No. 854,756. PATENTED MAY 28, 1907.

J. E. NOEGGERATH.

DYNAMO ELECTRIC MACHINE.

APPLICATION FILED MAR. 30, 1904.

6 SHEETS—SHEET 1.

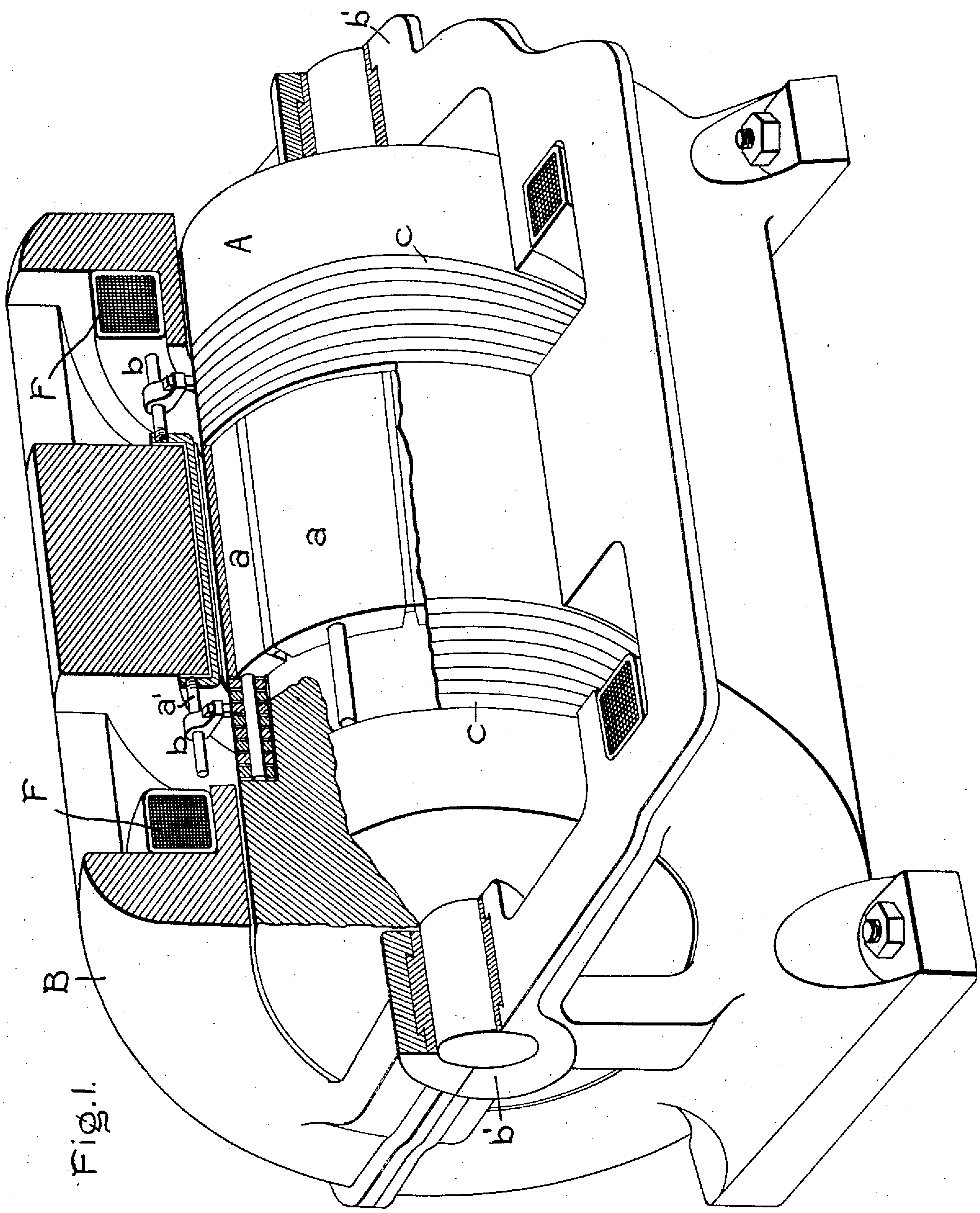

Fig. 1.

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6 SHEETS—SHEET 2.

Fig. 2.

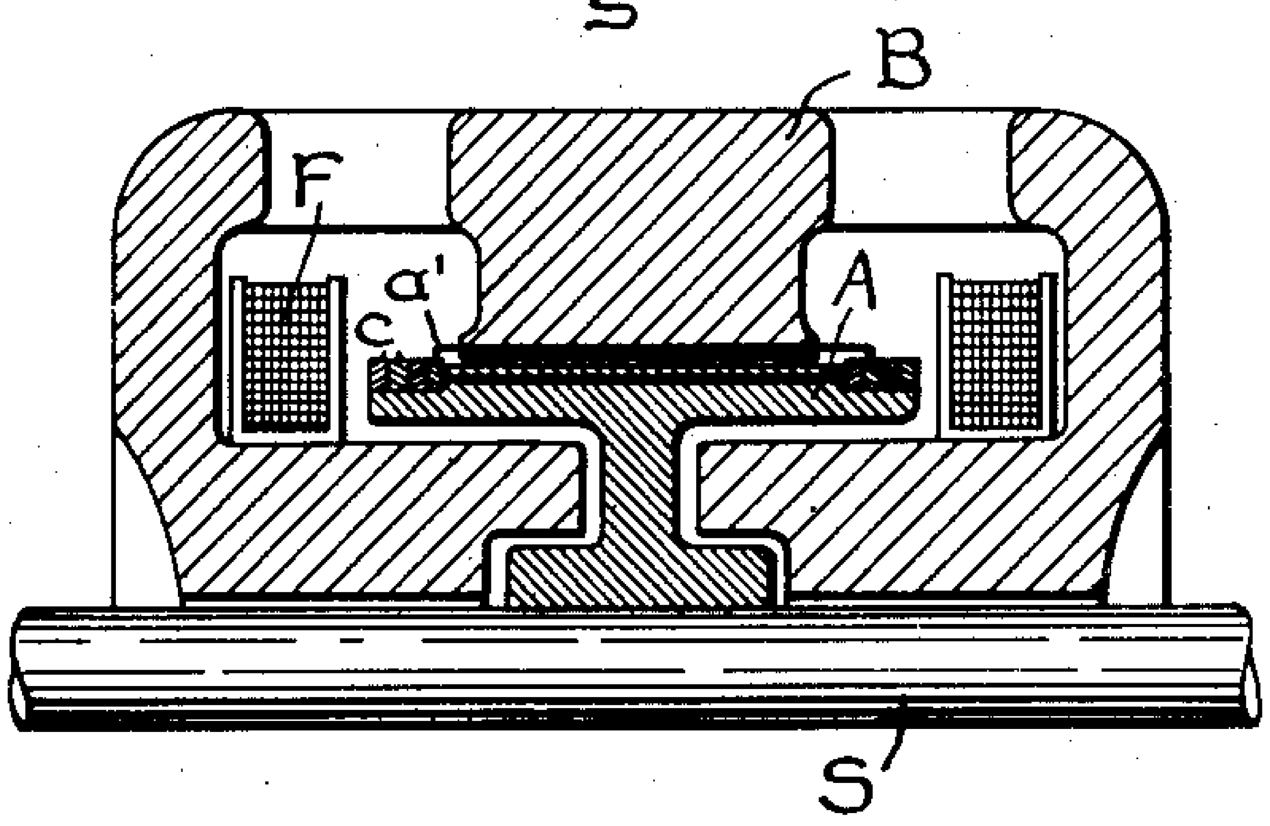


Fig. 3.

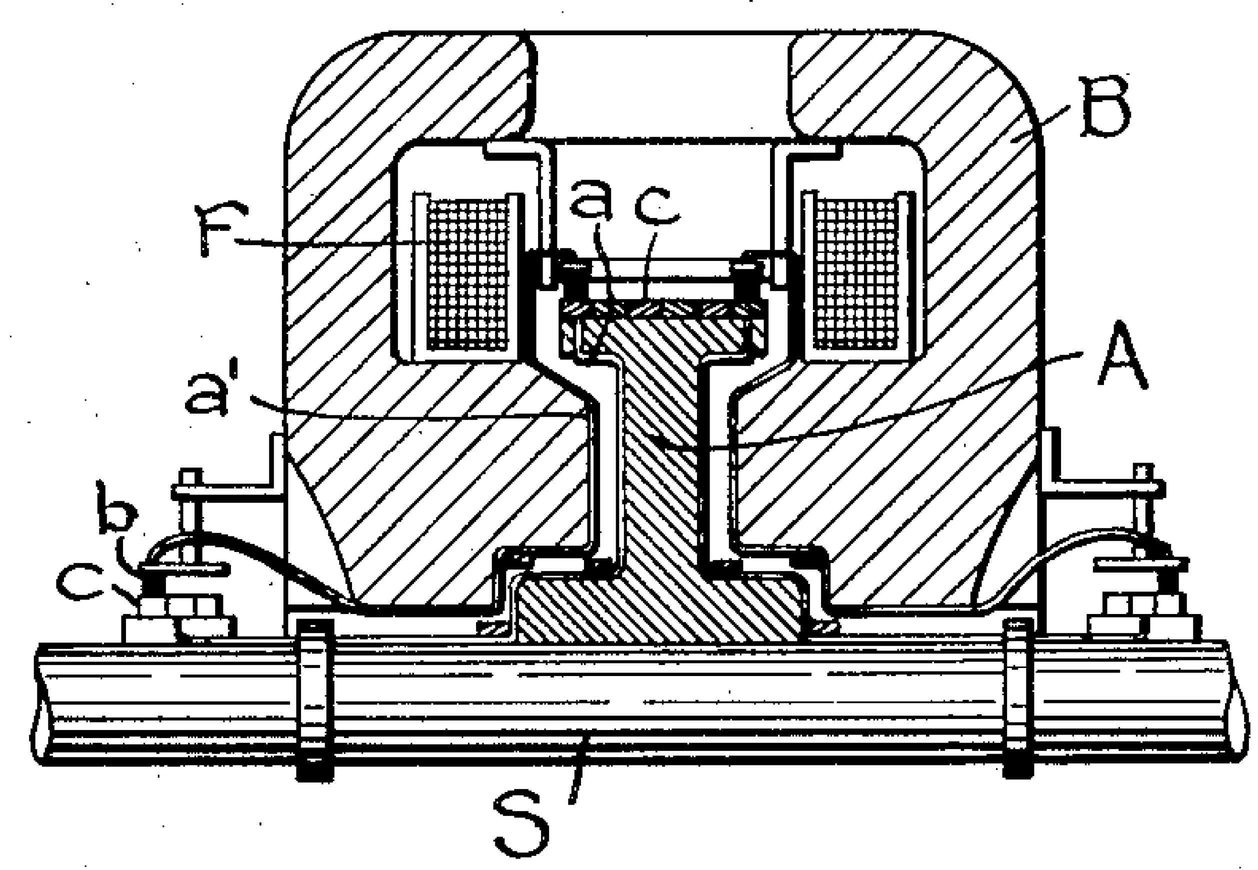


Fig. 4.

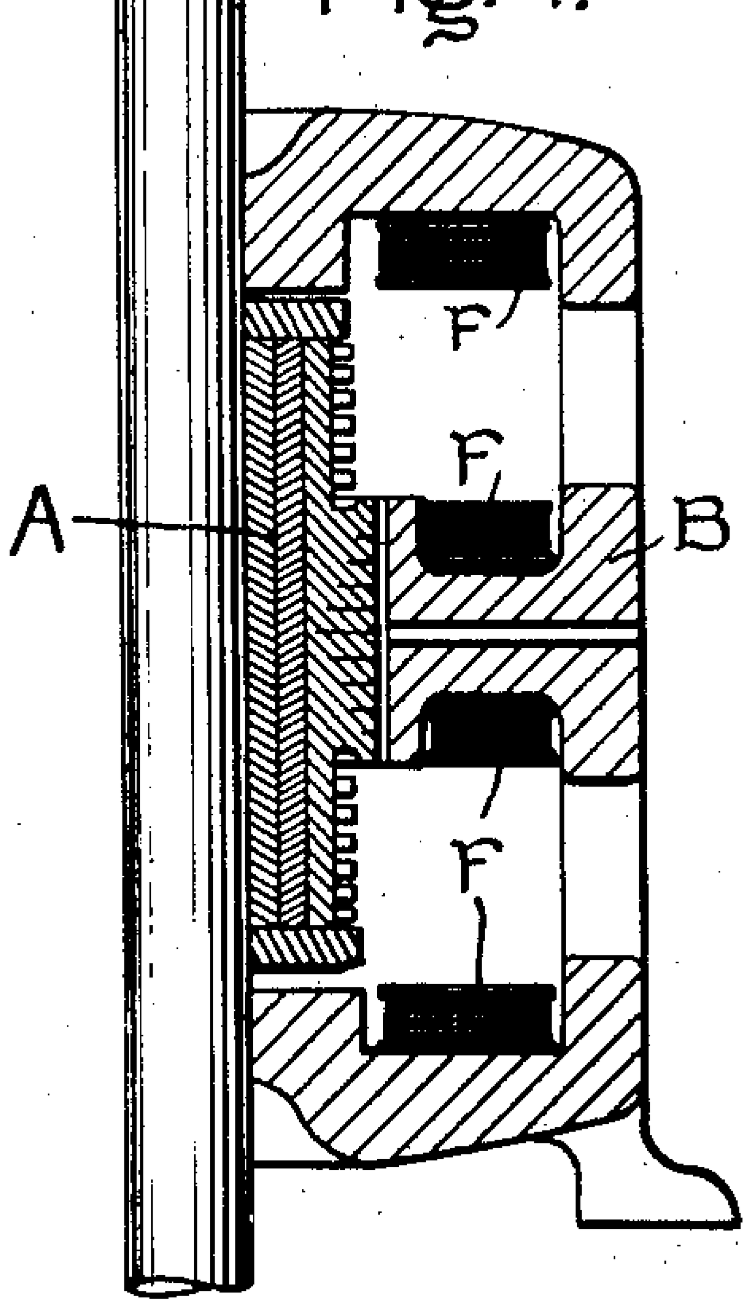


Fig. 5.

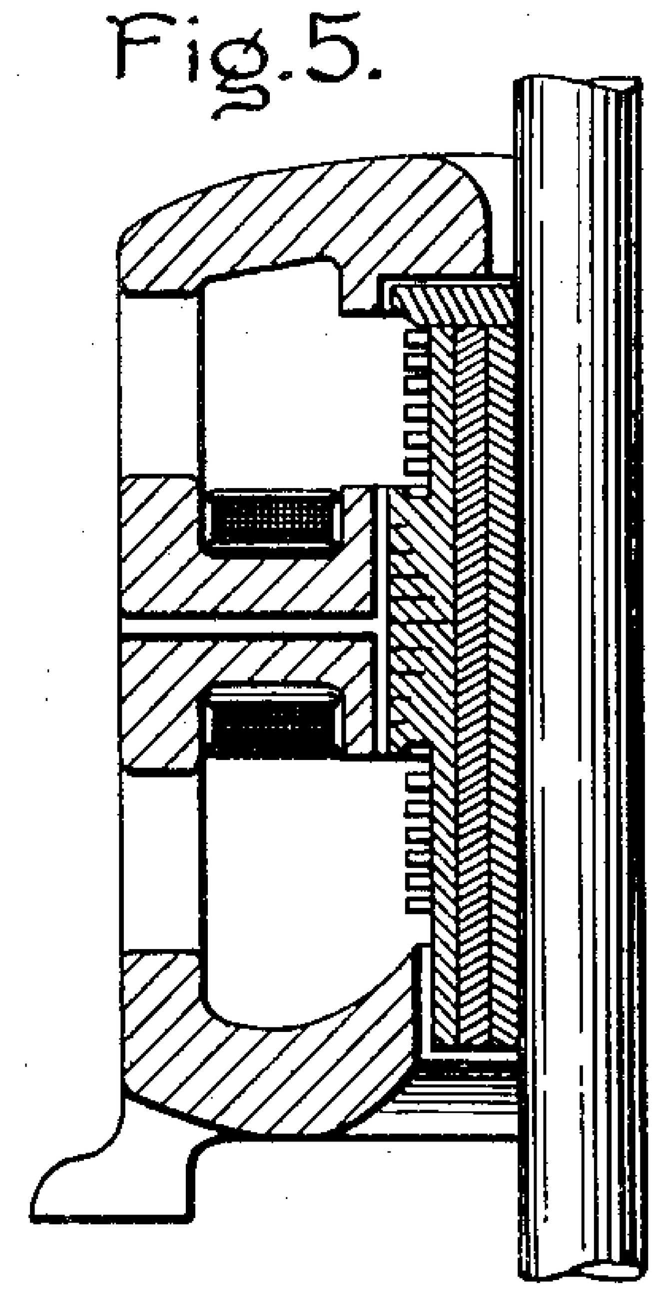
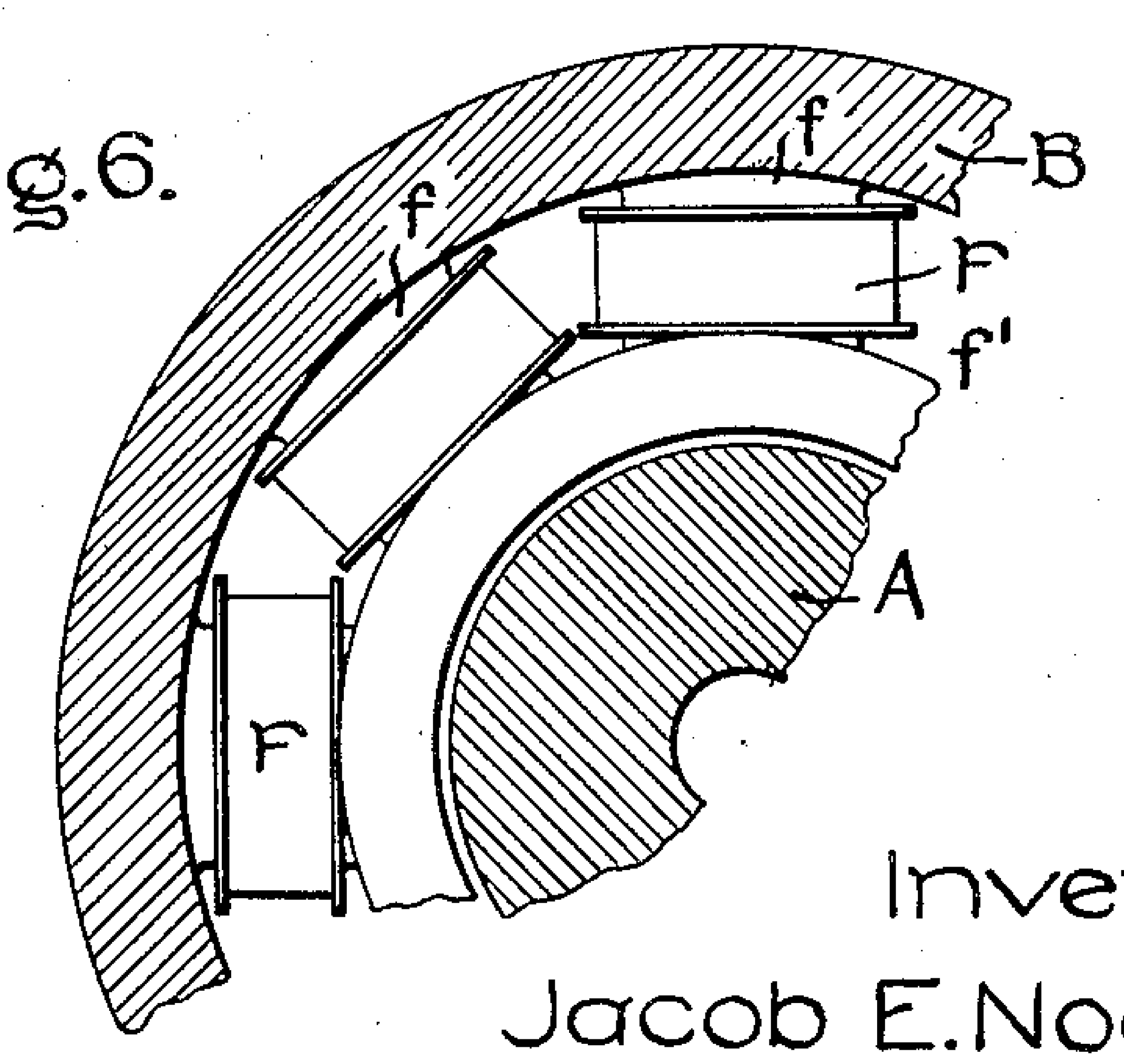


Fig. 6.



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6 SHEETS—SHEET 3.

Fig. 7.

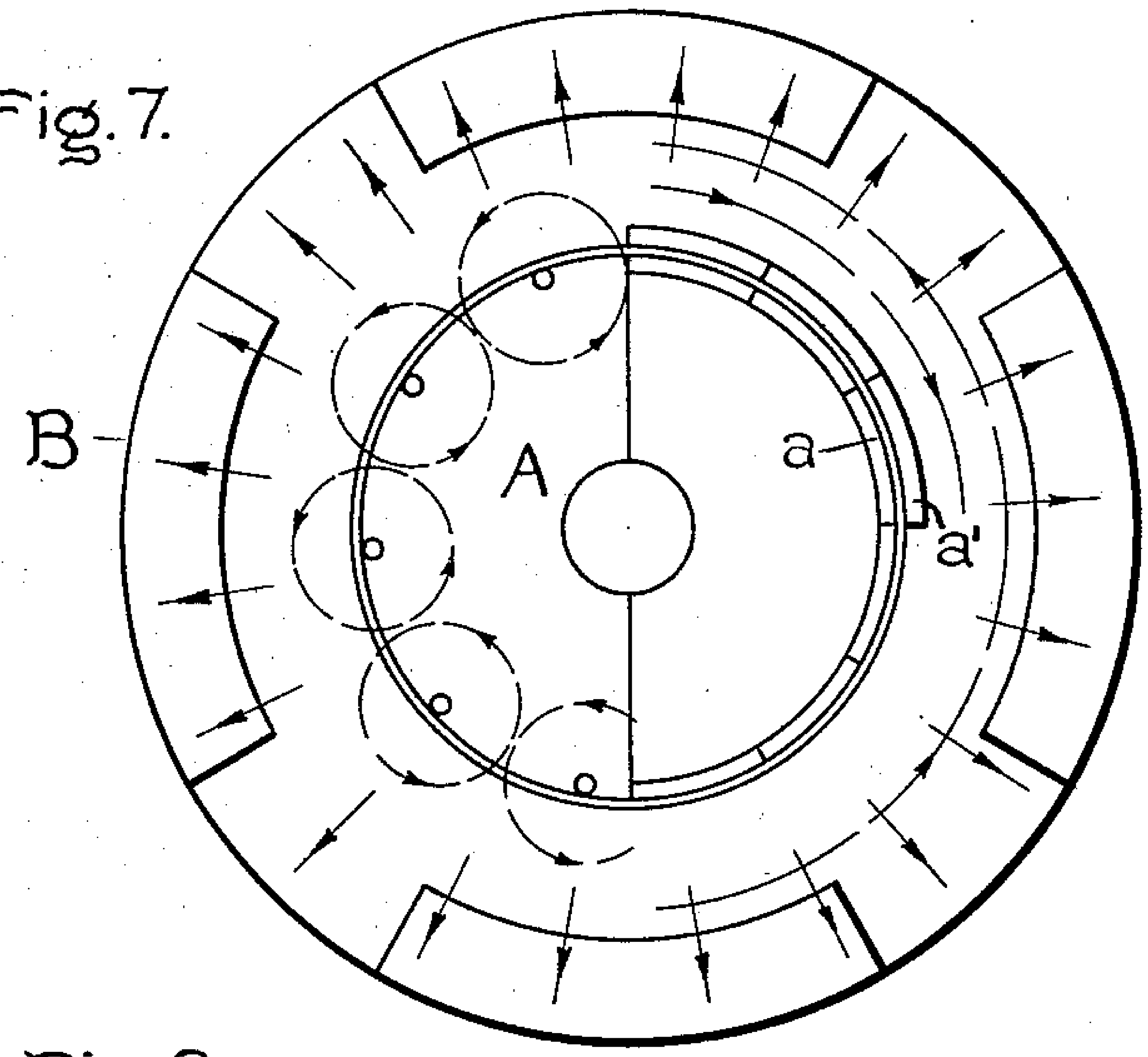
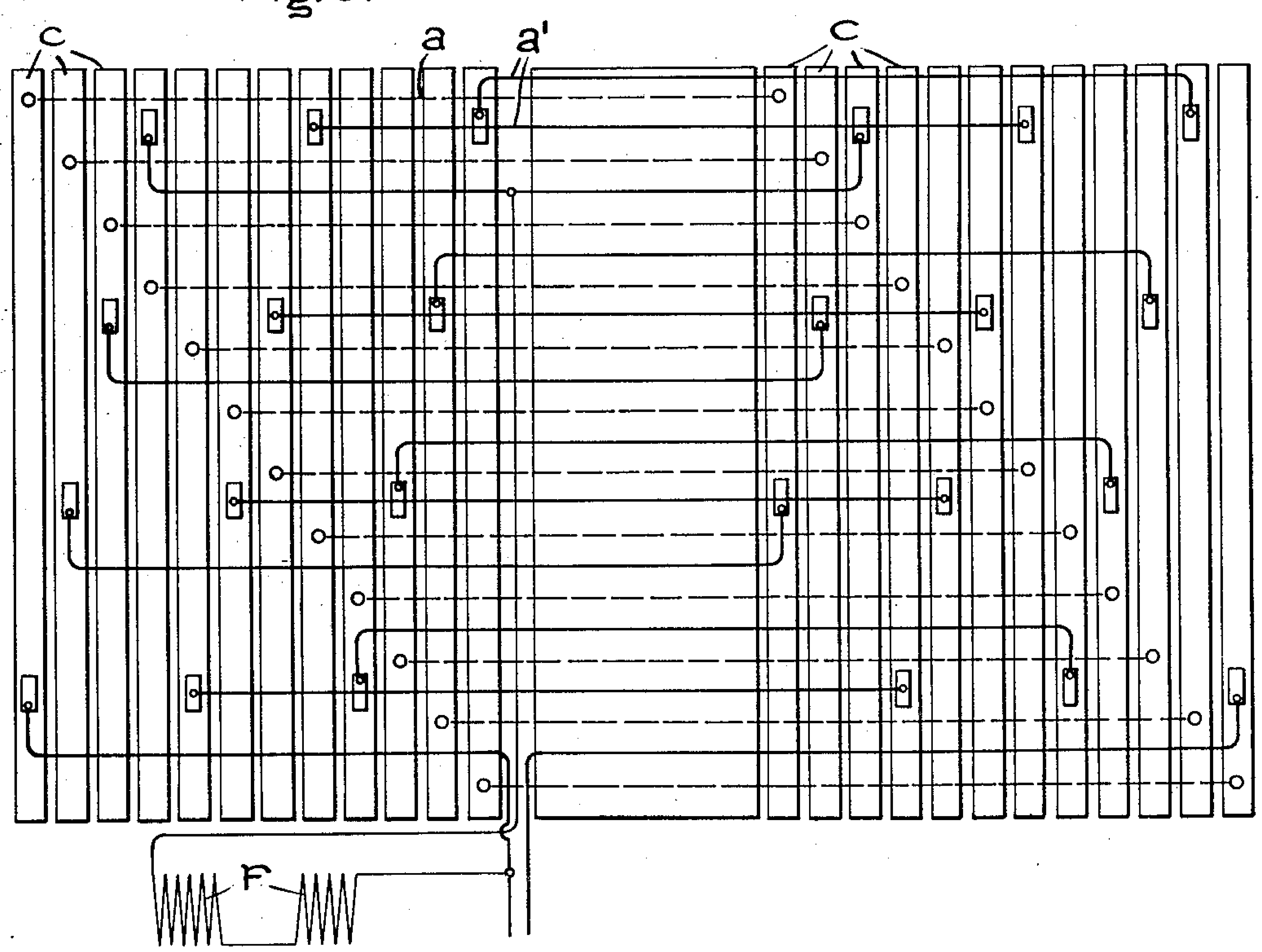


Fig. 8.



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6 SHEETS—SHEET 4.

Fig. 9.

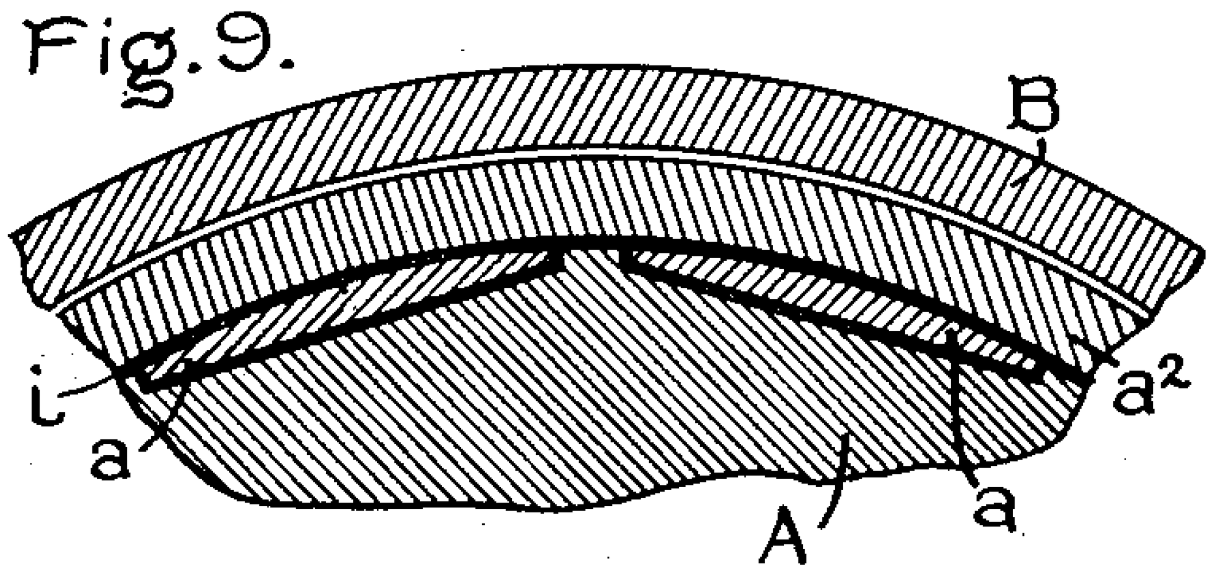


Fig. 10.

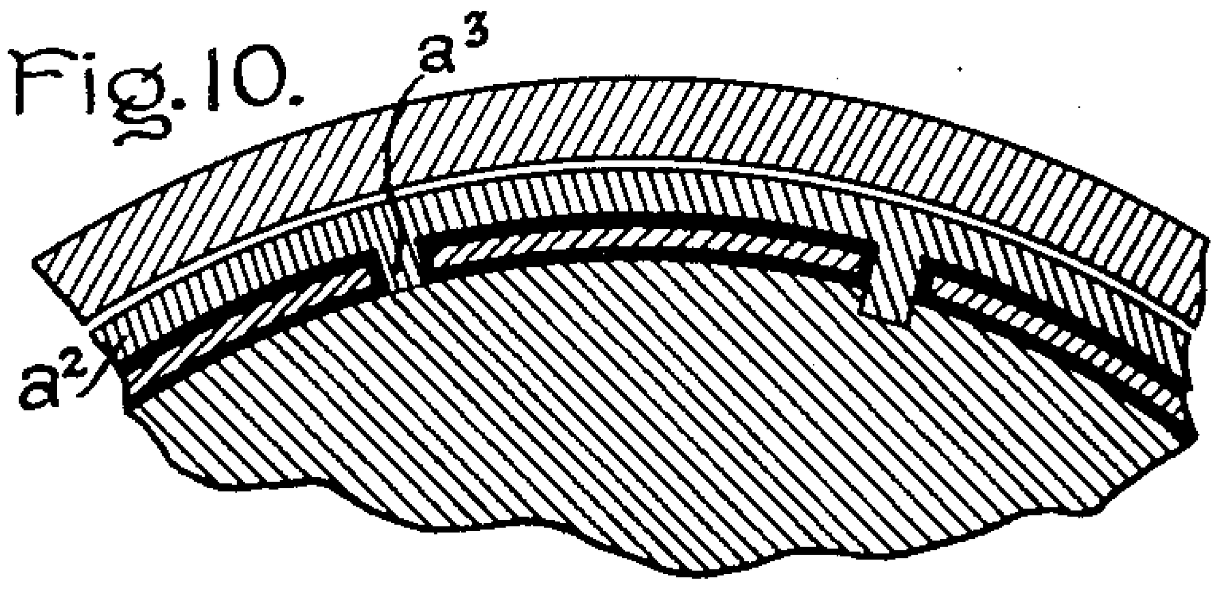


Fig. 11.

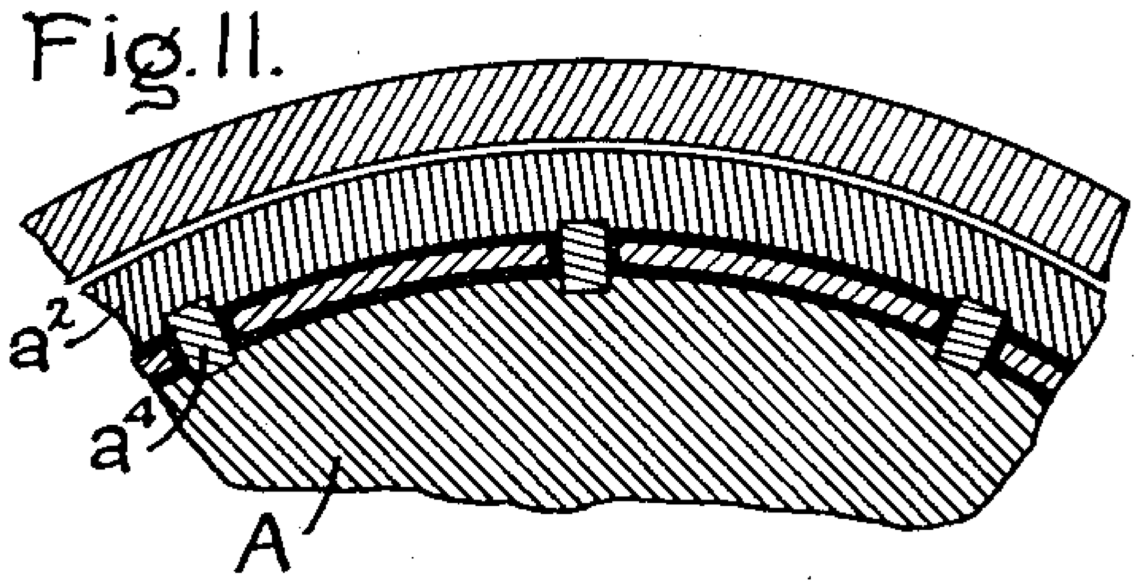


Fig. 12.

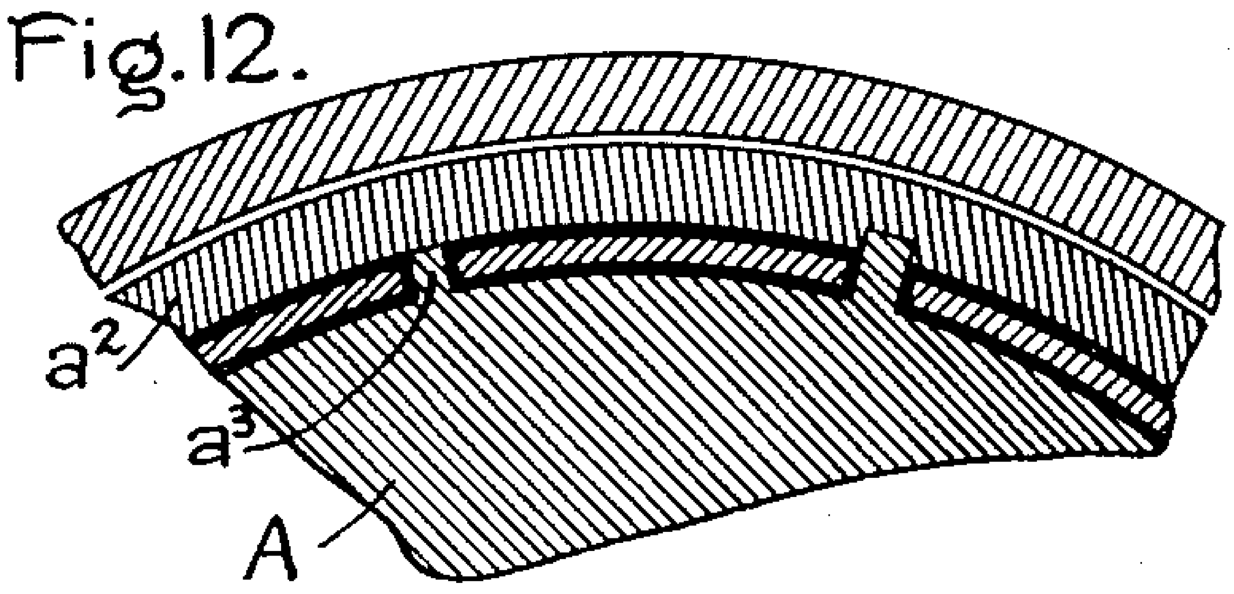


Fig. 16.

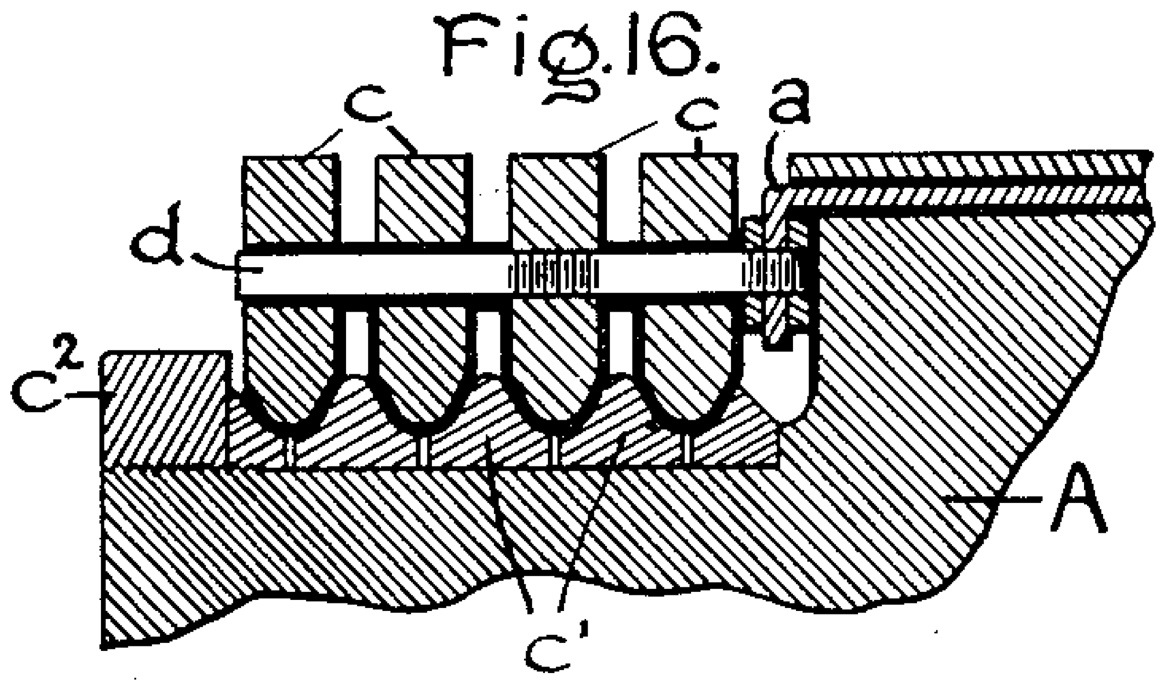


Fig. 13.

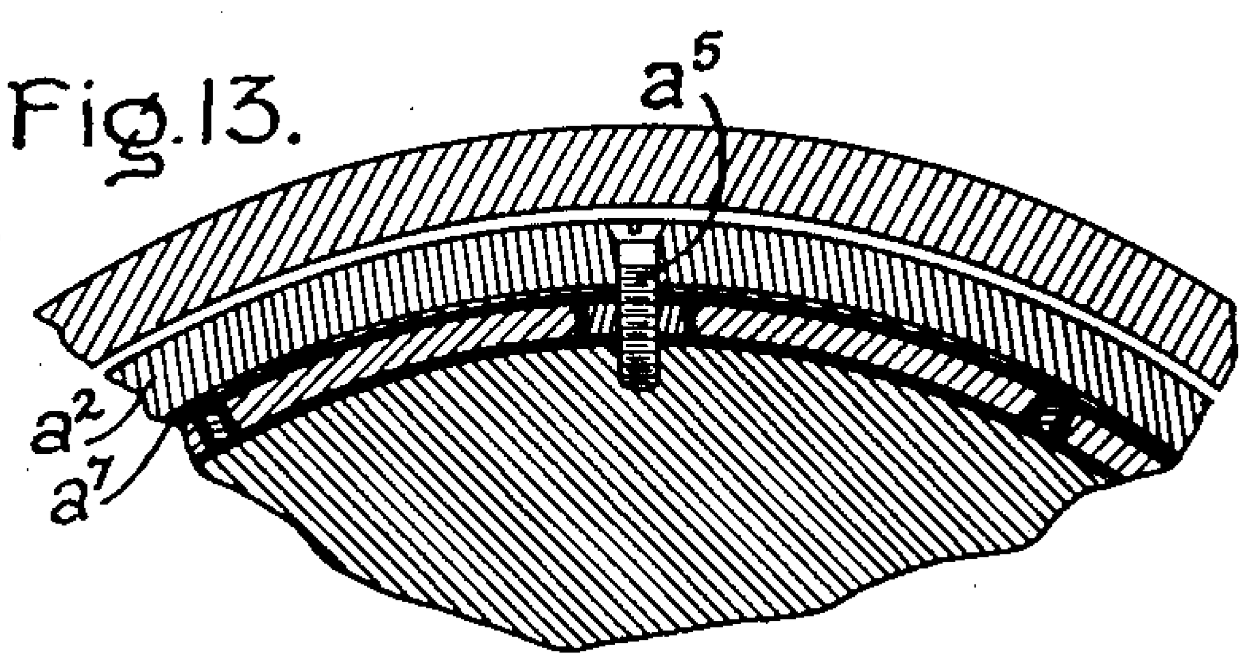


Fig. 14.

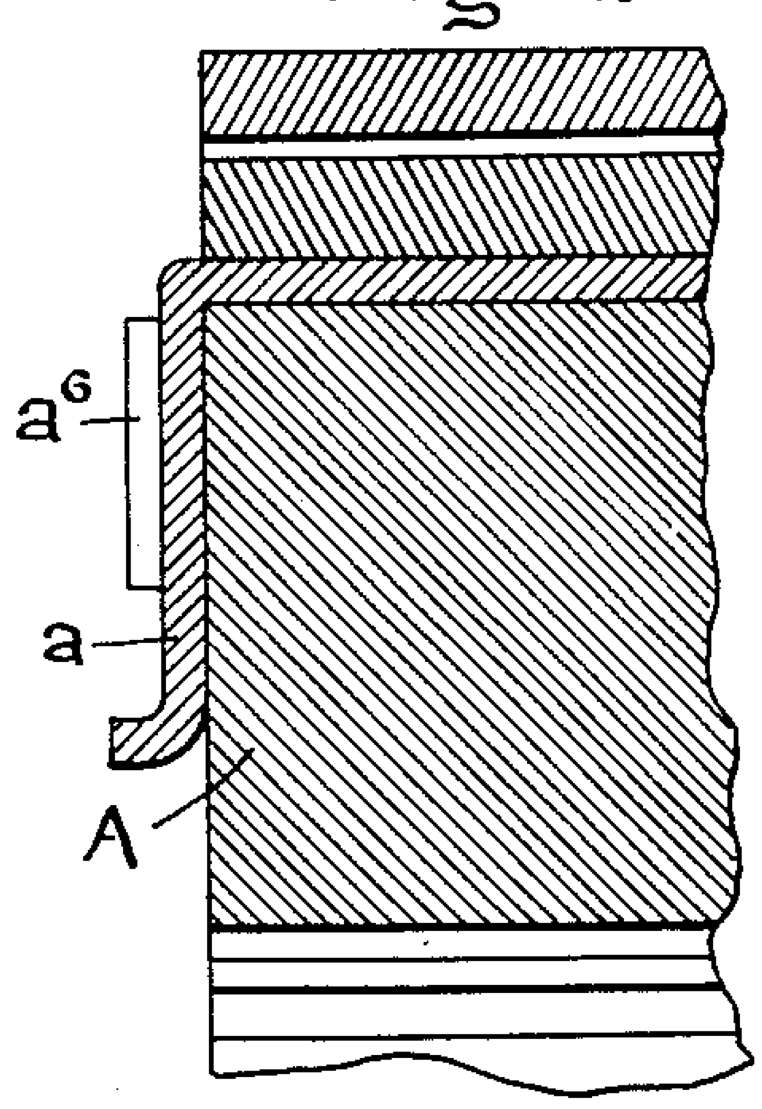
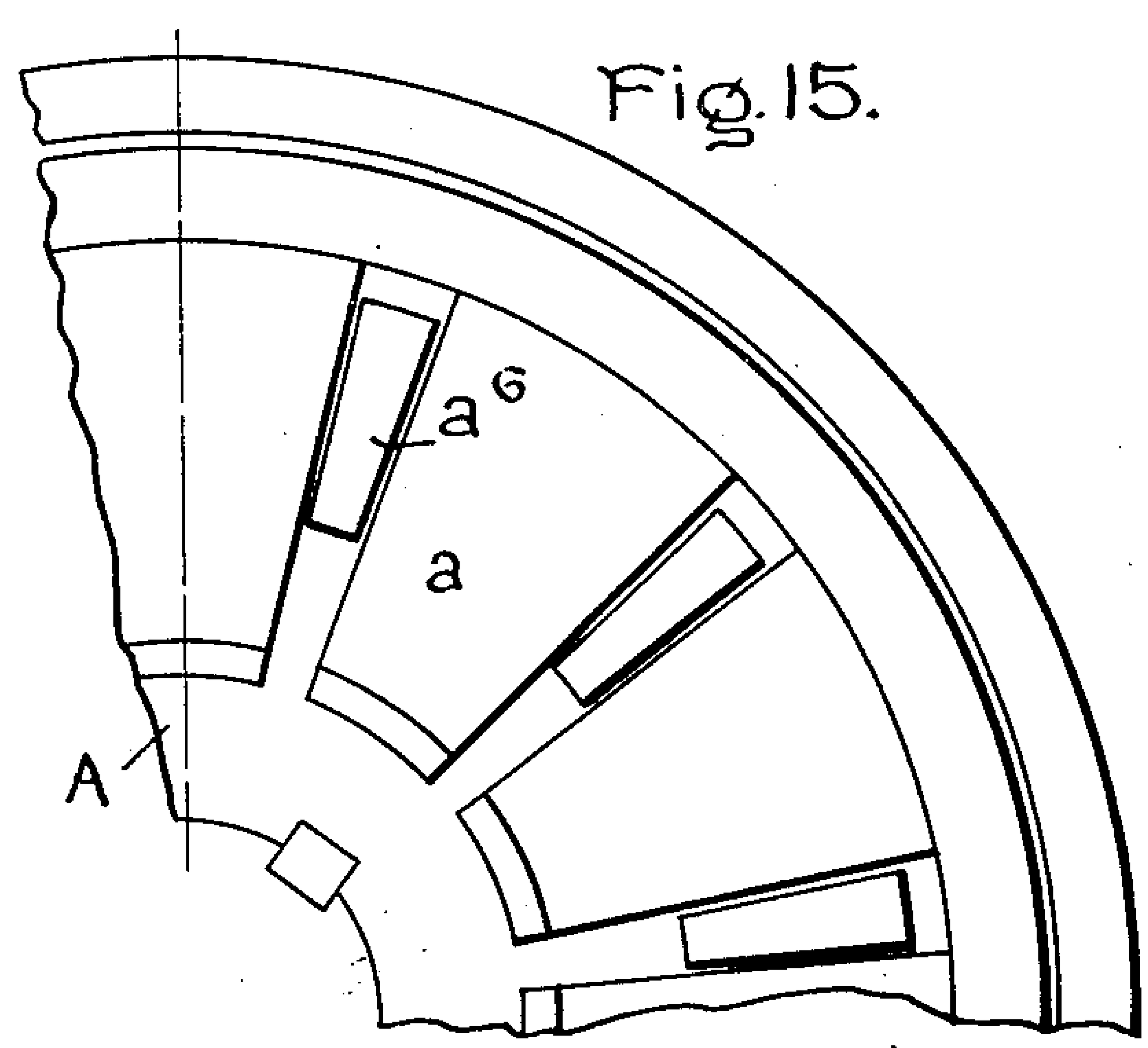


Fig. 15.



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6 SHEETS—SHEET 5.

Fig. 17.

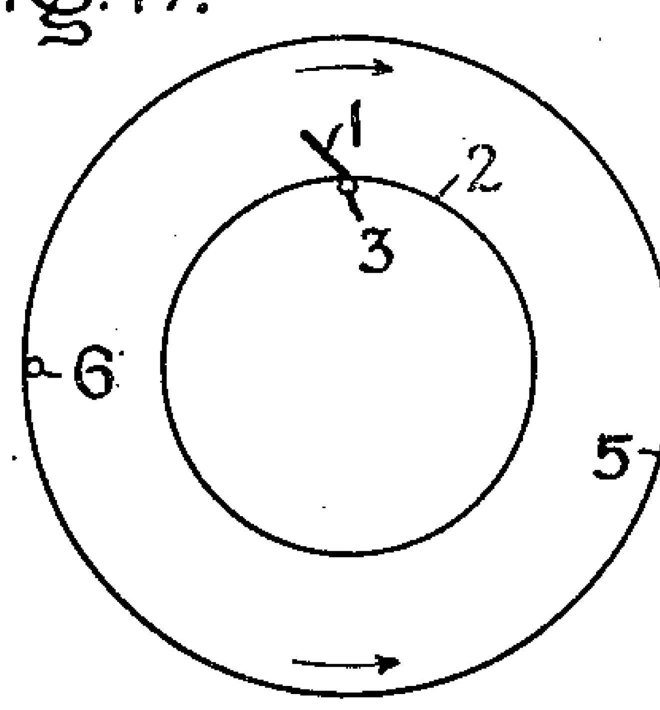


Fig. 18.

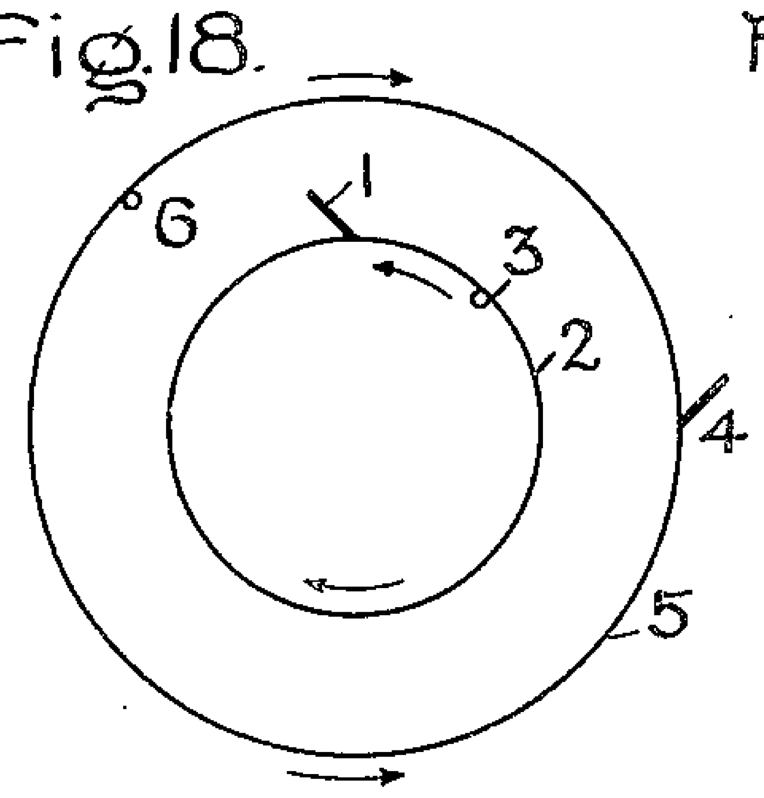


Fig. 19.

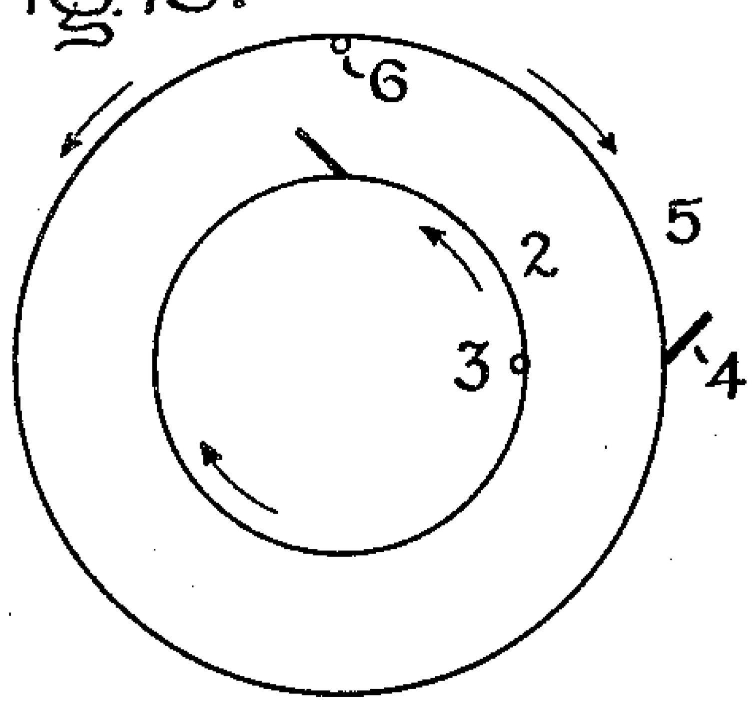


Fig. 20.

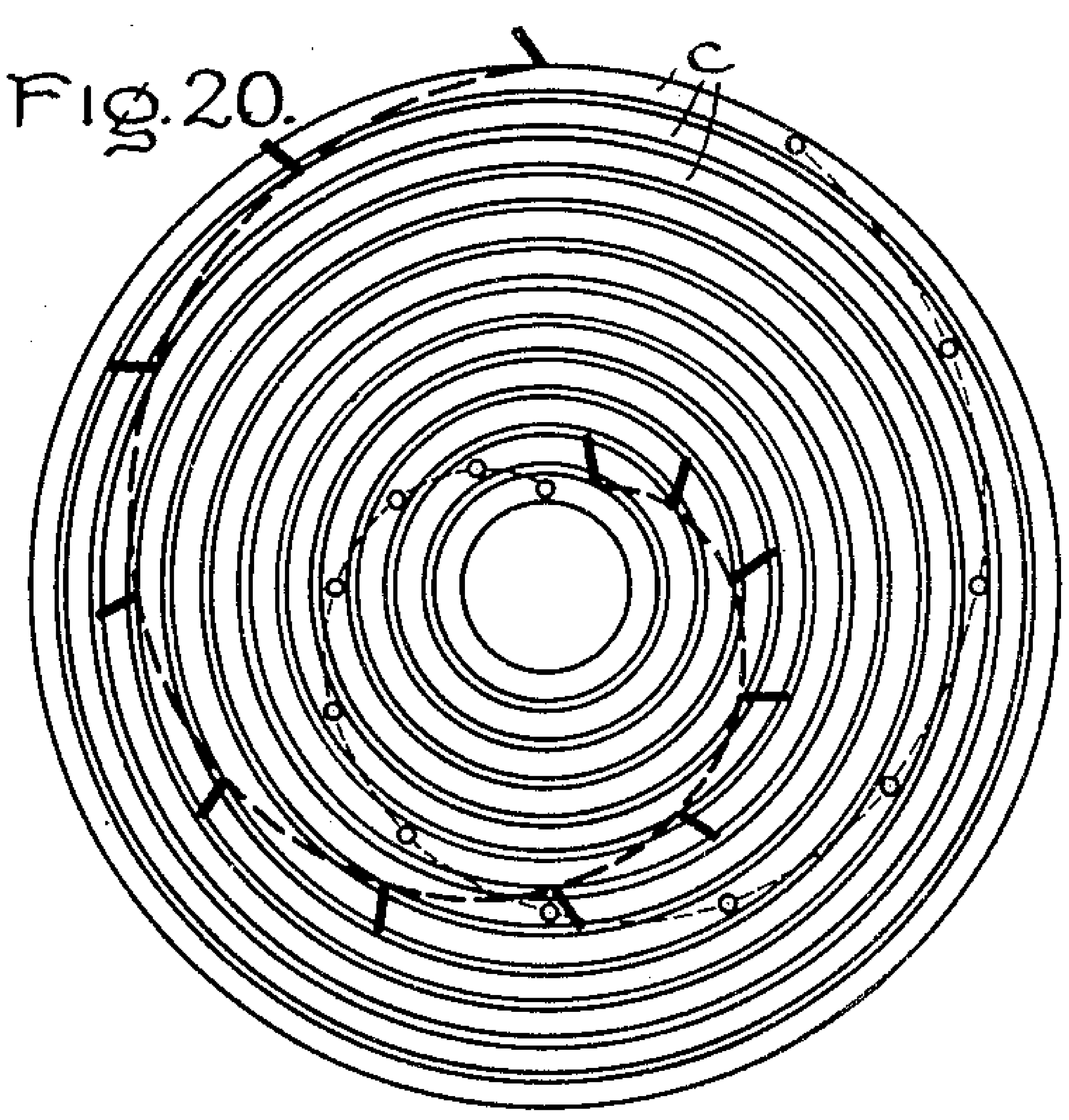


Fig. 21.

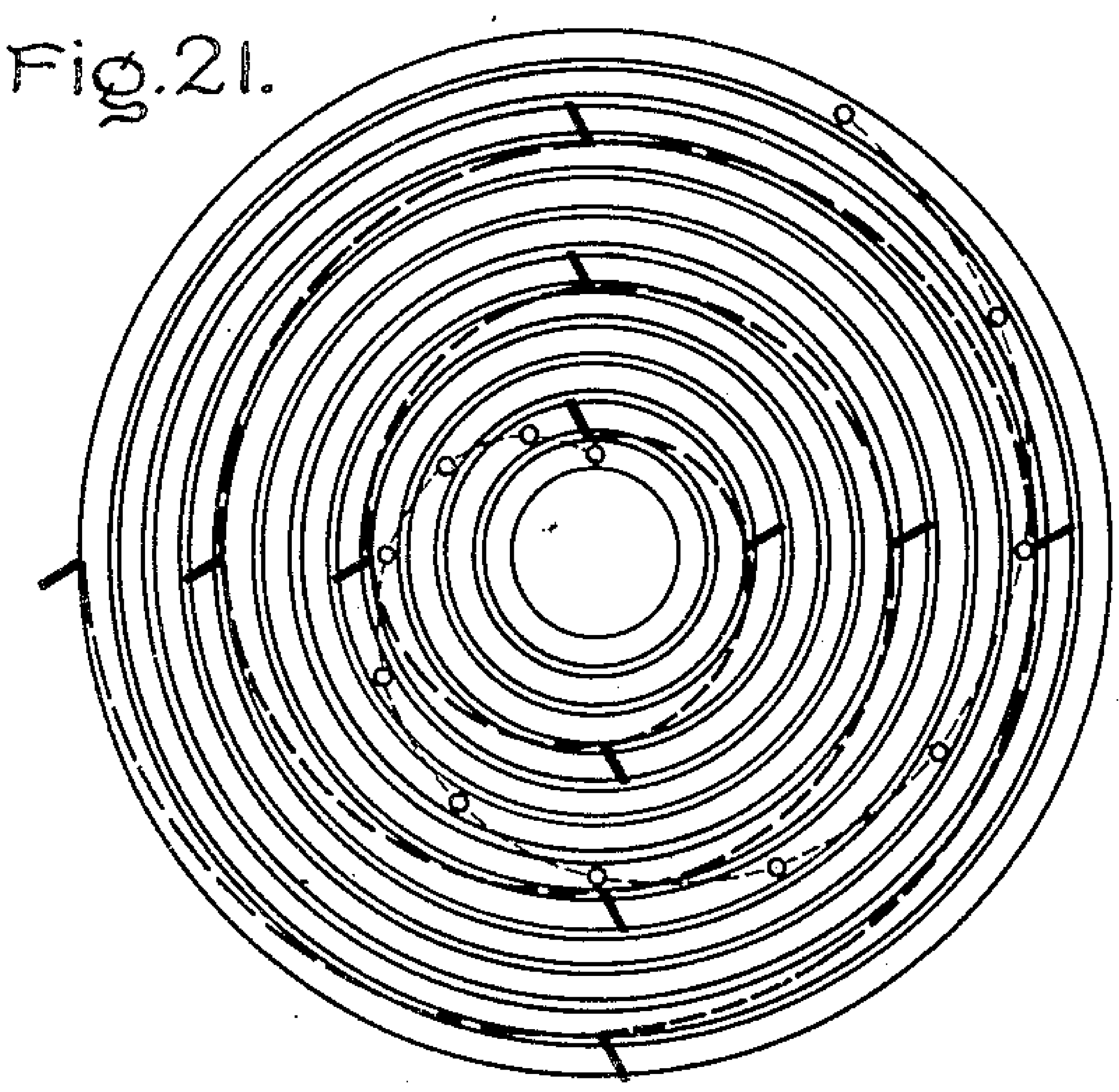


Fig. 22.

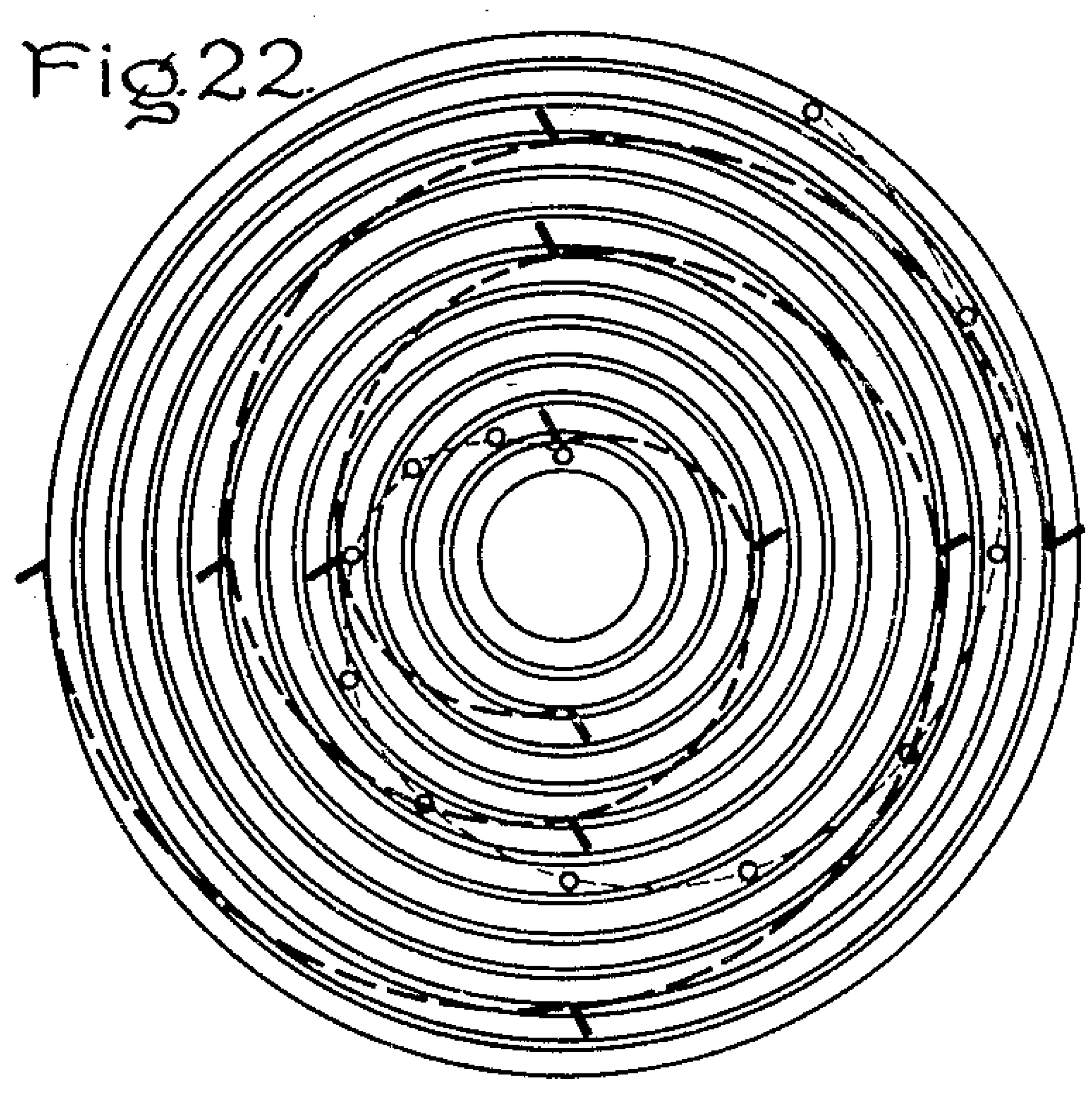
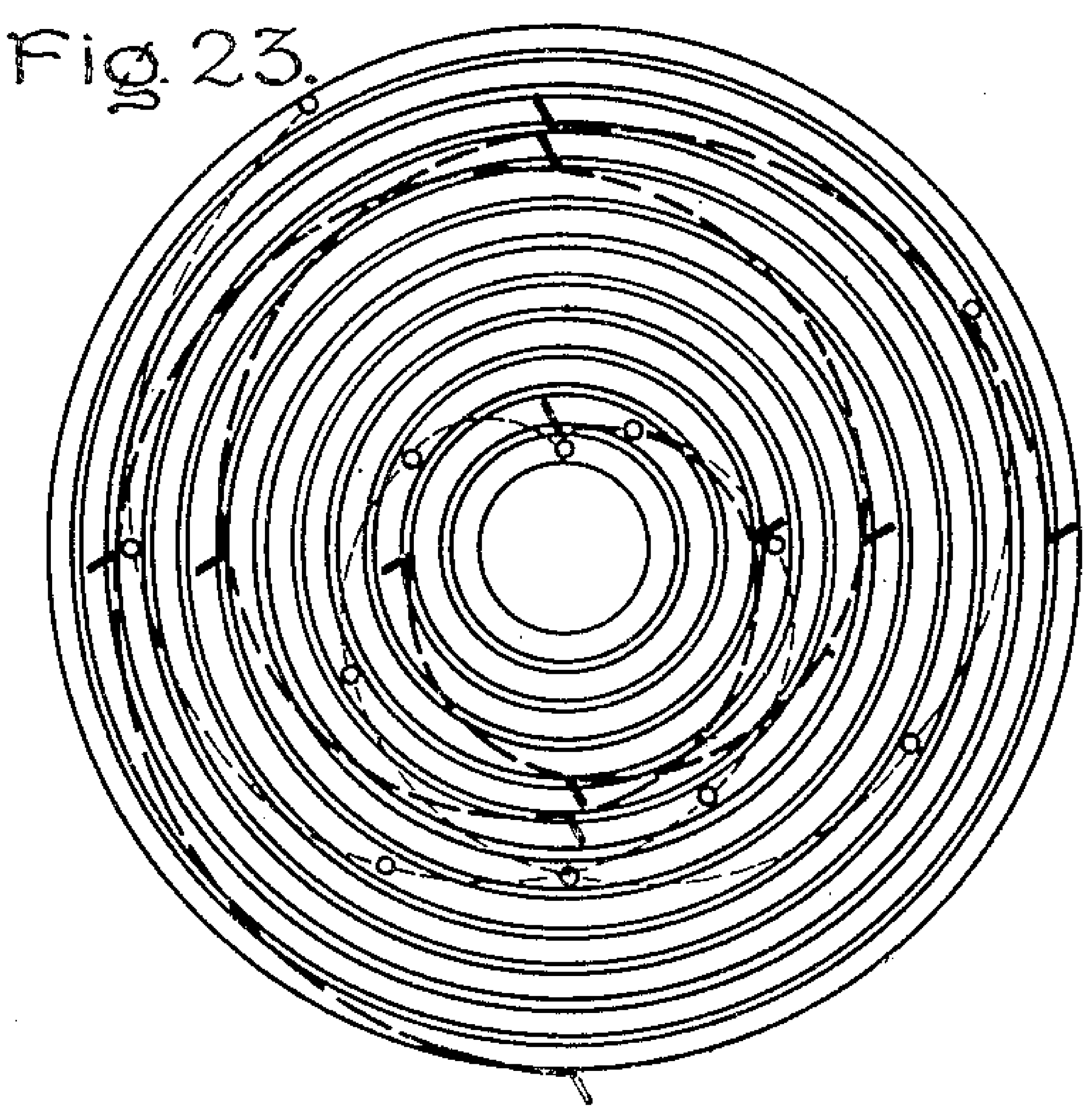


Fig. 23.



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DYNAMO ELECTRIC MACHINE.

APPLICATION FILED MAR. 30, 1904.

Fig. 24.

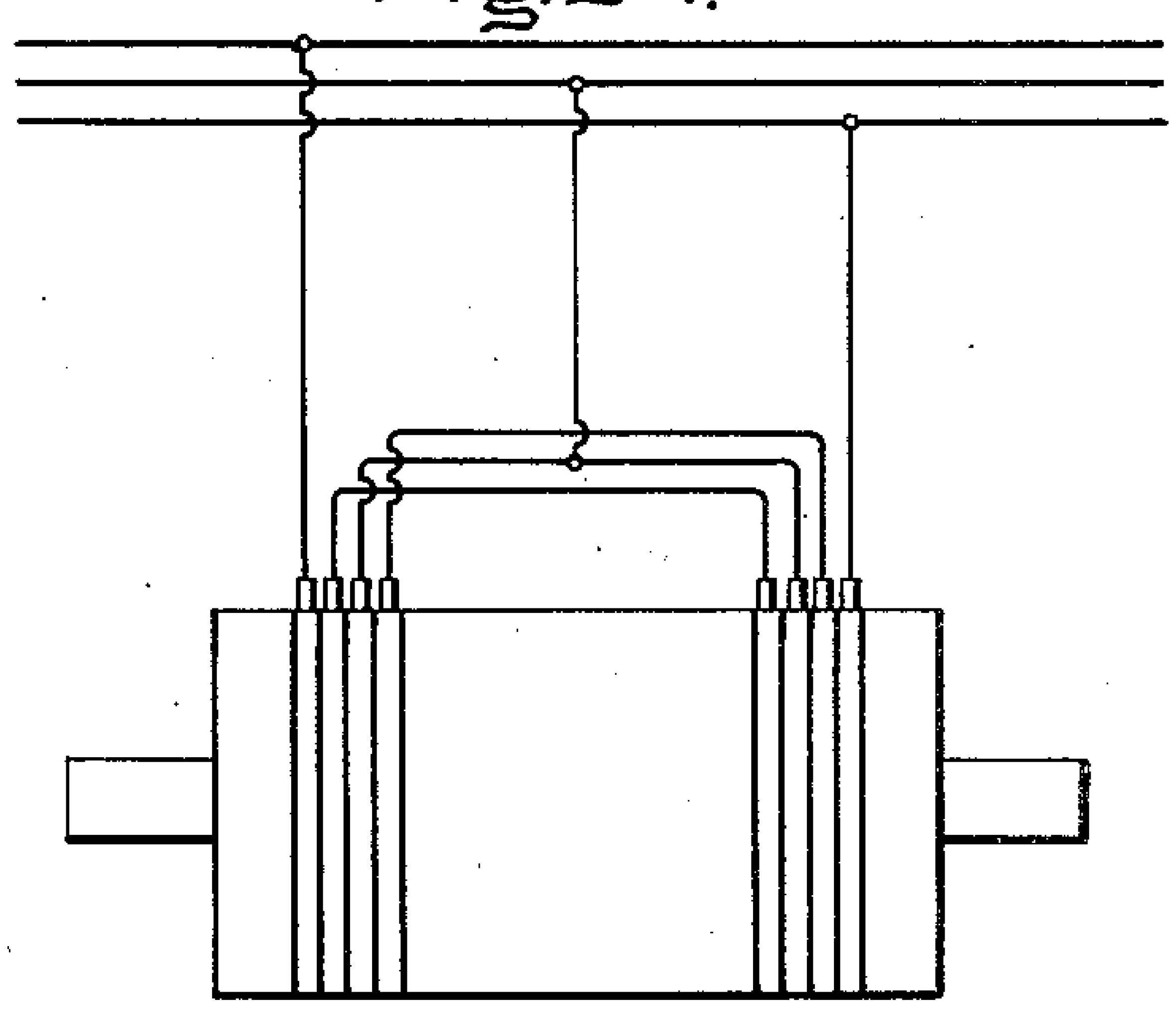


Fig. 25.

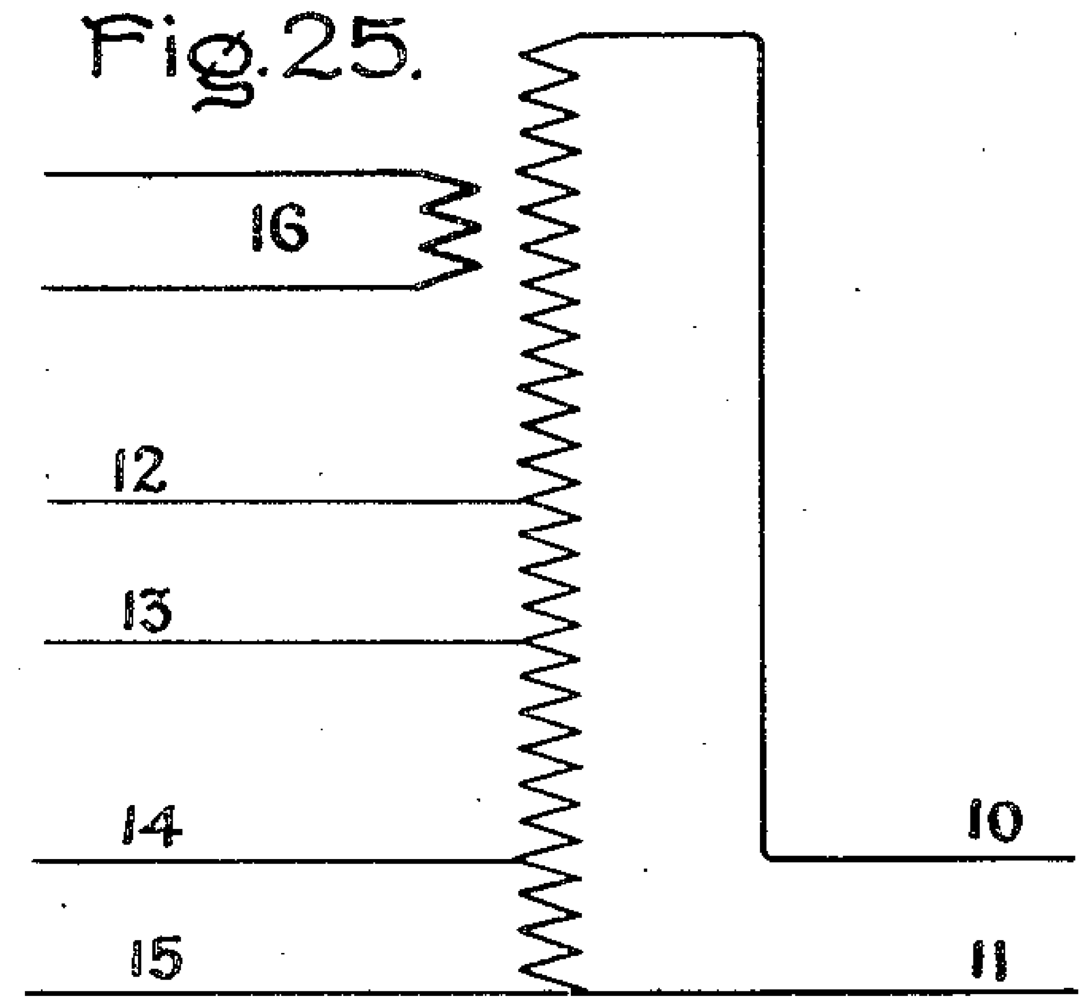


Fig. 26.

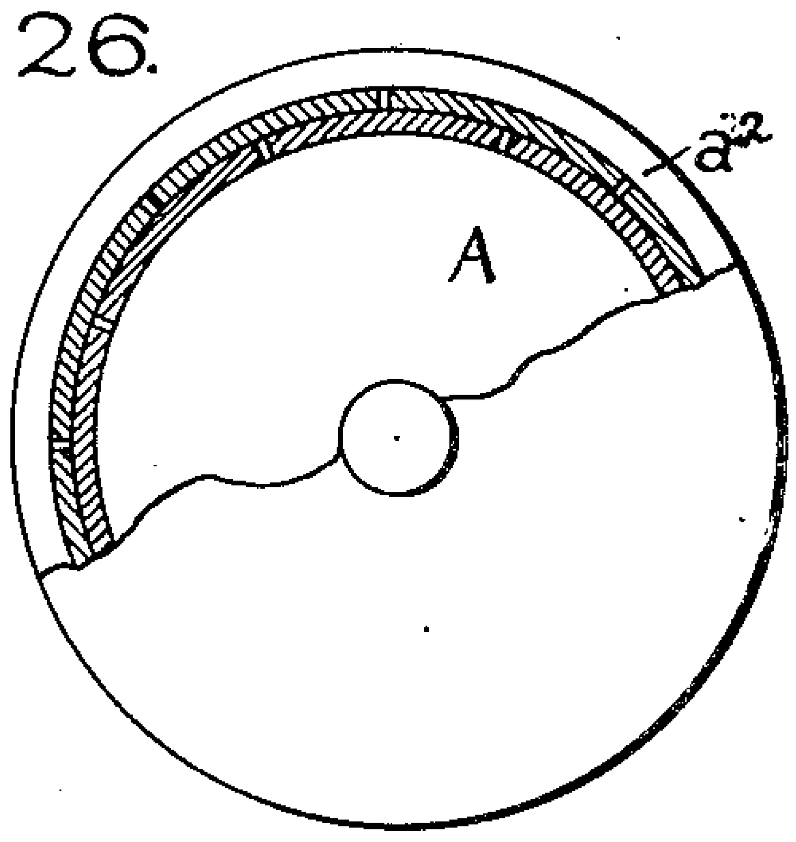


Fig. 27.

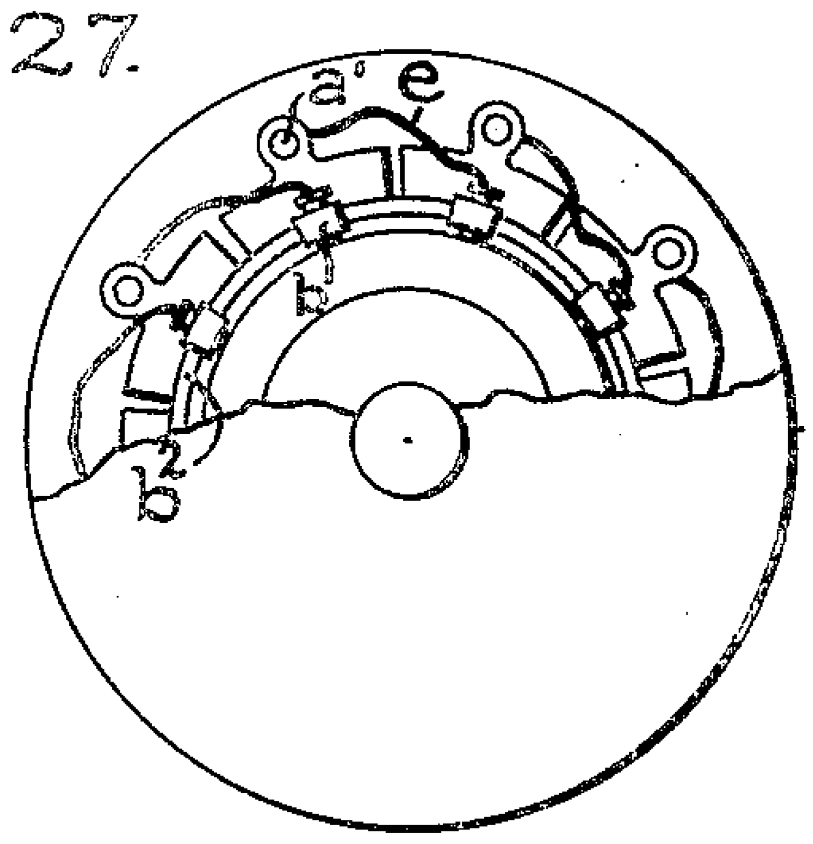
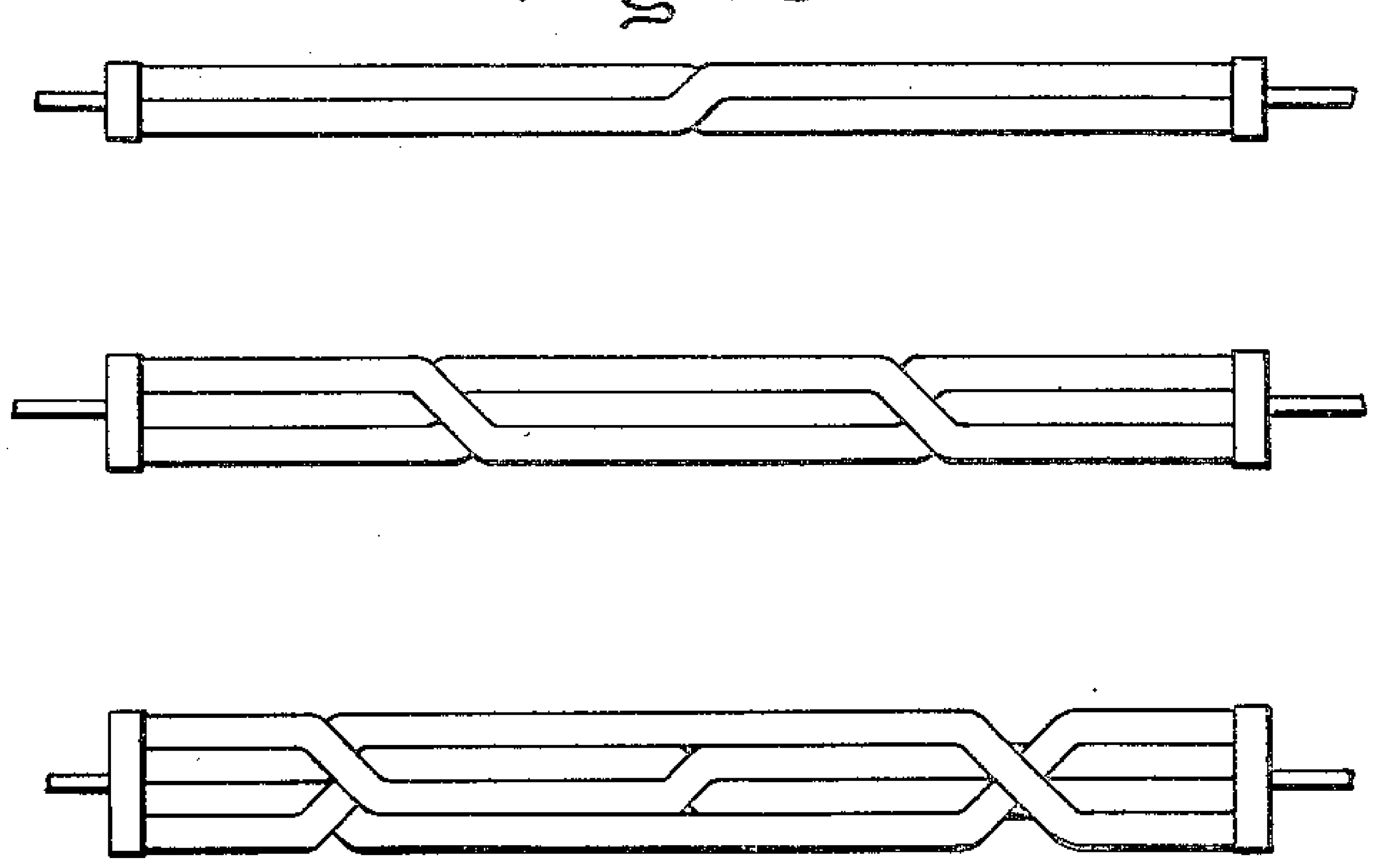


Fig. 28.



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UNITED STATES PATENT OFFICE.

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DYNAMO-ELECTRIC MACHINE.

No. 854,756. Specification of Letters Patent. Patented May 28, 1907.

Application filed March 30, 1904. Serial No. 200,677.

To all whom it may concern:

Be it known that I, JACOB E. NOEGGERATH, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Dynamo-Electric Machines, of which the following is a specification.

My invention relates to dynamo-electric machines, and refers particularly to machines of the type known as "homopolar" or "acyclic." These machines consist in general of a revolving armature in a uniform field. The rotation of the armature in this field produces a constant difference of potential between the extremities of the armature, so that by means of brushes bearing on opposite ends of the armature a unidirectional current may be led off from the machine. The advantage of obtaining a unidirectional current without employing a commutator has long been recognized, and many attempts to utilize a homopolar machine commercially have been made. Two difficulties have heretofore been found by the designers of such machines. In the first place, at speeds at which dynamo-electric machines have ordinarily been operated heretofore, the voltage obtainable from machines of this type has been much too low to permit of their general use. It is not possible to wind the armature of such a machine with a number of conductors in series as in commutating machines, but if a voltage greater than that of a single conductor is desired, it is necessary to place a number of conductors on the armature and provide each with two collector rings. The conductors can then be placed in series by properly connecting the brushes bearing on the collector rings. The impossibility of obtaining anything but a very low voltage without resorting to a prohibitive number of collector rings has heretofore limited the application of "homopolar" machines to purposes for which only a low voltage and large current is required: such, for instance, as in electric welding. A second objection to the use of these machines consists in their enormous armature reaction due to the large volume of current flowing in the conductors and collector rings. This reaction produces a large drop of voltage under load, and has made the regulation of such machines too poor to permit of their use for general light and power purposes, even if a sufficiently high voltage could have been obtained without excessive multiplication of the number of collector rings.

The first of the above objections to the use of "homopolar" machines is being rapidly removed by the growing utilization of steam turbines as prime movers. The great peripheral velocities obtainable by the use of steam turbines render it possible to obtain a sufficiently high voltage in a "homopolar" machine for general commercial use without employing an excessive number of collector rings. Furthermore, it is very difficult to design direct-current generators of the commutator type suitable for rotation at the very high speed of steam turbines, both on account of difficulties in mechanical construction and also on account of the difficulty of securing proper commutation, while the mechanical construction of "homopolar" machines may be readily adapted to withstand high centrifugal strains and the question of commutation does not enter at all. These machines are consequently particularly desirable for use in connection with steam turbines.

One object of my invention is to eliminate the second objection to the use of "homopolar" machines by providing an arrangement of conductors and collector rings which shall eliminate the armature reaction and thereby secure excellent regulation.

Another object of my invention consists in providing a simple arrangement for compounding multipolar machines, which shall permit the degree of compounding to be varied readily.

A further object of my invention consists in arranging the conductors so that they may be connected in different combinations to provide different voltages without producing an unbalancing of the current flow in the armature, which would interfere with the proper regulation of the machine.

Further objects of my invention will appear from the following specification and the accompanying drawings in which

Figure 1 shows a perspective view of a machine constructed in accordance with my invention, a portion of the field structure being broken away; Figs. 2, 3, 4, 5 and 6 show various forms of magnetic circuit adapted to various types of machines; Fig. 7 is an explanatory diagram showing the method of eliminating reaction by the current in the armature conductors; Fig. 8 is a diagrammatic development of conductors and collector rings arranged in such manner that all the conductors are of equal length and a minimum voltage exists between adjacent collector rings; Figs. 9, 10, 11, 12 and 13 show various arrangements for securing the armature conductors to the periphery of the armature; Figs. 14 and 15 show a method of securing the ends of the conductors to the ends of the armature; Fig. 16 shows an arrangement of collector rings and studs; Figs. 17, 18 and 19 are explanatory diagrams showing the theory of the arrangement of armature conductors, collector rings and brushes to eliminate reaction of the current in the rings; Fig. 20 shows diagrammatically an arrangement of collector-ring connections designed to prevent reaction of the current in the collector rings upon the field; Figs. 21, 22 and 23 show modifications of the same; Fig. 24 shows diagrammatically a machine connected for supplying a three-wire system; Fig. 25 shows diagrammatically an armature winding for a rotary direct-current transformer; Fig. 26 shows an arrangement of armature conductors which permits the use of a large number of conductors; Fig. 27 shows diagrammatically an arrangement for compounding; and Fig. 28 shows different forms of conductors adapted for use in "homopolar" machines.

Referring first to Fig. 1, A represents an armature of magnetic material journaled in bearings *b′* and carrying on its periphery the flat conducting strips *a;* B represents the field structure energized by two field coils F F; *c c* represent collector rings carried by the armature A, and each collector ring connected to an armature conductor *a; b b* represent brushes supported from the field structure and bearing on the collector rings *c; a′* represents a return conductor connecting the brushes *b b*. With this arrangement it will be seen that the two field coils F F if properly connected produce a magnetization of the field structure which may be considered as passing down through the central portion of the field structure through the armature conductors *a a* outwardly in both directions toward the end of the armature A and back to the ends of the field structure B. As the armature conductors rotate in this field it is evident that a difference of potential will be produced between the ends of the conductors, which will be led off by the brushes *b b* bearing on the collector rings *c c,* and that by properly connecting the brushes *b b* any or all of the armature conductors *a a* may be placed in series.

Referring now to Fig. 7, the method of preventing armature reaction will be explained. In this figure A represents diagrammatically the armature, and B the field structure, the arrows showing the direction of the flux. The flux, due to the field magnetization, is supposed to be passing outwardly from the armature to the field, as indicated by the outer circle of arrows. Now consider a single armature conductor of the usual circular form and supported at some distance from its adjacent conductors. This is shown in the left-hand half of armature A. If the current is flowing through one of these conductors, a circular field will be set up around the conductor as indicated by the circular dotted arrows. This circular flux would in the first place produce a distortion of the field flux, so that it would no longer pass radially outward, as shown by the outer circle of arrows, but would be inclined at an angle to a radius. This would produce a longer path for the flux, which means a greater number of lines through the same area and consequently a greater density, as will be well understood, and this increased length of path and greater density would result in a decrease of the total flux and consequently a drop in the induced voltage. This armature reaction would vary with the amount of current flowing in the machine, and at full load would produce an excessive drop in voltage. This is one of the factors which has heretofore rendered the regulation of "homopolar" machines unsatisfactory for general use. Furthermore, the distortion of the field flux is not uniform around the surface of the armature, for in some places the armature flux assists and in other places opposes the field flux. This not only produces an uneven flux density, which on account of saturation further weakens the total flux, but also produces a constant variation of flux at the inner periphery of the field as the armature revolves, which results in eddy current losses and decreased efficiency. Now if the conductors are broadened out and brought close together so as to form a practically continuous sheet of current-carrying material, as shown in the lower right-hand view of armature A, the flux passing between the conductors will be eliminated since adjacent conductors tend to produce opposing fluxes in the space between them and consequently neutralize each other, but all of the conductors will combine to produce a flux concentric to the axis of the machine, as shown by the circular arrow opposite these conductors. Thus, although the local disturbance and resulting eddy currents are avoided by this arrangement, the distortion of the field flux still remains and the regulation of the machine would be effected. And now referring to the upper right-hand quarter of Fig. 7, if the conductors *a′* be placed at or near the inner periphery of the field structure B directly opposite to the armature conductors *a* and if the conductors *a′* are so connected that the current through them is in the opposite direction to that in the armature conductors, the field of each armature conductor will be neutralized by an equal and opposite field of one of the conductors a'. This is indicated by the two concentric arrows, the heads of which point in the opposite direction. With this arrangement, the cross-magnetization of the armature conductors is wholly eliminated. This is the arrangement which is shown in Fig. 1. The conductor a', which is supported at or near the inner periphery of the field structure and directly opposite one of the armature conductors a, acts as a return conductor for the current in one of the armature conductors, and consequently produces a field equal and opposite to that of an armature conductor, thereby completely neutralizing all tendency to cross-magnetization by the armature conductor.

Referring now to Fig. 2, I have shown somewhat diagrammatically a modified form of magnetic circuit. The armature A consists of a comparatively thin drum mounted on the shaft S and carrying on its surface the armature conductors and collector rings in the usual manner. In this arrangement the flux passes directly through the armature in a radial direction. This arrangement produces a lighter revolving member than that of Fig. 1 and consequently a decreased core loss, but does not possess as great mechanical strength. Fig. 3 shows another form in which the armature A is formed as a radial disk attached to the shaft S. The conductors as shown in the figure are carried on the surface of the armature, conductors being shown on both sides of the armature. If preferred, however, a single conductor may be used, extending through the central portion of the disk, or the disk itself may be used as a conductor, in which case it may be divided into segments or into parallel disks if desired. Fig. 4 shows an arrangement for a vertical machine. The magnetic circuit is similar to that of Fig. 1, except that I have shown it divided at the center by a space of any desired width so as to form two independent magnetic circuits in order to preserve independence of the fluxes due to the two sets of field coils and the flux leaves the ends of the armature axially instead of radially. I have also shown two field coils F, F for each half of the magnetic circuit, instead of one, as in Fig. 1. In all the arrangements shown, the field structure may be divided in the middle, as shown in Fig. 4, if desired, and the number of field coils may be varied.

In Fig. 4 I have shown the air gaps at the ends of the armature of different lengths and of different cross-sections. The upper air gap is made shorter and of higher magnetic density than the lower air gap. By this arrangement, part of the weight of the revolving armature may be taken from the bearings. In this figure also I have shown a method for laminating a drum armature. The armature conductors which would be placed the same as in Fig. 1 are removed in order to show the armature body more clearly. The face of the armature opposite to the central portion of the field is slotted as shown, thereby preventing losses of energy in eddy currents. The slots are preferably of different depths as shown in order to prevent eddy currents effectively without decreasing the efficiency of the magnetic circuit. The armature is built up of a plurality of concentric steel rings which act as laminations to prevent eddy currents due to the flux entering the ends of the armature.

In Fig. 1, in which the flux both enters and leaves the armature at the periphery, the form of lamination consisting of slots shown at the center of the armature of Fig. 4 would be utilized both at the center and at the ends. The slots are not shown in Fig. 1 which is not intended to show the details of construction.

Fig. 5 shows a modification of Fig. 4, only two field coils being shown and the lower air gap being made vertical instead of horizontal. This furnishes another arrangement adapted for relieving the bearing of the weight of the armature.

Fig. 6 shows a modified form of field structure in which a plurality of small field coils are employed in place of the large field coils encircling the armature, which have been shown in the foregoing figures. A plurality of closely spaced inwardly projecting cores f are shown, each carrying a field coil F, as in the usual direct-current dynamo-electric machine, but the coils are all similarly wound and instead of the poles being independent at their faces, they are joined by a heavy magnetic ring f' of a thickness equal to or greater than the distance between the cores, which serves to produce a uniform "homopolar" field at the inner periphery of the field structure with a flux distribution the same as that at the central air gap of Fig. 1. The rest of the magnetic circuit is the same as Fig. 1. Since "homopolar" machines must be driven at a very high speed in order to obtain a commercial voltage with a reasonable number of collector rings, it is essential that proper provision be made for securing the conductors to the periphery of the armature, and since the armature is preferably "smooth-cored" in order to avoid eddy currents at the inner periphery of the field it is necessary to guard against both centrifugal strain and tendency of the flat conductors to slip on the armature surface. Fig. 9 shows a method of securing the armature conductors against both forces. The conductors may be formed with a flat lower surface and a rounded upper surface conforming to the curve of the armature periphery as shown. The conductors a,

a may be placed in broad shallow slots and held in place by a steel ring or drum a^2 shrunk on over the conductors.

Fig. 10 shows another arrangement for securing the armature conductors to the periphery. In this arrangement the binding ring a^2 is provided with lugs a^3, which separate the armature conductors, and some or all of which enter the surface of the armature as shown.

In Fig. 11 both armature periphery and binding ring a^2 are provided with slots in which are placed spacing blocks a^4, preventing the rotation of the armature conductors relative to the armature.

In Fig. 12 the lugs a^3 are shown on the surface of the armature, some or all of them entering the binding ring a^2.

In Fig. 13 a screw a^5 is employed to prevent the movement of the conductors relative to the armature, while the binding ring a^2 serves to hold the conductors against centrifugal strain, as in the other arrangements. A thin sheet a^7 of high tensile and compressive strength, preferably metal, may be placed directly over the conductors to protect the insulation from injury by the shrinking ring a^2. Instead of or in addition to the above arrangements for preventing the lateral slipping of the armature conductors, the arrangement shown in Figs. 14 and 15 may be employed. As shown in these figures, the armature conductors a are bent over the ends of the armature, and the lugs a^6, cast or bolted to the armature body, prevent the circumferential movement of the conductors relative to the armature.

Since "homopolar" machines must operate at a high speed in order to obtain the necessary voltage, it is essential that the revolving parts should be mechanically balanced. Fig. 16 shows a method of connecting the armature conductors to the collector rings by means of connecting studs which are all of the same length. In Fig. 16 the stud d is shown bolted to the armature conductor a and passing through all of the collector rings c, which are shown as four in number. Although the stud d passes through all the collector rings, it is insulated from all but one, while it is screwed into that one, making electrical contact therewith. Thus, all the studs for all the armature conductors may be made the same length, while each armature conductor is connected to its proper ring. Of course if it is desired to place a number of rings in parallel, each stud may be screwed into the proper number of rings and insulated from the rest. Fig. 16 also shows a method of supporting the collector rings. The rings c' are mounted on the armature body A in such a manner that they are free to move axially along the armature. Their upper surfaces are tapered and between each pair of rings c' is supported one of the collector rings c, the inner surface of which is also tapered. c^2 is a nut which screws onto the end of the armature body A, and as it is tightened presses the rings c' together. The collector rings c are thus compressed between and pressed outward by the rings c', and are thus supported rigidly and accurately centered thereby, although insulated therefrom.

I have already described the manner of eliminating cross-magnetization by the armature conductors. The conductors themselves, however, are not the only source of field distortion in "homopolar" machines. The currents in the collector rings have an important effect and produce serious distortion, unless properly compensated for.

Referring to Fig. 17, if 1 represents a brush bearing on the collector ring 2, and if 3 represents the point of connection of an armature conductor to the collector ring 2, it will be seen that when the collector ring is in the position shown relative to the brush 1, the collector ring carries no current, but the current passes directly from the point of connection 3 out of brush 1. When, however, the ring is displaced by any amount from the position shown in Fig. 17, as for instance, by an angle of 45 degrees, as shown in Fig. 18, it will be seen that current is now flowing through the entire collector ring from the point 3 to the brush 1. The current, on reaching point 3 divides, the larger part passing directly to brush 1, and the smaller portion passing around nearly the whole circumference of collector ring 2, the proportion of current in the two parts being determined by the relative resistance in the two parts. When the ring has rotated another 45 degrees, as shown in Fig. 19, current is still flowing through all the ring, but the distribution of the current is altered. From an inspection of Fig. 1 it is evident that current flowing in a collector ring acts to magnetize the magnetic circuit in the same way as current in a turn of the field coils F F, since the collector rings are parallel to the turns of these coils. Moreover, as is evident from the diagrams, Figs. 17 to 19, the distribution of current in each collector ring is constantly varying. Hence it is plain that unless properly compensated for, the current in the collector rings will produce serious disturbances in the magnetic circuit, and that these disturbances will be of a fluctuating nature. Now consider a second ring 5, as shown in Fig. 17, with a brush 4 bearing thereon, the point of connection of the armature conductor being represented by 6. Let the brush 4 be displaced by an angle, such as 90 degrees, from brush 1, and in a clockwise direction, and let the point of connection 6 be displaced from the point of connection 3 by an equal amount in the opposite direction; now if the current in both rings be considered, it will be seen that the conditions are as follows: in Fig. 17, ring 2 has no magnetizing or demagnetizing effect, as the current is passing from point 3 to brush 1. Ring 5, however, is traversed by current, but each half of the ring carries one-half the current and it is in the opposite direction to the current in the other half. Consequently, neglecting for a moment local distortion of the flux due to the current in each half ring, it is evident that the resultant flux of the ring can exert neither a magnetizing nor a demagnetizing action. Now if both rings have rotated 90 degrees, as shown in Fig. 19, it will be seen that the current flowing through the shorter path from point 3 to brush 1 will be of the same amount and in opposite direction to the current flowing in the shorter path from point 6 to brush 4, and consequently each current will neutralize the magnetizing effect of the other. The same is true of the current in the longer paths, so that in this position of the rings a complete mutual neutralization is secured. By calculating the currents in Fig. 18, it will be seen that, neglecting local distortions, the resultant magnetization will be zero. In other words, if one brush is displaced from the other by an amount equal and opposite to the displacement of one point of connection from the other, a complete neutralization of the currents will be obtained in certain positions of the rings; and neglecting local distortions, the resultant fluxes will at all times balance. With only two rings it is impossible to produce a complete neutralization for all positions of the rings. In all but one position there will be local distortions. As the number of rings is increased, however, a close approach to complete neutralization may be obtained by following out the theory explained in the diagrams. Thus, in Fig. 20, I have shown diagrammatically twelve collector rings *c c* with the points of connection of the armature conductors thereto indicated by small circles, as in the above diagrams, and it will be seen that the points of connection are progressively displaced by an angle equal to one-twelfth of the circumference. The brushes are displaced similarly, but in the opposite direction, the brushes and the points of connection of the armature conductors each forming a complete spiral curve, as indicated by dotted lines. With this arrangement a practically complete neutralization of the magnetizing effect of the collector ring currents is obtained, as may be proved by calculating the current distribution. Instead of two simple spirals, as shown in Fig. 20, other arrangements of the spirals may be employed, while maintaining the same neutralization effect. Thus in Fig. 21 the armature connections form the same spiral as in Fig. 20, while the spiral of the brushes is altered by displacing each brush from the adjacent brushes by 90 degrees instead of 30. This makes a spiral of three turns instead of one, and has the advantage that the brushes may be grouped instead of being distributed around the entire circumference of the machine, thereby making it easy to inspect and replace the brushes by means of properly located holes in the frame of the machine. Fig. 22 shows another arrangement of the brush spirals, a double spiral being formed in place of a single spiral, the rings of an even number being employed for one spiral and the rings of an odd number being employed for the other spiral. The brushes in each spiral are displaced from each other by 90 degrees, as in Fig. 21, and two complete spirals of a turn-and-a-half each are thus formed.

In Fig. 23 a further modification is shown, both brushes and armature connections being disposed in double spirals. Thus, numerous variations may be made with spiral arrangements, and after a spiral has been properly laid out, the rings may be transposed as much as desired without losing the advantages which the spiral arrangement gives of compensating for reaction in the collector rings. Of course when the rings are transposed the positions of the points of connection and of the brushes may no longer lie on an actual spiral curve, but as long as they are deduced from the original spiral, the proper compensation will be obtained. Thus for instance the arrangement of Fig. 23 is deduced from that of Fig. 22 by transportation of the rings, in this case the actual spiral arrangement being maintained.

It is sometimes advantageous to be able to connect a machine for different voltages. This can be accomplished readily with a "homopolar" machine by placing different numbers of the conductors in series and in parallel. If it is desired to connect the conductors in parallel, however, it is very important that the resistance of the parallel circuits should be equal. The conductors being large, the resistance is low and a small variation in resistance would produce a very serious unbalancing of the current flow in the parallel circuit. In order to secure the equality of resistance in parallel circuits formed of the armature conductors connected in any desired manner, I so arrange the armature conductors and their connections that all the conductors are of the same length, and consequently of the same resistance. Thus, in Fig. 8, which shows diagrammatically a development of an armature winding and collector rings, the dotted lines *a* represent the armature conductors each connected at both ends to collector rings *c c*. It will be seen that the armature conductor which is connected to the outside ring *c* at one end of the machine is connected to the inside ring at the other end, and that the other armature conductors are similarly symmetrically connected. Consequently the armature conductors are all of the same length and resistance.

Fig. 16 shows one mechanical construction of the armature studs, as has been described. Thus, if the stud at one end of armature conductor *a* is screwed into the next to the inside ring *c*, as shown in Fig. 16, the stud at the other end of the conductor would be screwed into the next to the outside ring. In this manner not only are the conductors and studs of the same length mechanically and consequently mechanically balanced, but they are also of the same length electrically, and consequently electrically balanced.

Referring again to Fig. 8, the full lines *a'* represent the return conductors supported on the field structure, as shown in Fig. 1. These return conductors are also in this arrangement so arranged that they are all of the same length and consequently of the same resistance. Furthermore, it will be seen by tracing out the circuits, that the collector rings are so connected that a minimum difference of potential exists between adjacent rings, the maximum potential existing between the outside and inside rings. The brushes are grouped in four groups of three brushes each, as shown in Figs. 21, 22 and 23, the spiral arrangement of Fig. 21 being used. In Fig. 8, I have shown the field coils F F as shunt coils connected across a portion of the armature conductors. It will be understood, however, that the field coils may be shunt, series, or compound-wound as desired.

A simple method of compounding is shown in Fig. 27. In this figure, the return conductors *a'* are shown connected to the brushes *b* by the flexible connections *e*. The brushes are displaced circumferentially by any desired angle from the ends of the return conductors to which they are connected. As shown in the figure, the brushes are displaced by an angle approximately equal to the angle between adjacent return conductors. It will be seen that the flexible leads *e e* each form a fraction of a turn surrounding the armature and all the leads taken together are the equivalent of a single field turn carrying a current equal to the armature current and varying therewith. In other words, these leads produce a circumferential component of current flow in the armature circuit. Consequently they act as a compound winding, the effect of which may be varied by shifting the brushes to a position of greater or less displacement by moving the brush-holder ring b^2. A simple method of compounding is thus provided, which permits the degree of compounding to be varied at will. Obviously, compounding may be similarly obtained by displacing the point of connection of the armature conductors to the collector rings from the armature conductors. This arrangement, however, does not permit of the ready adjustment of the degree of compounding that is obtainable where displaced connections are used with the stationary return conductors.

Fig. 28 shows different forms of conductors, each one made of a plurality of strips connected in parallel. Where a single wide conductor is used a slight difference in the air gap and a consequent uneven distribution of flux threading the conductor would produce potential difference in the conductor which would result in wasteful eddy currents. This may be avoided by "laminating" the conductors, as shown, the strips of which the conductor is composed being properly transposed so as to equalize the potentials generated in the several strips. Other methods of transportation than those shown may be employed. Collector rings may also be laminated, if desired, in order to prevent eddy currents, but with collector rings of usual size, lamination is unnecessary.

It is not necessary that the conductors should be placed in a single layer on the periphery of the armature. Fig. 26 shows two layers of conductors placed on the armature A and held in position by the binding ring or cylinder a^2.

Not only is it possible to vary the connections of a "homopolar" machine arranged in accordance with my invention, so as to obtain different potentials from the machine at different times, but it is also possible to obtain any desired number of potentials at the same time from a single machine. Thus, Fig. 24 shows diagrammatically a "homopolar" machine connected for supplying a three-wire system. The field structure is omitted and the return conductors are shown symmetrically connected to the brushes, and consequently of equal length. The neutral wire of the three-wire system is connected to the central return conductor.

In addition to serving as a generator for different voltages, a "homopolar" machine arranged in accordance with my invention may be used as a motor or as a transformer of direct current voltages. The arrangement of windings for operation as a transformer is shown diagrammatically in Fig. 25. The low potential winding may form a part of the high potential winding, or may be separate therefrom and on the same or different parts of the machine, or both arranged to be used in a single machine. Thus, in Fig. 25 a high potential winding is shown connected to the mains 10 11. Leads 12, 13, 14 and 15 are tapped off from the winding, and any pair of these leads may be used for obtaining the voltage desired. Furthermore, an additional winding 16 may be applied to the armature independently of the high potential winding. It is obvious that the machine may be used as either a step-up or step-down transformer.

It will be seen from the foregoing that my invention embodies a number of features which, while I prefer to use them together, may to advantage be used independently or with one or more of the features heretofore described omitted, and which I desire to claim whether used together or not. Moreover, I do not desire to limit myself to the particular construction and arrangement of parts here shown, since changes which do not depart from the spirit of my invention, and which are within the scope of the appended claims, will be obvious to those skilled in the art.

What I claim as new and desire to secure by Letters Patent of the United States is,

1. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature, a set of broad conductors carried by said armature and closely spaced so as to form a practically continuous sheet of current-carrying material encircling the armature, and a similar set of conductors carried at or near the inner periphery of said field structure and severally connected in series with the several armature conductors.

2. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature, a plurality of broad conductors connected to collector rings, and similar return-conductors carried by the field structure, both sets of conductors being closely spaced so as to form two opposing substantially continuous sheets of current-carrying material and each return conductor being connected in series with its corresponding armature conductor.

3. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature composed of a plurality of superimposed concentric rings of magnetic material, and a plurality of conductors carried at or near the periphery of said armature.

4. In a dynamo-electric machine, a "homopolar" field structure, and a revolving armature composed of a plurality of concentric rings of magnetic material, said armature being slotted perpendicularly to the axis.

5. In a dynamo-electric machine, a "homopolar" field structure, and a revolving armature slotted perpendicularly to the axis, the slots being of varying depth.

6. In a dynamo-electric machine, a revolving armature body, a plurality of collector rings, and rings movable on said armature body and supporting said collector rings.

7. In a dynamo-electric machine, a revolving armature body, a plurality of collector rings, rings movable on said armature body and supporting said collector rings, and means for moving said supporting rings to vary the tension of said collector rings.

8. In a dynamo-electric machine, a revolving armature body, rings movable axially on said body and having tapered outer surfaces, collector rings having tapered inner surfaces and each one supported between a pair of the first-named rings, and means for moving the first-named rings axially to vary the outward pressure on said collector rings.

9. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature carrying a plurality of conductors connected to collector rings, brushes bearing on said rings, and stationary return conductors connecting said brushes, said brushes arranged relatively to the points of connection of the armature conductors to the several collector rings to produce current distributions in the several rings mutually neutralizing their magnetizing effects.

10. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature carrying a plurality of conductors connected to collecter rings, brushes bearing on said rings, and stationary return conductors connecting said brushes, said brushes being arranged in groups and arranged relatively to the points of connection of the armature conductors to the several collector rings to produce current distributions in the several rings mutually neutralizing their magnetizing effects.

11. In a dynamo-electric machine, a revolving armature carrying a plurality of armature conductors connected to collector rings, the points of connection forming one or more spirals, and brushes bearing on said rings, the points of contact forming one or more opposite spirals.

12. In a dynamo-electric machine, a revolving armature carrying a plurality of armature conductors connected to collector rings, the points of connection forming one or more spirals, and brushes bearing on said collector rings, said brushes being in groups and the points of contact forming one or more spirals opposite in direction to the first-named spirals.

13. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature, a plurality of conductors carried thereby, a plurality of collector rings carried by the armature, a set of connections connecting said conductors to said rings, brushes bearing on said rings, stationary conductors carried by the field structure, and a second set of connections connecting said brushes to said stationary conductors, the connections of one or both sets extending a fraction of a circumference in the same direction around the armature whereby the current in said connections produces a portion of the magnetization of the machine.

14. In a dynamo-electric machine, a "homopolar" field structure, a field winding, a revolving armature carrying a plurality of conductors connected to collector rings, brushes bearing on said rings, stationary

conductors carried by the field structure, connections between said brushes and said stationary conductors, each of said connections extending a fraction of a circumference around the armature whereby a compounding magnetization is produced, and means for shifting the brushes to vary said fraction.

15. In a dynamo-electric machine, a "homopolar" field, a field winding, a revolving armature carrying a plurality of conductors connected to collector rings, stationary conductors carried by said field structure, and brushes bearing on said rings and connected to said stationary conductors, the brushes being displaced circumferentially in the same direction from the conductors to which they are connected.

16. In a dynamo-electric machine, a "homopolar" field, a field winding, a revolving armature carrying a plurality of conductors connected to collector rings, stationary conductors carried by said field structure, brushes bearing on said rings and connected to said stationary conductors, each brush being displaced circumferentially from the conductor to which it is connected, and means for varying the amount of said displacement.

17. In a dynamo-electric machine, a revolving armature, a plurality of broad flat conductors carried thereby, the ends of each of said conductors being bent over the ends of the armature, and axially projecting lugs on the ends of the armature extending between the ends of said conductors and adapted to prevent circumferential movement of said conductors relative to said armature.

18. In a dynamo-electric machine, a revolving armature, binding means encircling said conductors and adapted to restrain said conductors against centrifugal force, and a thin sheet of high tensile and compressive strength inserted between said conductors and said binding means and adapted to protect the insulation of said conductors from injury by said binding rings.

19. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature body carrying two sets of collector rings, and a plurality of armature conductors disposed between said sets, each conductor having extensions at both ends extending through said sets so that all of said conductors are of the same length mechanically, and each conductor being symmetrically connected electrically to said sets so that all of said conductors are of the same length electrically.

20. In a dynamo-electric machine, a "homopolar" field structure, a revolving armature body carrying two sets of collector rings, a plurality of armature conductors disposed between said sets, each conductor having extensions at both ends extending through said sets so that all of said conductors are of the same length mechanically and each conductor being symmetrically connected electrically to said sets so that all of said conductors are of the same length electrically, brushes bearing on said sets, and stationary conductors carried by the field structure connecting brushes of opposite sets, said stationary conductors being symmetrically connected to said brushes so that all of said stationary conductors are of the same length electrically.

21. In a dynamo-electric machine, a "homopolar" field structure, a field winding, an armature, and an armature circuit comprising conductors carried by the armature, collecting means, and connections between said collecting means for connecting the armature conductors in series, a portion of the conductors of the armature circuit having a general circumferential direction, whereby the current in the armature circuit assists the field current in producing the magnetization of the machine.

22. In a dynamo-electric machine, a "homopolar" field structure, a field winding, an armature, and an armature circuit comprising conductors carried by the armature, collecting means, and connections between said collecting means for connecting the armature conductors in series, the conductors of the armature circuit being arranged to produce a circumferential component of current flow in the armature circuit, whereby the current in the armature circuit assists the field current in producing the magnetization of the machine.

In witness whereof I have hereunto set my hand this 29th day of March, 1904.

JACOB E. NOEGGERATH.

Witnesses:

BENJAMIN B. HULL,
HELEN ORFORD.