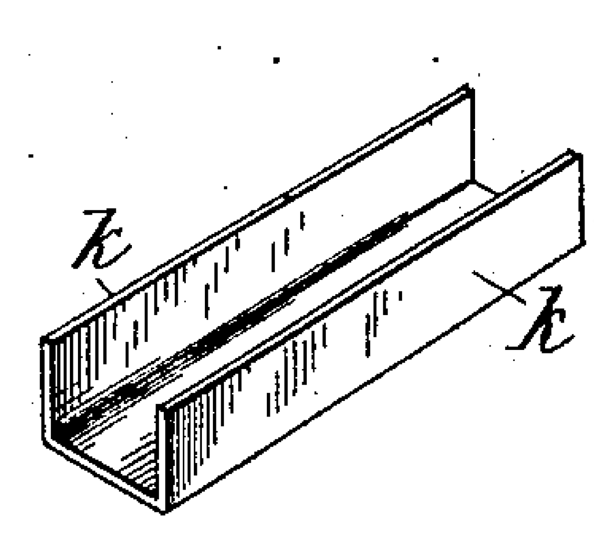


Fig. 21.



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UNITED STATES PATENT OFFICE.

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ELECTROMOTOR AND DYNAMO-ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 373,146, dated November 15, 1887.

Application filed April 22, 1887. Serial No. 235,785. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM MAIN, a citizen of the United States, residing at Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Electromotors and Dynamo-Electric Machines, of which the following is a specification.

This invention has reference chiefly to electromotors, but is also applicable in great part to dynamo-electric generators.

In an electromotor or dynamo the magnetic circuit consists of two parts—one comprised in the field-magnet and the other in the armature. Throughout this circuit there exists during excitation a condition of strain known as "magnetism," which develops itself along certain lines known as "lines of force." In a closed magnetic circuit these lines of force are confined entirely within the circuit; but in motors and dynamos it is necessary for mechanical reasons to leave a gap or air-space at two places in the magnetic circuit in order to divide the moving from the stationary part thereof, and across these gaps the lines of force are compelled to stretch themselves through air. If the armature were removed, the lines of force would stretch themselves across between the terminals or pole-pieces of the field-magnet, the intervening space being what is commonly known as the "field of force." It is desirable in a motor or dynamo to make the resistance of the magnetic circuit as low as possible, in order to avoid magnetic saturation and other sources of loss of magnetic energy. The field-magnet should be given such shape that there shall be the least possible short-circuiting of the lines of force, in order that all the lines of force shall be collected or concentrated in the field of force.

The armature consists, essentially, of coils or convolutions of wire or other conductor, being placed in the field of force and revolved therein in such manner that each coil shall at times be traversed by lines of force passing through it, which lines of force become more or less dense or numerous from time to time, or which change their direction relatively to the coil. Thus an armature—such, for instance, as a Gramme ring-armature, or others operating on a similar principle—is simply a device for throwing coils of wire around the lines of force, then removing them, again throwing them around, and again removing them, all in one revolution or part of a revolution. By the reaction of the lines of force upon the conductor elecrical currents are induced in the latter in alternately opposite directions, the alternating currents being ordinarily rectified by the commutator and directed as a continuous current into an external circuit, or, operating as a motor, a continuous external current, being directed by the commutator into the armature-coils, reacts against the stationary lines of force and drives the coils forward, thereby rotating the armature and converting electrical energy into mechanical motion.

In the construction of a motor or dynamo it is desirable not only to keep the resistance of the magnetic circuit as low as possible, but also to insure as complete a reaction as possible between the magnet and the conducting-wire, in order that the greatest number of lines of force may be converted with the least waste. To this end the electric conductor should be disposed as close as possible to the iron and should be of the greatest possible length. Another desideratum of the utmost importance is to so arrange the armature and its coils relatively to the field-magnet poles that the field of force shall pass wholly through the armature, so that no lines of force shall be wasted by leaking around the armature instead of passing through its coils. It is also important to the economical operation of such machines that the disposition of armature-coils and field-poles shall be such relatively to one another that the direction of the lines of force through the coils shall be reversed as frequently as possible. The importance of this feature is well understood with reference to the class of machines known as "flat-ring" dynamos, wherein it has been found that the multiplication of the field-magnet poles results in a considerable gain in efficiency. These general principles being well understood, I will now proceed to describe the generic features of my present invention.

My invention relates to electromotors or dynamos employing an armature, wherein at one point in the revolution the armature-coils assume planes perpendicular to the lines of force and inclose them, while at another point in the revolution the coils and lines of force are in the same planes, so that the lines of force are not inclosed by the coils. This type of machine includes those employing the Siemens shuttle-and-drum armatures and the Paccinotti or Gramme rings. My invention, however, is limited, generically, to ring-armatures having an open center, and specifically it is limited to what are known as "flat-ring" armatures, or to that class of machines wherein the armature consists of a flat ring and the field of force is composed of successive poles of alternately opposite polarity arranged around the ring.

My invention aims, first, to enable the field-magnet to be made as short as possible; second, to enable the field-magnet to be given the utmost desirable area of cross-section; third, to simplify the field-magnet coil and to bring the greatest possible number of turns thereof into the closest possible proximity to the field-magnet; fourth, to so arrange the field of force relatively to the armature that the path of least resistance for the lines of force shall be through the armature-coils, thereby avoiding the wasting of the lines of force by their escape around the armature; and, fifth, to enable all moving wire to be dispensed with, thereby greatly simplifying the mechanical construction of the machine.

The features of my invention whereby I shorten the field-magnet and enable its transverse area to be increased may be readily understood by imagining an annular armature of the character of a Gramme ring, and so wound and connected that on passing a current through its coils opposite magnetic poles are developed at diametrically-opposite sides of the ring. In the ordinary constructions of dynamos the magnetic circuit is closed between these poles through the medium of a field-magnet, which extends around exterior to the armature from one pole thereof to the other. The defect of this method lies in the necessity of making the field-magnet cores of inordinate length, so that, especially for electromotors, there is necessarily a great disproportion in weight and bulk between the armature and field-magnet. This disproportion is not necessarily objectionable in dynamos, and, in fact, for self-excited dynamos it is essential; but for electromotors the greatest efficiency for a given weight is attained by equally dividing the weight between the armature and field-magnet—a result which is impracticable with the construction above referred to.

According to another construction the magnetic circuit has been closed by means of a field-magnet arranged within the armature, crossing diametrically from one side thereof to the other. This construction has the disadvantage that the field-magnet is too small proportionally to the armature, and its polar arc is too large.

By my invention the field-magnet is disposed neither entirely outside of the armature, as in the construction first referred to, nor entirely inside thereof, as in the construction last referred to, but it is arranged partly outside of and partly inside of the armature. The middle portion of the field-magnet passes through the center of the annular armature from one side thereof to the other, being approximately parallel with the axis of rotation, and each end of the field-magnet extends thence radially and terminates close to the armature, adjacent to one of the poles therein. Thus the opposite poles of the field-magnet are on opposite sides of the armature, and, with a two-pole armature, extend in opposite directions to diametrically-opposite points on the armature.

If (as will usually be the case) the armature has four, six, or more poles instead of two, the field-magnet will have an equal number of poles or polar projections, half of which, being those of one polarity, will be disposed on one side of the armature, and the remainder, being those of the contrary polarity, will be disposed on the other side of the armature.

The field-magnet coil is wound, according to my invention, concentric with the axis of rotation and inclosing the central portion of the field-magnet. The ends of the coil extend nearly to the radial pole-pieces of the field-magnet. The coil is arranged within or partly within the ring-armature. According to my preferred construction the armature is made stationary and the field-magnet coil is fastened to it, being also stationary, while the field-magnet is made to rotate within the stationary coil. Thus all moving wire is dispensed with.

My invention may be better understood by reference to the accompanying drawings, wherein—

Figures 1 and 2 are diagrammatic views of an elementary construction of electromotor embodying my invention. Fig. 3 is a diagram of the fields of force and armature developed in a straight line or plane, and the remaining views, which will be explained hereinafter, are illustrations in detail of a complete machine constructed according to my invention and of various modifications thereof.

I will first describe Figs. 1 and 2, wherein A designates the armature; F, the field-magnet; E, the field-magnet coil, and C the axial rotative shaft. The armature A is a flat-ring armature of the ordinary Gramme winding, wound to develop two pairs of poles—that is, two north poles diametrically opposite to one another and two south poles diametrically opposite to one another at angles of ninety degrees from the north poles. The winding for such a Gramme armature is so well understood that no further description thereof is necessary. The armature is stationary, being fixed to a base, B. The field-magnet F is rotative, being fixed on the axial shaft C, which shaft will have suitable bearings. (Not shown.) The field-magnet consists of a central core, *b*, concentric with and arranged longitudinally parallel to the rotative axis, and radial arms or pole-pieces *a a* at opposite ends of the core, which extend from the center outward and terminate in close proximity to the opposite sides of the armature. There are four pole-pieces, the two on one side being north poles and the two on the opposite sides being south poles. The poles on the opposite sides of the armature are not arranged opposite to each other, but are alternated, as shown in Fig. 2, each pole having its center ninety degrees from the centers of the two poles of contrary polarity ahead of and behind it. The exciting-coil E has its axis coincident with the axis of rotation and incloses the core *b* of the field-magnet, being arranged between the pole-pieces *a a* of opposite polarity, which thus traverse radially the ends of the exciting-coil. The coil E is fixed within the armature and is non-rotative, the core *b* rotating freely within it.

The passage of a current through the coil E magnetizes the field-magnet F and develops N poles in the pole-pieces *a a* on one side of the armature and S poles in the pole-pieces on the opposite side of the armature. Thus four distinct fields of force are established, the lines of force extending themselves from each N pole through the armature to the next S pole, as denoted by the arrows in Fig. 2, which show one of the four magnetic circuits. The passage of a current through the armature develops two N poles and two S poles therein, which react against the poles of the field-magnet, and if they be given a "lead" in either direction will attract the field-magnet poles in that direction, and thereby cause the field-magnet to rotate.

In consequence of the alternate arrangement of the field-poles on alternately-opposite sides of the armature, and in consequence, also, of the arrangement of the field-magnet coil within the armature, it follows that the path of least resistance for the lines of force in passing from one field-pole to the next is through the armature. Only two other routes are possible—first, that through the field-magnet coil itself, which is prevented by the reaction of the current in that coil, and, second, through the air outside of the armature—a route which offers a resistance much greater than the armature, both by reason of air being an extremely poor magnetic conductor and by reason, also, of the greater distance which must be traversed.

It is obvious that the iron core of the armature offers thus a much more direct path for the lines of force and one of much less resistance than any other path that it is possible for them to take. It is also to be observed that the lines of force must of necessity pass through the armature from one side to the other thereof, which is not necessarily the case with the armatures of electro-motors or dynamos of the ordinary construction, wherein it frequently happens that some of the lines of force pass around the exterior of the armature instead of directing themselves through the coils thereof. In such armatures this result is due to the same side of each coil in the armature being presented to the opposite field-poles in the same manner as though in my construction both the N and S poles were arranged all on one side of the armature. In such a case it is quite conceivable that many of the lines of force in passing from one field-pole to the next will encounter less resistance in flowing through the air alongside of the armature than in forcing themselves into the armature-core and then passing out therefrom at the next pole on the same side by which they entered. Such a result is absolutely avoided in my construction, since the lines of force which pass into the armature-core at one pole-piece pass out at the next pole-piece on the opposite side to that at which they entered; hence up to or nearly to the limit of saturation the lines of force will pack themselves into the armature-core, finding that the path of least magnetic resistance. In so doing they necessarily pass through and are wholly inclosed by the armature-coils, so that the maximum inductive effect is attained. This action will be made more apparent from an examination of Fig. 3, which shows the armature opened out into a straight line, with the field-poles disposed alternately on its opposite sides. The dotted lines show the direction of the lines of force in streaming across from each pole-piece to the two next ones of opposite polarity.

Another feature peculiar to my invention is also to be noticed. Since the S poles of the field-magnet are all on one side of the armature and the N poles are all on the opposite side thereof, it follows that the armature-core, if we may imagine it to be divided by a plane perpendicular to the axis of rotation and cutting through its middle, presents on one side of this plane a series of polarities the sum of which will be a considerable S polarity, and on the other side thereof polarities the sum of which will be a considerable N polarity. This is due to the inductive effect of the field-poles, the S poles on one side inducing N polarity in that side of the armature core, and the N poles on the opposite side inducing S polarity in the armature-core on that side. This effect differs materially from that in the armatures of flat-ring motors or dynamos heretofore made, since in those machines the north and south field-poles come against the same portion of the armature, (usually against both sides thereof and the outer periphery thereof,) so that each projection on the armature-core assumes at one instant an extreme S polarity and at the next instant an extreme N polarity. These extreme magnetic reversals are a fruitful source of heating in the armature-core and of consequent waste of energy. In my armature, on the contrary, each portion of the armature-core is at one instant magnetized with an extreme S polarity in its polar projections on one side and at the next instant is magnetized with an extreme N polarity in its polar projections on the other side; but these extremes of polarity are confined to its polar projections, and at no one point in the armature-core does any transition occur from one extreme of polarity to the other. The polar projection on one side of the armature-core which assumes an extreme S polarity when in proximity to the N field-pole simply loses this extreme of polarity by the time it reaches a position opposite the succeeding S field-pole, and becomes approximately neutral or slightly magnetized with N polarity. Thus the polar projections on one side alternate between what we may consider a condition approximately neutral and extreme N polarity, while those on the other side alternate between an approximately-neutral condition and an extreme S polarity. Nevertheless, the average of each portion or radial cross-section of the core alternates between a considerable N polarity and a considerable S polarity to the same extent as in previous machines, so that the efficiency of my machine is in this respect fully as great as that of its predecessors, while it has over them the advantage of less magnetic resistance in the armature and less heating.

The commutator is not shown in Figs. 1 and 2; but it will be the same in principle as has been heretofore used with four-pole flat-ring machines. Since the armature is stationary, the commutator-segments will also be stationary, and the brushes will be carried around by the shaft C.

The principle of my invention being now well understood, I will proceed to describe in detail a fully-developed and practical electromotor constructed in accordance therewith, referring for that purpose to Figs. 4 to 10, inclusive, of the drawings, wherein Fig. 4 is a front elevation of the machine. Fig. 5 is a side elevation thereof. Fig. 6 is a vertical mid-section cut in the plane of the axis of rotation. Fig. 7 is a fragmentary section cut in an oblique plane, as denoted by the lines 7 7 in Fig. 4. Fig. 8 is a fragmentary front view, partly in vertical section, cut in the plane of the line 8 8 in Fig. 7. Fig. 9 is a front view of the field-magnet removed; and Fig. 10 is a rear elevation, on a larger scale, of the operating-handle. The remaining views illustrate modifications and details of construction, which will be referred to hereinafter.

The machine shown in Figs. 4 to 10 is of the same general construction as that already described. Its flat ring armature A is of the Gramme winding, with four poles, and is stationary, and its field-magnet F has four pole-pieces and is rotative. On the base B are fixed two upright frames, D D, the shape of which is best shown in Fig. 4. These frames form bearings for the axial shaft C, on which the field-magnet is fixed. The short cylindrical core *b* of the field-magnet is slipped over this shaft and secured thereto by set-screws or otherwise, and its pole-pieces are formed by two end pieces or cross-heads, *a' a'*, which are fastened against the opposite ends of the core in the manner shown in Fig. 6, or otherwise. It is necessary that one at least of these end pieces should be separable from the core, in order that the core may be inserted within the field-coil and armature. The mechanical construction of the field-magnet is clearly shown in Figs. 6 and 9. To the opposite ends of the end pieces or cross heads, *a' a'*, are fixed blocks *p p*, which constitute the poles of the field and come into close proximity with the opposite sides of the armature.

The armature A has an annular core, *j*, of soft iron, which should be laminated to avoid Foucault currents. It is best constructed by winding a soft-iron ribbon or strip of hoop-iron upon itself spirally, with a strip of insulating material to separate its convolutions. The armature-coils *c c* are wound around this core in the usual manner. In the angular gaps between the coils are inserted wedge-shaped pieces or teeth *k k*, which constitute the polar projections of the armature-core, hereinbefore referred to. These teeth or polar projections may be constructed in various ways, as I will presently explain.

The field-magnet coil E is wound within the ring-armature in the manner shown in Fig. 6, its open center being sufficiently larger than the core *b* to permit the latter to rotate freely in it. It is fastened to the armature and supported thereby by means of any suitable construction. In the construction shown two disks, *l l*, are placed against the opposite ends of the field-coil, and are fastened peripherally to two rings, *m m*, which fit over the exterior of the field-magnet coil and come against opposite sides of the armature, being drawn together by means of screws or bolts *n n*, whereby they embrace the armature and unite the field-coil thereto in a firm and solid manner.

The armature is fixed solidly to the frames D D in the manner shown in Figs. 7 and 8. The frames D D are secured to each other at four points (more or less) through the medium of cross-bars L L, to which the frames D D are fastened by screws *q q*. The cross-bars L L pass through the gaps between the armature-coils *c c* and come close against the periphery of the armature-core. The angular teeth *k k* are omitted from the armature at these points or are modified in construction, in order to afford a means by which the cross-bars may be united to the armature-core. For this purpose angular plates *r r* are fitted into the gaps on opposite sides of the core and fastened to it by means of bolts which pass through the core from one plate to the other. The cross-bar L is then screwed to the plates *r r*. The several screws should be insulated to avoid eddy currents.

The field-pole pieces revolve in the spaces between the frames D D and the armature and field-magnet coil, the clearance between the respective parts of the magnetic system being preferably as narrow as is consistent with mechanical safety. The polar blocks *p p* are nearly as wide in radial direction as the space between the rings m and cross-bar L, (see Fig. 7,) and their thickness should be sufficient to bring their inner faces into close proximity with the sides of the armature. The ends or forward and rear edges of the polar blocks are made with oblique outlines, which are flared outwardly to a degree greater than that of the radii from the armature center, as clearly indicated in Fig. 4. The effect of this shape is that as the poles advance their outer edges will first encounter the core projections $k'k$ of the armature, and will receive first the pull of the lines of force streaming across between them, and as they move farther forward, so that these edges will overlap the core projections and be pulled thereby in less degree, the inner portion of the block which has not yet overlapped the core projections will receive the pull, so that the concentrated lines of force as the polar-block encounters each new projection k will move inward along the advancing oblique edge of the block. Thus the magnetic pull is rendered more continuous than heretofore, the pull of the lines of force from each successive projection k continuing for a longer interval, whereby the efficiency of the machine is to some extent increased.

Whenever it is desired to house in the magnetic parts of the machine in order to protect them from dust and from encountering any obstacles to the rotation of the field-poles, this may be done in the manner indicated in Figs. 7 and 8. Thin disks t t, of insulating material, are placed against the inner surfaces of the frames D D, and a tubular band, s, also of insulating (or non-magnetic) material, is placed around the periphery of the armature, being secured in place by screwing it to the flattened ends of the several arms of the frames D D. In this manner, or in any other similar way, the magnetic parts of the machine may be completely inclosed.

The commutator consists of stationary segments e e and rotating brushes f f'. In the construction shown, where the armature has twenty-four coils, c c, the commutator has twenty-four segments, e e, which are connected, respectively, by an equal number of wires or conductors, d d, with the connecting terminals between the several armature-coils, in the usual manner. The commutator-brushes are duplicated, there being two brushes f f in connection with the positive binding-post of the machine and two brushes f' f' connected with the negative binding-post. The current entering the machine is divided between the two positive brushes and divides again at the commutator, each quarter of the current flowing through one-quarter of the armature-coils and passing out by the two negative brushes, after which the current is reunited. Thus the current flows through the armature in derivation. If, however, it is preferred to use the current undivided, but two commutator-brushes will be used, and the armature will be wound and connected accordingly, in manner well known in the construction of flat-ring dynamos.

The positive brushes f f are carried by arms g g, which spring from a hub, h, which is fastened to but insulated from the shaft C. The two negative brushes f' f' are carried by arms g' on a hub, h', which is mounted on the shaft C over the hub h, from which it is insulated.

i i' are two take-off brushes or strips of metal, which make contact, respectively, with the hubs h h', being pressed apart and against the respective hubs by an insulated adjusting-screw, n'. The take-off strips i i' are fastened, respectively, to two insulated standards, o and o', Fig. 4, at their bottom ends. These standards constitute the terminals of the machine, or they may be connected, respectively, to positive and negative binding-posts, which shall constitute the terminals.

In an electromotor it is highly desirable to provide means for stopping, starting, and reversing the machine at will. In motors of the ordinary type, wherein the armature revolves, this is done by means of a lever which varies the lead or position of the commutator-brushes. In my machine it is accomplished by shifting the position of the commutator-segments. The commutator-segments e e are fastened to an insulating disk or ring, G, which in turn is secured to a hand-lever, H, so that by moving this lever to one side or the other the commutator-segments are advanced or retrograded. In Fig. 4 the lever H is shown in its mid-position, or that which it occupies when the machine is at rest. In order to cause the machine to rotate in a forward direction, the lever H is thrown over to the position indicated by the dotted line H' in Fig. 4, and to reverse the machine the lever is moved to the position denoted at H''. In the latter case the brushes will be pushed over the commutator-segments instead of drawn over them; but this disadvantage is of slight consequence in a machine that is only occasionally reversed, which is the case with the great majority of electromotors. In order to permit of this degree of movement of the commutator-segments, it is necessary that their connection with the armature-coils be made through the medium of conductors which are sufficiently flexible and which are mounted with sufficient slack. For this purpose I divide the twenty-four conductors d d into four groups of six conductors in each, lead the six conductors of one group from their connections with the coils to a convenient point on one of the four arms of the front frame D, as shown in Fig. 4, and there fasten them by a suitable clamp, u. I then unite the six conductors, by suitably wrapping them, into a compact flexible cable, v, which is so looped or twisted as to give it sufficient slack, and at a point near the commutator this cable terminates, and the six conductors diverge to their respective segments.

In order to retain the hand-lever H in any position in which it is placed, I provide it with a spring lock or latch which engages a curved rack bar or sector, I, which is fastened to the front frame D by the two screws *q q* thereof. I make this latch of peculiar construction, in order to admit of a convenient and close adjustment of the lead of the commutator after the lever H has been thrown into either position. This construction is best shown in Figs. 4 and 10. A latch-lever, Q, is pivoted to the lever H just above the rack I, and extends across in front of the lever H to the opposite side thereof, where it extends rearwardly and upwardly, its upward portion forming a finger-piece by which to operate it, and its rearward portion forming a bearing for one end of an adjusting screw or worm, J. The latch Q is pivoted on a screw or bolt, *w*, the head of which is on the rear side of the lever H. The adjusting-screw J has bearings both in the head of this screw *w* and in the rearward part of the latch Q, so that as the latter is moved toward the lever H, as shown in Fig. 10, the screw J is swung upward around the axis of the pivot *w*, and is thus lifted clear of the rack I, as shown, whereupon the lever H may be moved to any other position. Upon throwing it to the position desired, the latch Q is released and a spring, *y*, presses it down, so that the screw J meshes with the teeth of the rack I. Any desired minute adjustment of the brushes may then be given by turning the screw J by means of its milled head J'. This adjustment may be made very minute, if desired, by making the screw J a differential screw consisting of a thread of coarse pitch engaging the rack I and a thread of fine pitch engaging an internal screw in the head of the pivot-bolt *w*.

My improved electromotor thus described has, in addition to the advantages hereinbefore stated with reference to Figs. 1, 2, and 3, the merits of being simple in construction, compact, not liable to get out of order, and easy to adjust and control. Its weight is less in proportion to the power that is developed than that of any electromotor thus far made, so far as I am aware. Experimental trials made with a machine of this construction show a very high efficiency.

My invention may be modified in various ways without departing from its essential features, as will be readily understood. I have introduced some illustrations of modified constructions as examples of a few of the modifications of which my invention is susceptible.

In the accompanying drawings, Fig. 11 is a vertical transverse section in the plane of the axis of rotation, illustrating one modification. Fig. 12 is a front elevation of the construction shown in Fig. 11. Fig. 13 is a vertical mid-section in the plane of the axis of rotation, illustrating another modification. Figs. 14 to 18, inclusive, are views illustrating different constructions of the armature-core projections or teeth *k k*. Fig. 19 is a fragmentary view of a portion of the armature answering to Fig. 8 and showing a modified construction. Fig. 20 is a fragmentary sectional view of a portion of the armature shown in Fig. 19, looking in the direction of the arrow 20 therein; and Fig. 21 is a perspective view of one of the armature polar projections used in the construction shown in Figs. 19 and 20.

In the construction shown in Figs. 11 and 12 the field-magnet is made of much larger diameter than in the constructions already described and is of substantially annular form, since its core *b* is no longer a short solid column, but is expanded into a tube of large diameter, which is confined between the end plates, *a' a'*, of the field-magnet. The portion of the field-magnet within the tube *b* is hollow and open. Each of the end plates, *a'*, of the field-magnet is formed with six pole-pieces, *a a*, the poles on one side being arranged midway of those on the other side, as denoted by the dotted lines in Fig. 12. The armature is of the same construction already described, except that it should be wound with more coils, since it has twelve poles instead of four—six north and six south poles. The commutator and its connections (not shown) will be modified accordingly; as any practical electrician will readily understand.

In Fig. 13 is shown a modification of my invention wherein the field-magnet is stationary and the armature is made to rotate. The shaft C is screwed fast to the upright frames D D, and the field-magnet F is fixed to this shaft. The armature A is mounted within a case, P, the outer part of which may constitute a belt-pulley for communicating motion from the motor to the part to be driven thereby. This casing P has on opposite sides two disks, P' P', which are formed at their centers with hubs which rotate on the fixed shaft C. The commutator-segments *e e* are arranged radially and are carried by one of the disks P', being connected with the armature-coils through conductors *d d*. The commutator-brushes are stationary. The field-coil E is not carried by the armature, but is wound directly on the field-magnet and remains stationary.

Fig. 14 is a perspective view showing the preferred construction of the wedge-shaped teeth or armature-core projections *k k*. I make these projections or teeth hollow or trough-shaped, or of other construction, in such manner that they shall present two edges of metal to the inductive action of the field-poles, these edges being separated somewhat from each other. The construction shown in Fig. 14 consists of two pieces of angle-iron, their sides *k' k'* projecting outwardly, and their bases *k''* lying one upon the other and being tapered, so that when united, as shown, the two constitute a hollow wedge open along one side. This wedge is placed against the armature-core in the manner shown best in Fig. 5, a piece of insulating material being interposed between its base *k''* and the bare iron of the core, as shown in Fig. 6, to prevent the formation of Foucault currents through the core laminations and the metal of the two wedges on its opposite sides. The wedges or teeth *k k* on opposite sides of the core are fastened to it and to each other by means of screws or bolts *z z*, as shown in Fig. 5. These screws should be insulated to prevent Foucault currents.

The teeth *k* may be made in various ways. Fig. 15 shows a tooth both sides of which are bent up from one piece of iron plate. Fig. 16 is an end view of a tooth bent up from a piece of sheet-iron, its sides *k'* being re-enforced in thickness by being bent double, as shown. Fig. 17 is a similar view showing the re-enforcing of the sides by planting a thicker piece of iron against them. Fig. 18 shows a wedge made of two thicknesses of sheet metal arranged one inside the other. The construction of these armature-core projections or teeth *k k* in such manner as to present two walls or edges *k'* to the action of the magnetic field results in a distribution or division of the lines of force between these two edges to such effect that an advancing pole-piece is first attracted chiefly by the lines of force streaming across from the wall or edge nearest it, and as it advances to a position where it overlies that edge, so that it in a measure ceases to be attracted thereby, new lines of force will spring to it from the other edge or wall of the tooth and further attract it, thus utilizing most fully the magnetic effect.

Figs. 19, 20, and 21 show another construction for accomplishing the same result, which is especially adapted to armatures of large diameter which are wound with numerous coils, so that the wedge-shaped gaps or spaces between the coils are too narrow and acute to permit readily of the passing of screws through the hollow spaces in the wedge-shaped teeth in order to secure them to the core. In this construction I employ parallel troughs, one of which is shown in Fig. 21. I place two of these against the armature-core directly opposite each other and wind one of the armature-coils around the core and in these troughs, as shown in Fig. 20. The winding of the wire will fasten the troughs securely in position on the core, so that no screwing or riveting is necessary. The fastening of the armature to the cross-bars L L is clearly shown in Fig. 19. Two of the troughs have a wedge-shaped block of metal, *r*, secured between them by riveting or otherwise. They are then laid against one side of the core, and two other troughs, constructed in like manner, are laid against the other side, and screws or rivets are passed through the core to unite them together. The cross-bar L is then fastened to the intervening blocks *r r* by screws, as shown.

In order to construct a dynamo according to my invention, no alterations are essential, except in matters of proportion. The construction shown in Figs. 4 to 9, inclusive, may be adopted, it being desirable, however, to increase the mass of the field-magnet and the number of convolutions in the field-magnet coil, and to make the armature of proportionately less mass, in order to give the field-magnet a suitable preponderance of weight and magnetic capacity over the armature.

I make no claim in this application to anything claimed in an application for patent for dynamo-electric machines and electromotors executed by me simultaneously herewith, Serial No. 235,179, filed April 18, 1887.

It will be understood that certain of the features of my present invention are not limited in their application to a machine wherein the field-magnet passes through the center of the armature, but may be applied in connection with some of the constructions heretofore known.

I claim as my invention, in an electromotor or dynamo electric machine, the following-defined novel features and combinations, substantially as hereinbefore specified, namely:

1. The combination, with a ring-armature of the Gramme type, of a field-magnet extending through the open center thereof from one side to the other and having its contrary poles disposed adjacent to the armature on opposite sides thereof and at different points on the circumference corresponding to the arrangement of poles in the Gramme ring.

2. The combination, with a ring-armature of the Gramme type, of a field-magnet extending through the open center thereof and having its contrary poles disposed adjacent to the armature on opposite sides thereof and arranged in alternation, each pole being disposed midway of two poles of the contrary polarity.

3. The combination, with a ring-armature of the Gramme type, of a field-magnet having its middle portion or core extending through the open center of the armature in a direction substantially parallel with the axis of rotation and having pole-pieces extending from the ends of the core radially and terminating adjacent to the armature on opposite sides thereof, the poles of one polarity being disposed on one side of the armature and those of the contrary polarity being arranged in alternation therewith and on the opposite side of the armature.

4. The combination, with a ring-armature of the Gramme type, of a field-magnet having its middle portion or core extending through the center of the armature in a direction substantially parallel with the axis of rotation and having its contrary poles disposed adjacent to the armature on opposite sides thereof and arranged in alternation, each pole being disposed midway of two poles of the contrary polarity, and an exciting-coil for said field-magnet arranged within the armature and inclosing said core.

5. The combination, with a non-rotative ring-armature of the Gramme type, of a rotatively mounted field-magnet extending through the open center of the armature and having its contrary poles disposed adjacent to the arma-

ture on opposite sides thereof and arranged in alternation, each pole being disposed midway of two poles of the contrary polarity.

6. The combination, with a non-rotative ring-armature of the Gramme type, of a non-rotative field-magnet coil fixed within said armature with its axis coincident with the axis of rotation, and a rotatively-mounted field-magnet extending through the center of the armature and field-magnet coil and having radial pole-pieces extending past the ends of the field-magnet coil and terminating adjacent to the armature on opposite side thereof, the contrary poles being arranged in alternation.

7. The combination, with a ring-armature of the Gramme type, of a field-magnet extending through the open center thereof and having its contrary poles disposed adjacent to the opposite sides of the armature and arranged in alternation, said magnet being constructed of a central axial core and end pieces forming the poles fastened removably to the opposite ends of said core.

8. The combination, with a ring armature of the Gramme type, of a field-magnet consisting of a cylindrical core, *b*, two opposite end pieces, *a′ a′*, fastened removably to the ends thereof and forming radial pole-pieces, and polar blocks *p p*, fastened to said end pieces.

9. The combination, with a ring-armature of the Gramme type, of a field-magnet having its contrary poles disposed adjacent to the armature on opposite sides thereof and arranged in alternation, whereby the lines of force proceeding from one pole to the next pole of opposite polarity enter the armature core at one side and pass out at the side opposite to that by which they enter.

10. A ring-armature of the Gramme type, constructed with an iron core wound with radial coils and having core projections in the angular spaces between the coils, said core projections constructed with a recessed middle portion and presenting each two walls or edges, one in advance of the other, at the sides of the armature.

11. A ring-armature of the Gramme type, constructed with an iron core wound with radial coils and with iron core projections in the annular spaces between the coils, said core projections projecting laterally to the opposite sides of the armature in the form of walls perpendicular to the plane of the side of the core, and the two walls in each angular space separated from one another, thereby forming an angular recess between them.

12. A ring-armature of the Gramme type, constructed with an iron core wound with radial coils and with core projections in the angular spaces between the coils, said core projections constructed each of two pieces of angle-iron with their bases tapered angularly and superposed against the sides of the core and their perpendicular projecting walls converging.

13. A stationary ring-armature of the Gramme type, in combination with a field-magnet revolving with its poles on opposite sides thereof, and with two fixed frames on opposite sides of the armature and exterior to the revolving field-magnet, and connections for uniting said armature to said frames, consisting of cross-bars extending between the frames and crossing the periphery of the armature-core perpendicularly thereto, and angular plates fitted against opposite sides of the core between the armature-coils, to which plates said cross-bars are fastened.

14. A ring-armature of the Gramme type, in combination with a revolving field-magnet, with the fixed frame of the machine to which the armature is rigidly connected, with a stationary field-magnet coil within the armature, and with connections for fastening said coil to the armature, consisting of rings fitting over the field-magnet coil and against opposite sides of the armature, and screws for fastening said rings together.

15. A ring armature of the Gramme type wound with radial coils and having angular core projections on its opposite sides in the angular spaces between the coils, in combination with a field-magnet having its contrary poles disposed in alternation against the opposite sides of the armature, and constructed with pole-pieces the forward and rear edges of which are flared outwardly to a degree greater than that of the radii from the armature center, whereby as the pole-pieces advance the concentrated lines of force passing between them and the core projections shift radially along the advancing edges of the pole-pieces.

16. In an electromotor, the combination of a toothed sector with a controlling-lever, a latch pivoted thereto, and a tangent-screw mounted in said latch, adapted to engage the teeth of said sector when the latch is pressed down and to be raised clear therefrom when the latch is retracted.

17. In an electromotor, the combination of a toothed sector, a controlling-lever, a latch pivoted to said lever, and a differential screw mounted in said latch, the coarser thread thereof adapted to engage the teeth of said sector when the latch is pressed down and the finer thread thereof engaging the said latch.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

WILLIAM MAIN.

Witnesses:
ARTHUR C. FRASER,
GEORGE H. FRASER.