J. BURKE.
DYNAMO ELECTRIC MACHINE.
APPLICATION FILED MAY 1, 1907.

987,044. Patented Mar. 14, 1911.

5 SHEETS—SHEET 1.

FIG. 1

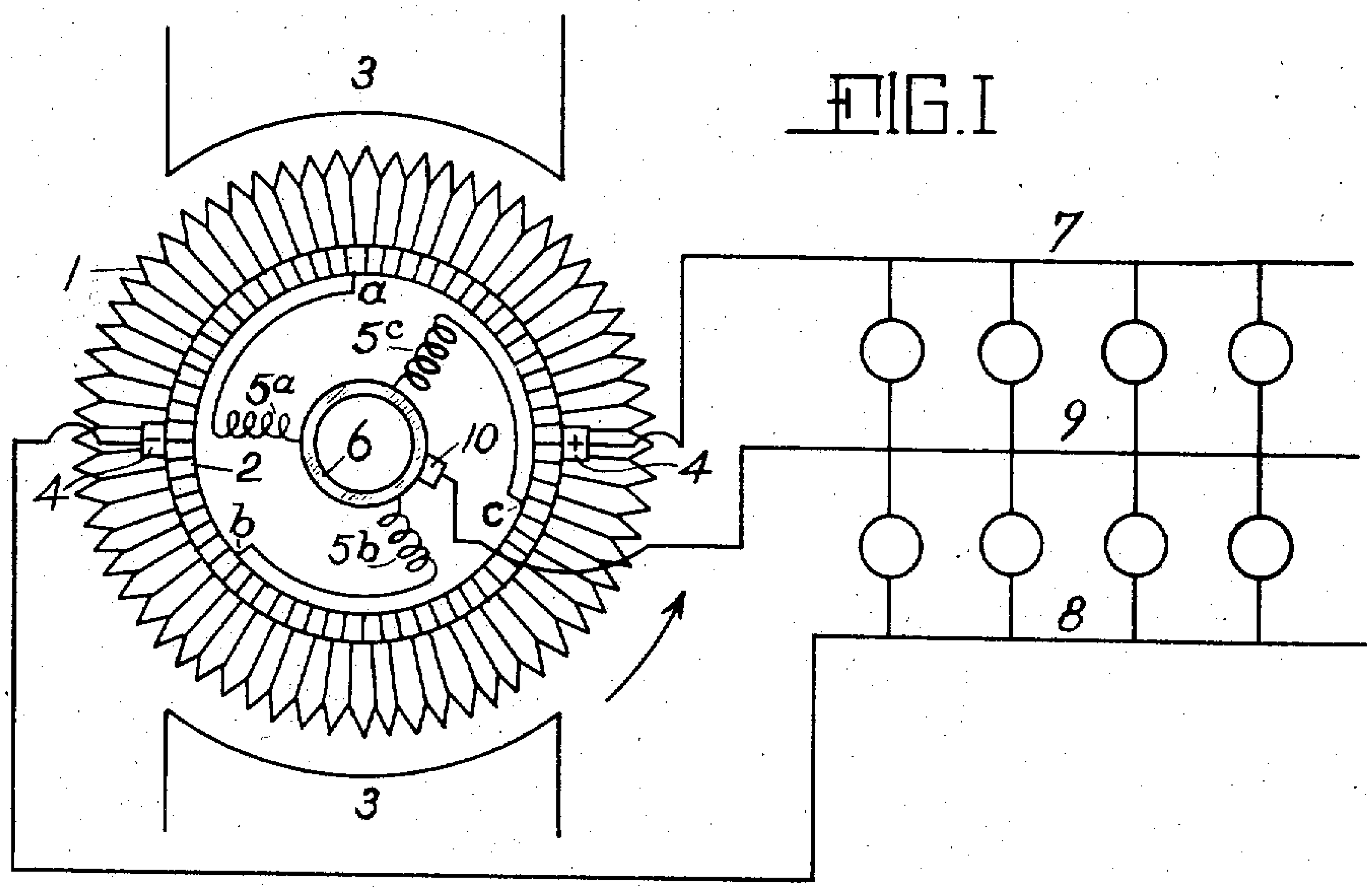
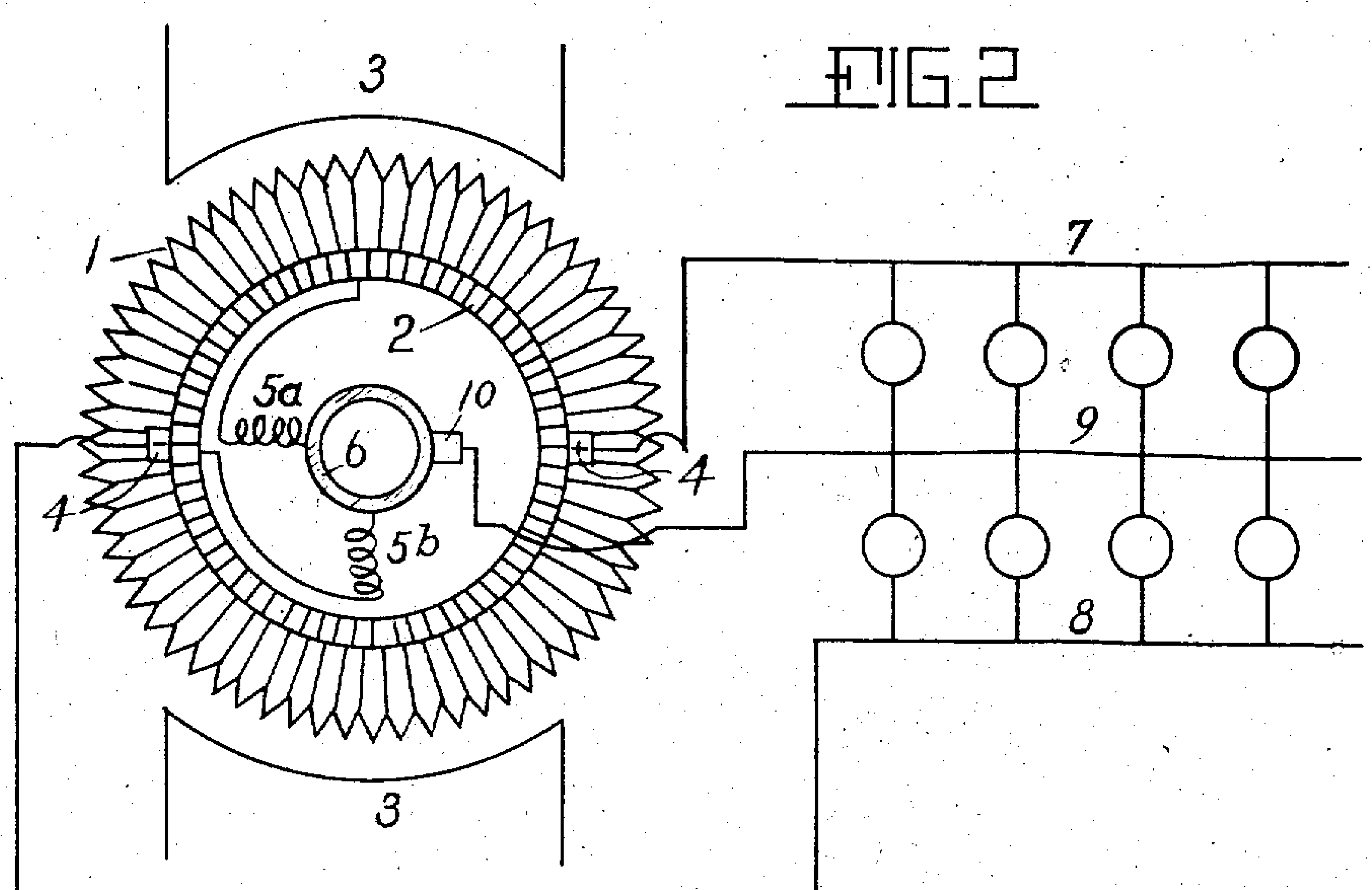


FIG. 2



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5 SHEETS—SHEET 2.

FIG. 3

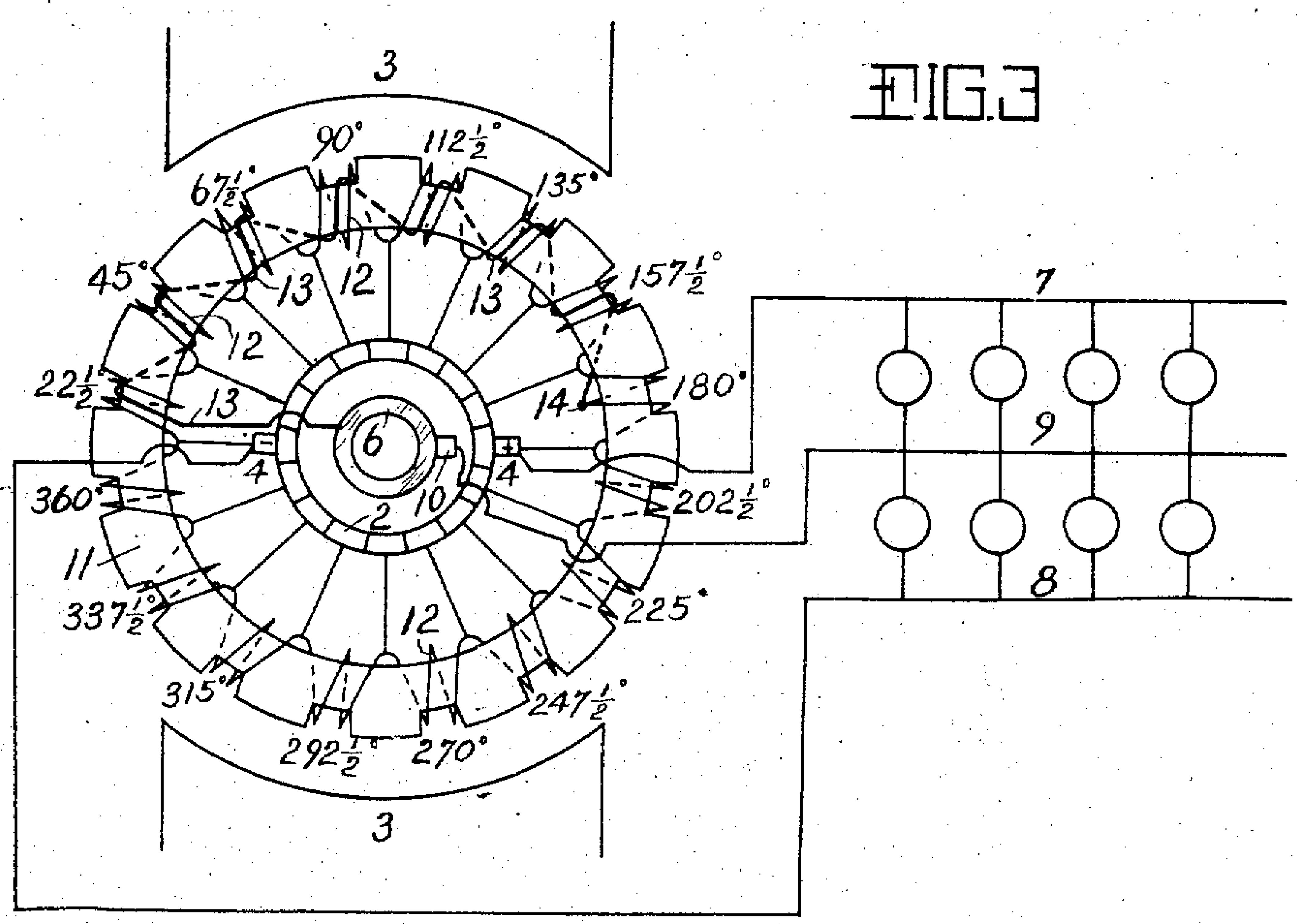
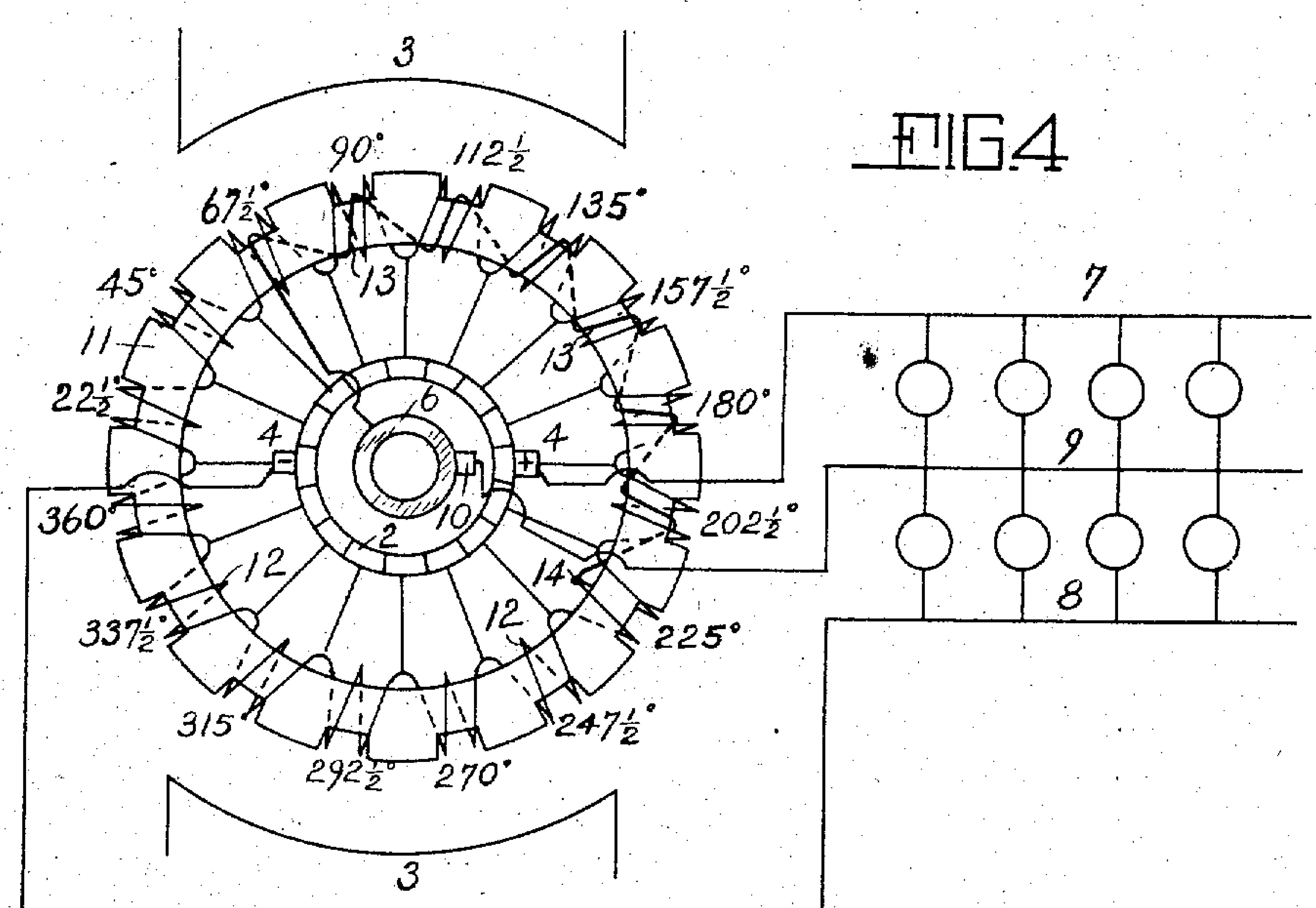


FIG. 4



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5 SHEETS—SHEET 3.

FIG. 5

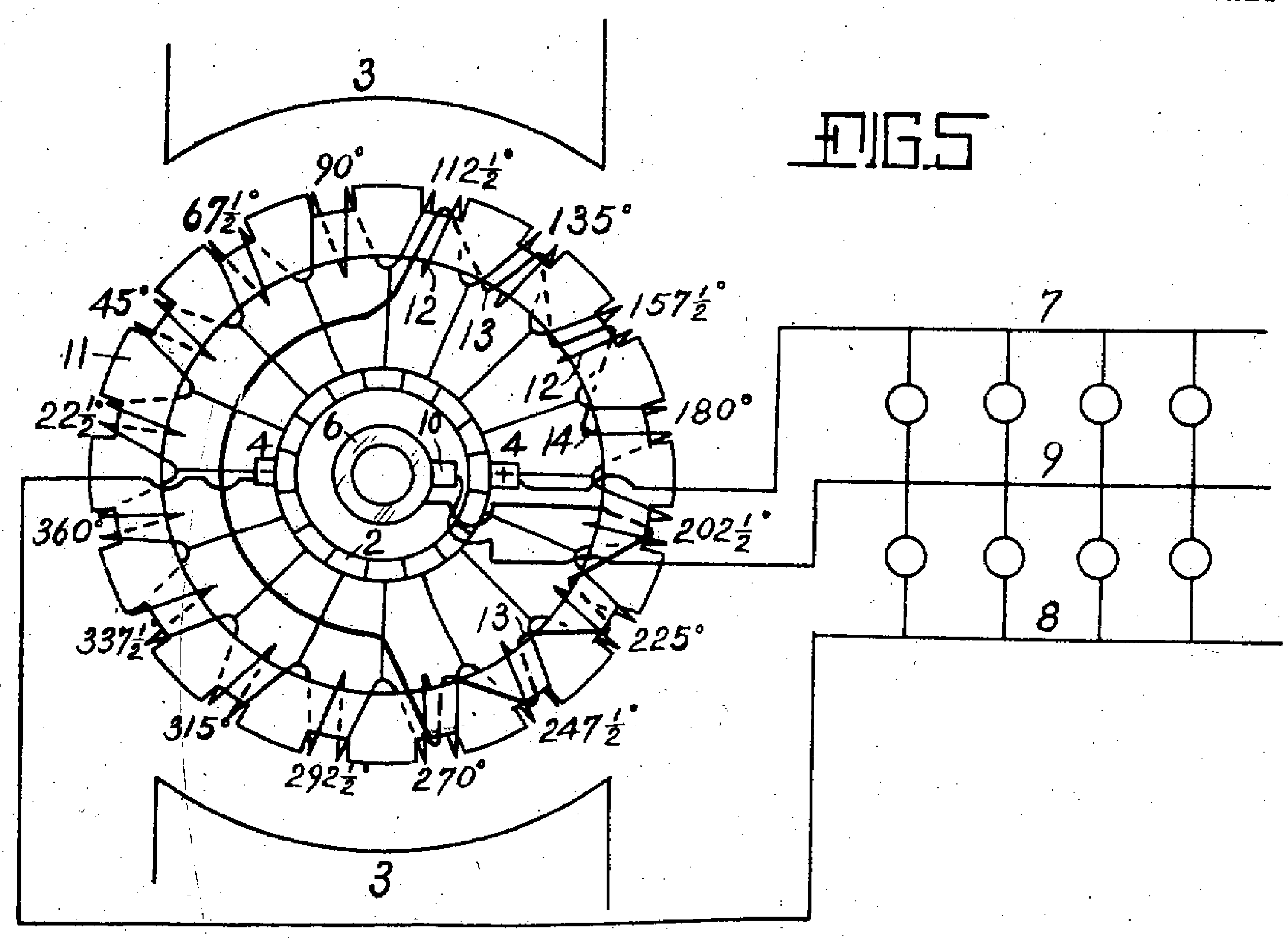

FIG. 6

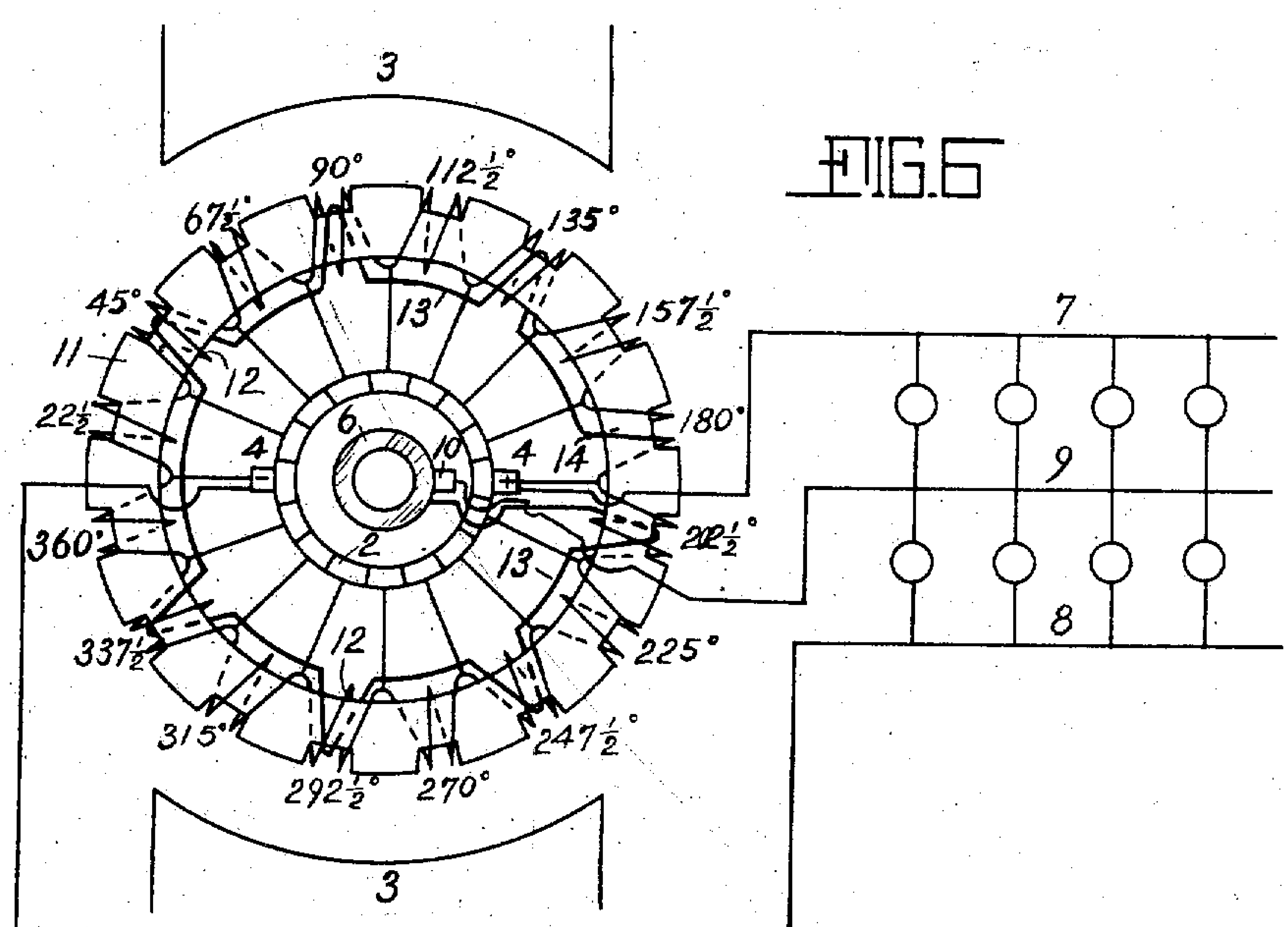

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FIG. 7

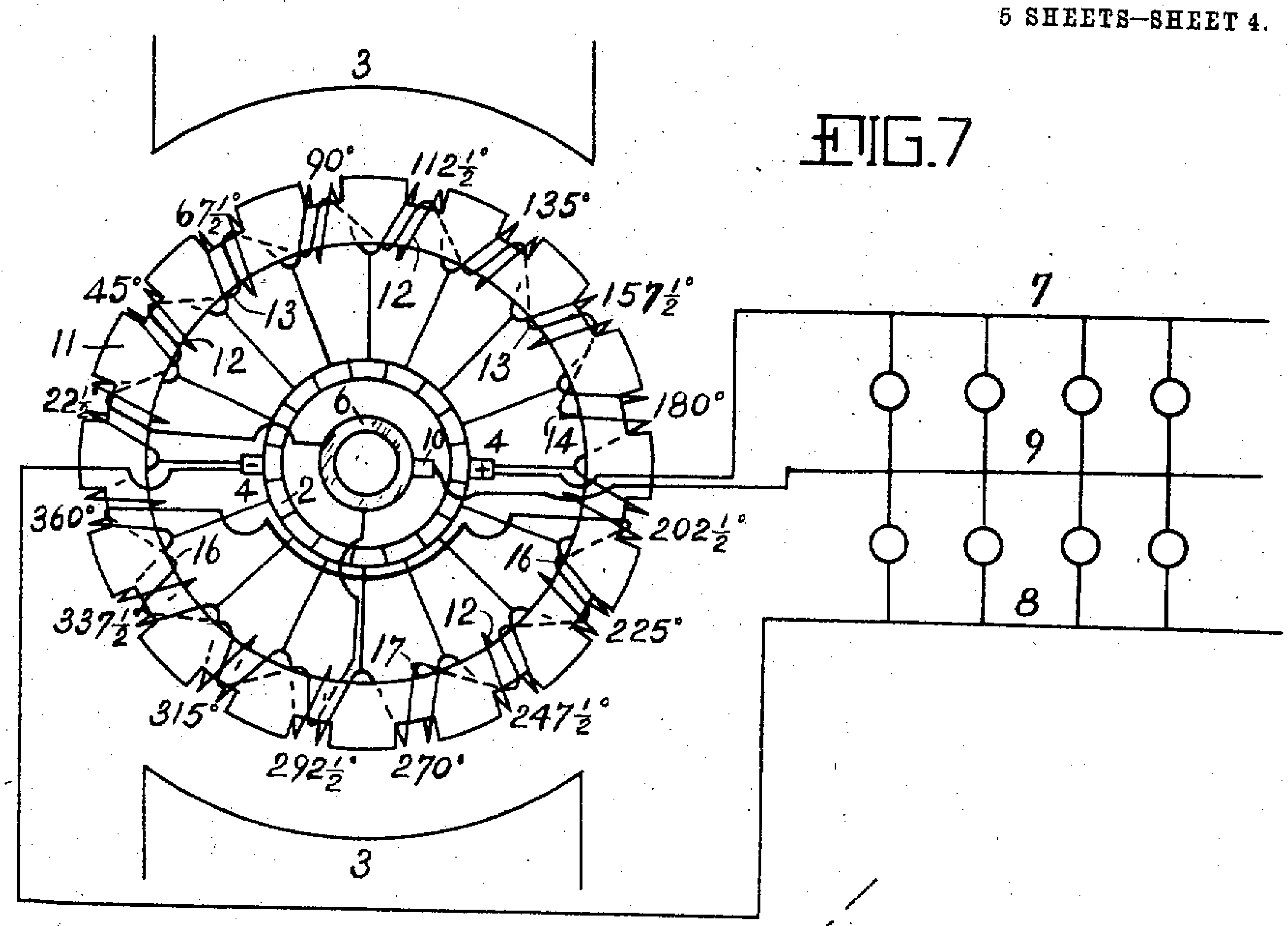
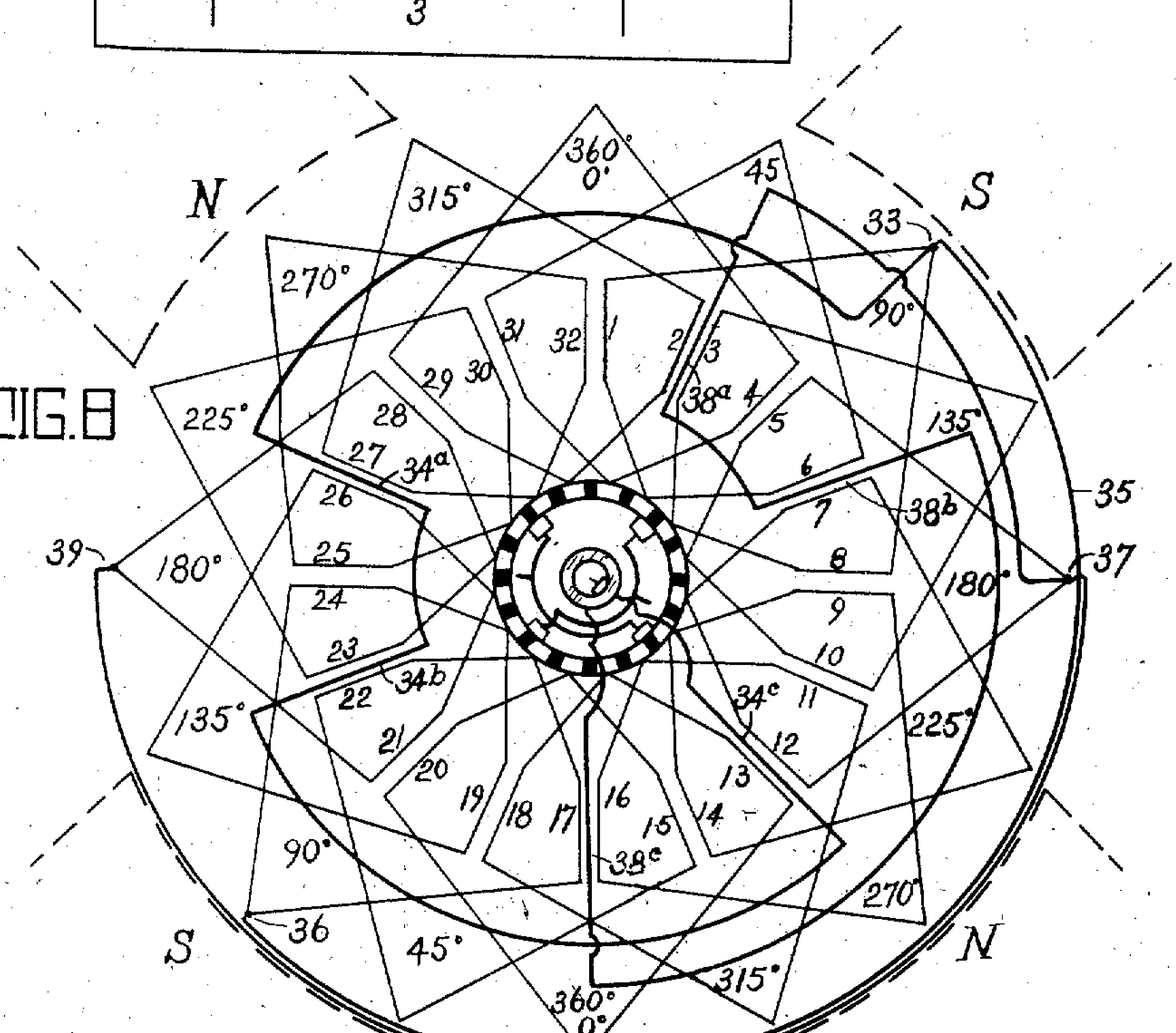


FIG. 8



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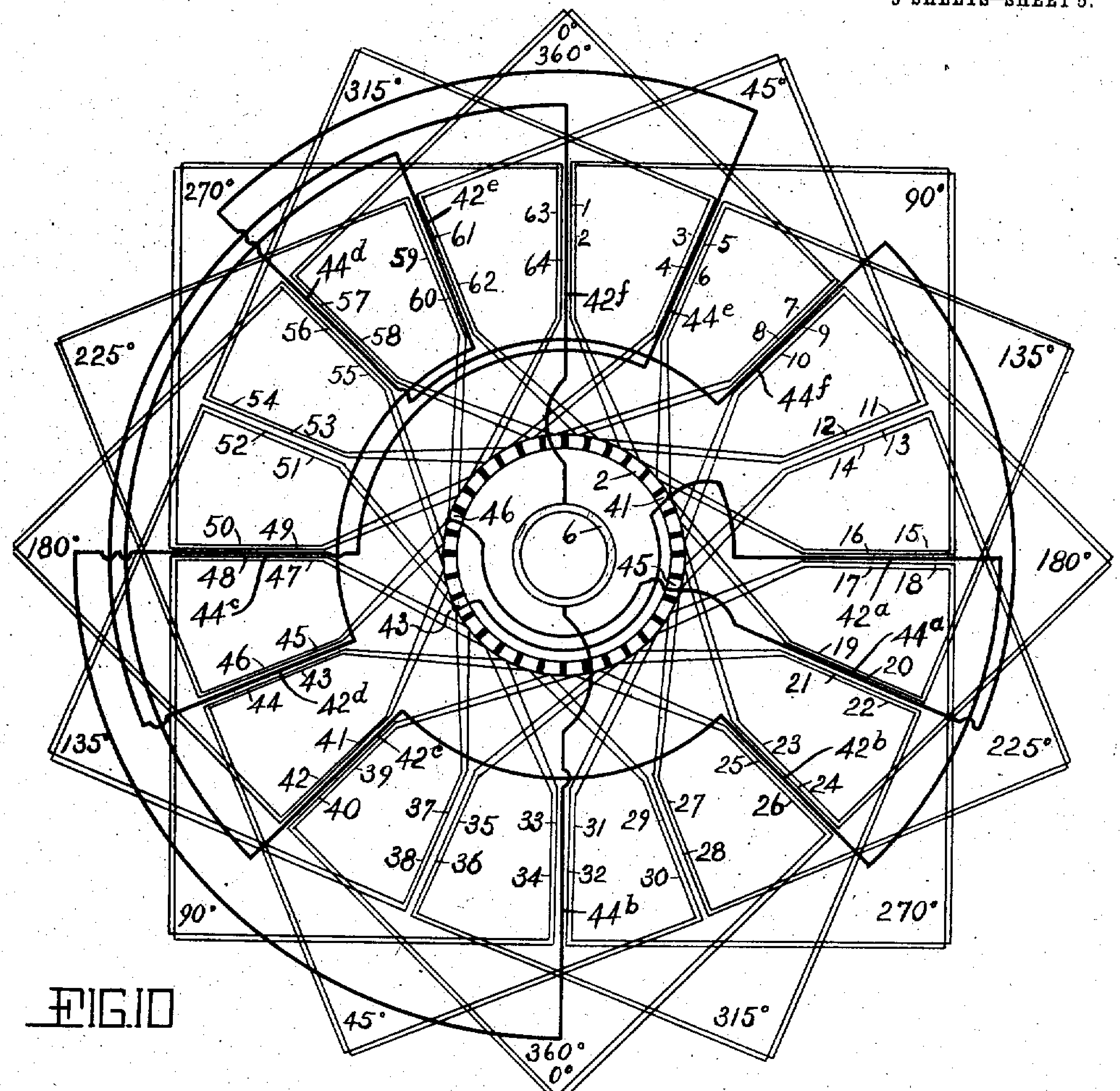

FIG. 10

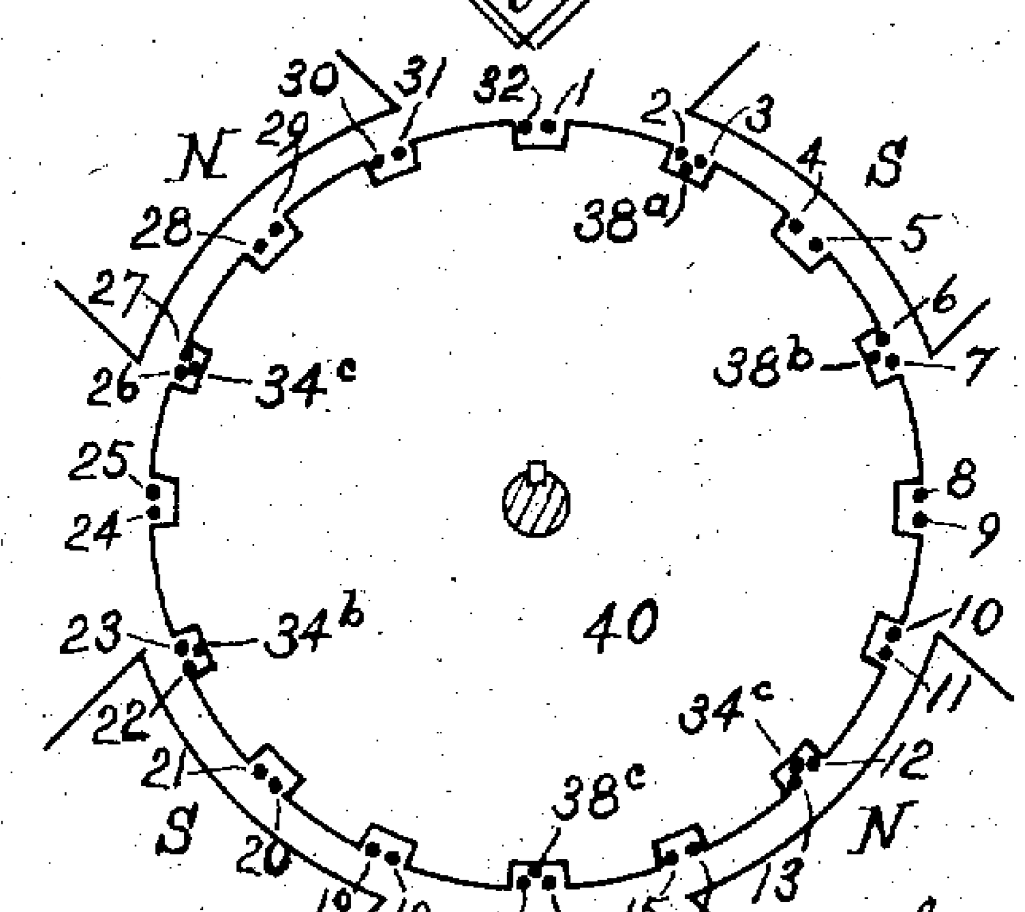

FIG. 9

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JAMES BURKE, OF ERIE, PENNSYLVANIA, ASSIGNOR TO BURKE ELECTRIC COMPANY, A CORPORATION OF PENNSYLVANIA.

DYNAMO-ELECTRIC MACHINE.

987,044. Specification of Letters Patent. **Patented Mar. 14, 1911.**

Application filed May 1, 1907. Serial No. 371,233.

To all whom it may concern:

Be it known that I, James Burke, a citizen of the United States, residing at Erie, in the county of Erie and State of Pennsylvania, have invented certain new and useful Improvements in Dynamo-Electric Machines, of which the following is a full, clear, and exact specification.

My invention relates to dynamo electric machines and particularly to a method of and means for generating current for supplying a three wire direct current system of distribution.

In my pending application Serial No. 355,564, filed February 4, 1907, which has matured into Patent No. 893,979, granted July 21, 1908, I have described a method and means for generating current for such a system and my present invention relates to further improvements upon the invention disclosed in said application.

My invention will be understood from the following description and accompanying drawings, in which—

Figures 1 and 2 are diagrams for explaining my invention; Figs. 3 to 7 are diagrams showing various embodiments of my invention; Fig. 8 is a diagram showing my invention applied to a multipolar machine having a drum wound armature; Fig. 9 is a sectional view showing the position of the conductors of Fig. 8 on the armature; and Fig. 10 is a diagram showing my invention applied to another multipolar machine having a drum wound armature.

In explaining the theory of my invention, and in order to understand the practical embodiments, I will first consider Fig. 1, in which the armature coils of a direct current machine are indicated at 1, and are connected to the commutator bars 2. The machine is indicated as bi-polar having the poles 3 and positive and negative brushes 4. In addition to the usual main winding, there are provided additional generating windings or coils 5^a, 5^b, 5^c wound upon the same core as winding 1, one end of each of these three windings being connected to the collector ring 6. The remaining ends of the windings are connected to points *a*, *b*, *c*, in the armature, which points in this example are 120 electrical degrees apart. The auxiliary windings or coils are shown as connected to the commutator segments, but they may, if desired, be connected to points in the armature winding itself. The positive and negative mains of the three-wire system are indicated at 7, 8 and the neutral wire at 9. The mains 7, 8 are connected to the positive and negative brushes 4 and the neutral wire is connected to a brush 10 bearing on the collector ring 6.

In order to maintain the neutral wire at a fixed potential with reference to the potentials of the positive and negative mains and so secure a three-wire distributing system, the ends of the windings 5^a, 5^b, 5^c being connected to ring 6 and thus to the neutral wire must also be maintained at a fixed potential with reference to that of said mains. In these windings there is generated an alternating electromotive force, but the electromotive force generated in each one at any instant, although different from that generated in the others, is always such in each winding that the potential of ring 6 remains unchanged, whereas the potentials of the ends of the windings connected to points in the armature are continually changing from positive to negative and from negative to positive with reference to the potential of the neutral. It is understood of course, that the potential around the commutator or around the winding 1, gradually falls from the positive to the negative brush and therefore the potential of *a*, which is shown midway between the positive and negative brushes, is approximately half-way between the potential of the positive and negative mains, or in other words is the same as that of the neutral, or the same as the desired potential of the neutral. Therefore since the winding 5^a is connected to the neutral through the collector ring 6 at one end and to point *a* at the other, then in order that the neutral should be at the same potential as point *a* as desired, the winding 5^a should be in such position at this instant that it will generate no electromotive force or no resultant electromotive force. The potential of point *b* is between that of the negative main and that of the neutral and is approaching the potential of the neutral assuming that the direction of rotation is that indicated by the arrow. As winding 5^b is connected between point *b* and the neutral, then in order to maintain the neutral at the desired potential, the winding 5^b must be so located as to generate an electromotive force equal to the difference in potential between that of point b and the desired potential of the neutral. Winding 5^b is therefore indicated in a position to generate an electromotive force equal to the difference in potential between point b and the neutral; and as the potential of point b is approaching the potential of the neutral at the instant represented, winding 5^b is represented in such position with reference to the magnetic field that it is generating a gradually decreasing electromotive force with reference to the direction of rotation indicated by the arrow. The potential or point c is above that of the neutral and between the neutral and positive brush, and is approaching that of the positive brush. Winding 5^c is therefore diagrammatically indicated in such a position that it is generating an electromotive force equal to the difference between the potential of the neutral and that of point c and generating an electromotive force opposite in direction to that of winding 5^b. It is also generating an increasing electromotive force so as to balance the increasing potential of point c. Consequently, the instantaneous electromotive force generated by each of the windings 5^a, 5^b, 5^c is equal to the potential difference between the neutral and the points in the armature to which the respective windings are connected. Moreover, as the armature rotates and the potential of points a, b, c continuously changes with reference to the desired constant potential of the neutral point, the electromotive force generated in each winding 5^a, 5^b, 5^c changes in the same way and to the same degree, consequently the potential of collector ring 6 remains fixed and always midway between that of the positive and negative brushes, and the desired potential of the three-wire mains is obtained. It will be seen therefore that the windings 5^a, 5^b, 5^c act to generate alternating current electromotive forces which balance the changing potentials of the points in the main windings to which they are connected and so maintain the potential of the neutral constant. When the load on the system is unbalanced, current will flow either to or from ring 6 through the neutral wire and will pass through the generating windings 5^a, 5^b, 5^c to or from the armature winding 1. The windings 5^a, 5^b, 5^c therefore not only serve as means for maintaining the neutral at fixed potential by their action as generating windings, but also serve as a path for the current due to an unbalanced load. It will be noted that the maximum electromotive force generated by each winding 5^a, 5^b, 5^c in one direction is equal to one-half the electromotive force between the positive and negative brushes under perfect conditions, and preferably is made as nearly so as possible in practice. This will be understood since the electromotive force generated by each winding must at some time equal the full electromotive force between the neutral and any one of the brushes, and this electromotive force is equal to one-half of the electromotive force between positive and negative brushes. That is, the number of conductors or turns per each alternating current winding or auxiliary winding 5^a, 5^b, 5^c, etc., should be equal to, or equivalent to, one-half of the number of conductors or turns per circuit from brush to brush of the main armature winding having the commutator.

I may in some cases provide a greater or lesser number of generating windings than three. If six windings should be used, the windings may be displaced approximately 60 electrical degrees from each other and connected to points in the armature winding 1, at 60 electrical degrees apart.

Fig. 2 illustrates a form in which only two windings 5^a, 5^b, are used. These windings are displaced approximately 90 degrees electrically and are connected to points in the main armature winding approximately 90 electrical degrees apart. In the position shown and at that instant, winding 5^a is connected to a point in the main winding midway between the positive and negative brushes, which point is consequently of the same potential as the neutral and therefore winding 5^a should and does generate no electromotive force being shown in the neutral position. Winding 5^b is shown connected to a point which at the instant considered, is at the same potential as the negative brush and should therefore generate its maximum electromotive force, and is shown diagrammatically in position for generating maximum electromotive force. As the armature rotates, the windings 5^a, 5^b will at all times coöperate to maintain the neutral potential. Only one auxiliary generating winding, as 5^a, may be used, but better results are obtained by the use of more than one auxiliary winding, particularly where the system is likely to be very much unbalanced.

From the preceding, the general theory upon which my invention is based will be understood, and which theory is fundamentally based upon generating in one or more auxiliary windings by dynamic action variable electromotive forces for maintaining a fixed potential between the potentials of the outside mains. I will now consider a few practical embodiments of this general theory and of my invention.

Fig. 3, shows a bi-polar machine having an armature winding of the Gramme type, the ring core being indicated at 11, and the main winding 12 is shown as having a total of 32 conductors or turns. As the machine is bi-polar and has two brushes, there are two circuits from brush to brush, giving 16 conductors per circuit of the main winding. The winding is also shown as having two conductors per coil between commutator segments, and these coils of two conductors each are indicated as displaced 22.5 electrical degrees from each other, and the two conductors of each coil are located in the same phase substantially, being shown in the same slot. It is apparent that the total electromotive force generated in each of the two circuits of the main winding is produced by the united effect of the eight coils per circuit, and that some of these coils are generating a high electromotive force while others, being in different phase position with reference to the magnetic field, are generating less electromotive force. The total electromotive force is therefore made up of the united effect of eight coils, each in a different phase and some of which are subjected to a magnetic field very much different in strength from that of the others. Moreover, the irregularity of the magnetic field causes corresponding variation in the electromotive forces generated by the different coils.

In my said prior application, I described constructions based upon the principles that in locating the auxiliary winding for maintaining the neutral potential, the irregularity of the magnetic field, and of the electromotive forces generated in the main winding, must be considered when such conditions exist, as is the case in all commercial types of machines at the present time; and for the purpose of balancing the main winding, the auxiliary winding must be so related thereto that for each phase of the main winding, there is a substantially corresponding location of part of the auxiliary winding. In other words, the auxiliary winding must be distributed so that its parts will be subjected to conditions similar or substantially similar to that of the parts of the main winding and so compensate for every variation in the magnetic field to which the parts of the main winding are subjected. If the auxiliary winding be so located or distributed, then the same variations to which the main winding is subjected, and which thereby determine the electromotive force generated by the main winding will correspondingly affect the auxiliary winding and a corresponding compensation will be secured. In my said prior application, I disclosed constructions in which the auxiliary windings contained one-half the number of conductors per circuit of the main winding. According to my present invention, I am enabled to reduce the number of conductors in each auxiliary winding so that less than one-half the conductors per main circuit are required and I accomplish this without any practical disadvantage and of course obtain further economy and simplicity in construction.

My present invention may be understood from Fig. 3, and we may consider the circuit of the main winding which is on the upper half of the core and designated by the character 12. This consists of eight coils of two conductors per coil in phases marked 22.5 degrees, 45, ... to 180 degrees, respectively. The auxiliary winding 13, comprises seven conductors in series having one conductor in each of the phases 22.5, 45, ... to 157½, inclusive. One terminal of the auxiliary winding is connected to the collector ring 6 and the other terminal is connected to a point 14 in the main winding between the two turns in phase 180 degrees. At the position represented, it will be understood that the auxiliary winding must generate an electromotive force such that the potential of the ring 6, and therefore of the neutral will be midway between the potential of the positive and negative brushes. Since the auxiliary winding is connected to a point which is below the potential of the positive brush, it follows that in this position, the electromotive force generated by the auxiliary winding should be less than one-half the potential difference between the positive and negative brushes, but at the same time should be sufficient to maintain the neutral at the desired potential. That this is so for the position of the armature considered, will be understood from the following: As the potential of the neutral should evidently be half way between the potential of the positive and negative brushes and since the electromotive force between these brushes is evidently generated by the conductors of the main winding on the upper half of the ring, the desired potential of the neutral will be secured if the neutral is at a potential from the positive brush created by an electromotive force equal to one-half that generated by the main winding. Evidently the seven conductors of the winding generate an electromotive force equal to one-half that generated by the coils of the main winding in phases marked 22.5, 45 to 157.5 inclusive, since there are one-half the conductors in the auxiliary winding for each of these phases, and as the auxiliary winding is connected at point 14 to the main winding between the two conductors of the main winding in phase 180°, the potential of point 14 will be, by reason of this connection, at a potential from the positive brush equal to one-half the electromotive force generated by the two conductors of the main winding in phase marked 180°. Consequently, the potential of the neutral will be below that of the positive brush by the amount of half the electromotive force generated by the main conductors in phase 180 degrees, giving the potential of point 14, plus one-half of the electromotive force generated by the conductors of the main winding in each of the phases 157.5, 135 . . . . . to 22.5 degrees inclusive. The necessary generation of electromotive force from point 14 will therefore be supplied by the seven conductors of the auxiliary winding giving the desired neutral potential. It will be seen that the potential of ring 6 or neutral following the circuit from the positive brush is that produced by the electromotive force of one turn of the main winding in phase 180, then passing through the point 14 to the auxiliary winding, is also that produced by the electromotive forces of one turn of the auxiliary winding in each of the phases 157.5, 135, 112.5, 90, 67.5, 45 and 22.5 to the ring, making a summation of one turn from all of the phases on the upper half of the armature core and seven of which are auxiliary turns and one a turn of the main winding.

The potential of the neutral will be maintained substantially constant for every other position of the armature, since the changing phases and electromotive forces of the conductors will always be such that the electromotive forces generated by the auxiliary winding will correspondingly vary. For example, consider Fig. 4 in which the armature is shown as having rotated 45 degrees from the position of Fig. 3. If in Fig. 4 we follow the circuit from the positive brush, it will be seen that the potential of ring 6 from the positive brush is that produced by the electromotive force of two turns of the main winding in phase 202.5 and one turn of the main winding in phase 225, then through point 14 to the auxiliary winding in which there is one turn in phase 202.5 and one turn in each of the phases 180, 157.5, 135, 112.5, 90 and 67.5. It is evident that the one turn of the main winding in phase 225 above mentioned, has the same value and electromotive force as if it were one turn in phase 45. It is also evident that the one auxiliary turn in phase 202.5 cancels one of the two turns in phase 202.5 leaving the effect of one turn in 202.5 which has the same value as one turn in 22.5. Therefore we have the effect from the positive brush of one turn in each of the phases 22.5 45 to 180 inclusive, which equals one-half the voltage from positive to negative brush.

Instead of placing the conductors of the auxiliary winding in the position shown in Figs. 3 and 4, relatively to the main winding, the auxiliary winding may be arranged as in Fig. 5 upon the principle that any conductor of an auxiliary winding may be shifted 180 electrical degrees and so be placed in a corresponding position under a pole of opposite polarity, provided the direction of the conductor is changed so that the electromotive force generated will have the same effect in the auxiliary winding. For example, in Fig. 5 the conductors of the auxiliary winding in positions 157.5, 135 and 112.5 are the same as in Fig. 3, but the remaining conductors are shifted 180 degrees from the position of Fig. 3, the auxiliary conductor at 270 degrees of Fig. 5 corresponding to that at 90 degrees of Fig. 3, that at 247.5 corresponding to that at 67.5, that at 225 corresponding to that at 45, and that at 202.5 corresponding to that at 22.5. Also the direction of the four conductors transposed in Fig. 5 is opposite to the corresponding conductors of Fig. 3, in order to preserve the desired action. This transposition of conductors will be understood to be correct from the fact that the result is the same in the auxiliary winding whether the conductor is moving in one field at a certain position or in the opposite field of corresponding position with its direction reversed. The application of this feature of my invention is important in tending to secure equal electrical and mechanical effects, that is, in tending to avoid unequal distortion of magnetic field when current flows in the auxiliary winding and in tending to maintain a mechanically symmetrical and balanced armature. For example, in Fig. 6, the winding will have the general effect of that of Fig. 3 and on account of the more symmetrical distribution of the auxiliary winding, the armature will be more nearly mechanically balanced and the electrical conditions become more uniform. In this figure the seven conductors of the auxiliary winding are not all on one half of the armature as in Fig. 3 and Fig. 5, but the conductors of the auxiliary winding of Fig. 3 in phases marked 22.5, 67.5, 112.5, and 157.5 are transposed to the other half of the core in Fig. 6, 180 degrees from the position in Fig. 3 and the direction is opposite as explained with reference to Fig. 5. The desired operation will consequently be secured, and at the same time secure a more symmetrical condition. Referring to Fig. 6, it will also be seen that the sequence of connection of the conductors of the auxiliary winding is not the same as in Fig. 3, and that in Fig. 6, the conductors are connected in succession around the ring which allows the connections to be simplified over what would otherwise be necessary. The same resultant electromotive force will be secured however, regardless of the sequence of connection so long as the location of the conductors and the direction of electromotive forces generated are correct.

Fig. 7 shows the same form of machine and windings as in Fig. 3, but in Fig. 7 there is an additional auxiliary winding 16 connected to the point 17 of the main winding 90 degrees from point 14 to which the auxiliary winding 12 is connected. Starting from point 17, the auxiliary winding 16 is similar in the first three turns to the winding 13 but instead of continuing and overlapping winding 13, the remaining four conductors are transposed 180 degrees and connected as explained with reference to Fig. 5. With this construction, it will be seen that the conductors are very symmetrically located throughout the armature giving the desirable advantages of such an arrangement. Also with two windings, the balancing effect will be improved as already stated. With two auxiliary windings it is preferable to connect them to points in the main winding substantially 90 electrical degrees apart, but they may be connected to points widely different from 90 degrees displacement if desired. In each case however, the auxiliary winding should have its conductors so located and connected as to balance or correspond to the conductors per circuit of the main winding beginning at the point of the main winding at which the auxiliary winding is connected, although without any auxiliary conductor or conductors to correspond to the conductors of the main winding in the phase of the point to which the auxiliary winding is connected. That is, in Fig. 7, for example, the auxiliary winding 16 is connected to the main winding at point 17 and the seven conductors of the auxiliary winding must correspond in their effect to the effect of the remaining number of conductors per circuit of the main winding and omitting the conductors in phase 270 which is the phase of point 17: that is, must correspond to the 14 conductors of the main winding in the seven phases marked 247.5, 225, 202.5, 180, 157.5, 135 and 112.5. In general it may be stated that the algebraic sum of the electromotive forces in the auxiliary winding plus the electromotive force in the main winding from the point where the auxiliary winding is joined to the main winding to either brush will be equal to one-half the electromotive force between brushes.

A rule which is applicable to the form of my invention above described is that the number of turns in each auxiliary winding is equal to one-half the number of turns per circuit of the main winding minus one-half the turns per slot of the main winding. Thus, the number of turns per circuit of the main winding is 16 and there are 2 turns per slot and therefore according to the rule there should be $\frac{1}{2}\times16-\frac{1}{2}\times2=7$ turns in the circuit of the auxiliary winding. It will be understood that instead of using the number called for by this rule, an intermediate number of turns may be used which might be between the number given by the rule and the full number of half the turns per circuit as described in my said prior application. Also a greater number than half the turns per circuit might be used by providing an additional turn or turns in an additional phase position and still obtain the resultant effect desired. The use of more conductors than necessary will however, generally be undesirable although, of course, within the scope of my invention.

If three auxiliary windings are used, the points of connection in the main winding are preferably substantially 120 electrical degrees apart; if six auxiliary windings are used they are connected preferably to points substantially 60 electrical degrees apart, or with 5 windings they may be 72 electrical degrees apart, but the points of connection may differ widely from these displacements and may be irregularly displaced if desired provided that the auxiliary conductors are correspondingly located as above explained. Usually the stated displacements will be preferable, but very satisfactory results may be produced with other displacements.

The connections of the auxiliary winding to the main winding may be made to the commutator bars if desired in those windings where intermediate points of the main conductors per slot are connected to commutator bars, or may be made to the end connections of the conductors of the main winding.

Although the best results will be secured by the arrangement of auxiliary conductors as described generally with reference to Figs. 3 to 7, it will be understood that such an arrangement is not absolutely required provided the divergence is not so great as to produce a commercially impractical machine. For example, instead of locating the auxiliary conductors in the same phase positions as the corresponding main conductors, they or some of them may be located in slightly different phase positions. However, the greater the displacement from proper position and provided this displacement is not properly compensated for, the more will be the generation of unbalanced electromotive forces and the greater the flow of useless and harmful local currents. Also, it is apparent that if the number of conductors in the auxiliary windings is not made exactly the same as described with reference to Figs. 3 to 7, the number may be slightly different and still obtain operation which may be sufficiently satisfactory, although not so satisfactory as might be secured with the best possible arrangement. For example, if the number of auxiliary conductors were very large, there might be a slightly different number employed from that theoretically required, or the phase location might be slightly different without rendering the machine useless. In all cases however, the substantial requirements for good balancing effect must be present in order to produce a commercially practical machine.

It will be understood that the auxiliary windings may be considered as connected in parallel with part of the main winding, and the auxiliary windings may therefore act to generate current in parallel therewith. By adding a large number of auxiliary windings and by making their resistance low, they may be made to carry a considerable portion of the current compared with that in the main winding. This will be so since the main winding, together with the auxiliary windings generate electromotive forces in parallel with each other and the current that will be caused to flow in the parallel circuits will be influenced by their relative resistances.

I have described my invention as applied to a bi-polar machine and to a Gramme winding, as it is then in its simplest form and more easily understood. It may likewise be applied to multi-polar machines and to machines having the various forms of drum windings.

Fig. 8 illustrates as one example, a multipolar machine having a drum winding and having my invention embodied therein. The four poles of the machine are indicated in dotted lines and designated by the characters N, S; within the poles is shown a development of the main winding and of the two auxiliary windings which are used in this instance. The commutator is indicated within the windings at 2, and the brushes 4 which engage the commutator are shown as bearing upon the inner surface of the commutator for the sake of clearness. The two positive brushes are shown connected together and the two negative brushes are joined together as is usual in multi-polar multiple circuit windings. The collector ring is shown at 6 having one terminal of each of the auxiliary windings connected thereto. The brush shown as engaging ring 6, will, of course, be connected to the neutral of the three-wire distributing mains, and the pairs of positive and negative brushes bearing upon the commutator will be connected to the outside mains of the three-wire distributing mains. The conductors of the main winding are numbered consecutively from 1 to 32 inclusive. The phase positions of the conductors are designated for the purpose of reference by designation of the number of electrical degrees beginning with zero degrees for conductors 1, 32. Passing from this position toward the right and coming to the lower conductors 16, 17 the number of electrical degrees passed has been 360, and similarly there are 360 degrees in passing from the lower conductors back to the upper conductors. It will, of course, be understood that conductors in a certain phase position with reference to a field pole of one polarity are in the same phase position as conductors located under another pole of the same polarity and in corresponding position with reference thereto. For example, conductors 4, 5 are in the same phase as conductors 20, 21. Although in Fig. 8, there are shown two conductors of the main winding displaced by a small amount from each other, it will be understood that they are intended to be in the same slot of the armature core and in substantially the same phase position.

As there are 32 conductors in the main winding, and there are four multiple circuits, being a four pole machine, there are eight conductors per circuit from brush to brush bearing on the commutator or four turns per circuit and one turn per slot. Applying the rule above given that the number of turns per auxiliary winding shall be one-half the turns per circuit minus one-half the turns per slot, we find that this is equal to $\frac{4}{2}-\frac{1}{2}=1\frac{1}{2}$ turns for each auxiliary winding, or 3 conductors for each auxiliary winding. The point of connection of the beginning of the auxiliary winding to the main winding should be the middle point of the turn or turns per slot selected. Thus, in Fig. 8, the turn selected for starting is turn 1, 8, the middle point being point 33, from which one of the auxiliary windings is started, which it will be observed is at the rear end of the armature. The three conductors of the auxiliary winding should now be located to correspond to the remaining conductors per circuit of the main winding; that is, assuming that the turn comprising conductors 1, 8 is taken care of, then the conductors 3, 10, 5, 12 and 7, 14, should be considered in locating the three conductors of the auxiliary winding. The auxiliary conductor which is to correspond to the conductors 3, 10 of the main winding should be either an outgoing conductor in phase 45 degrees, or an incoming conductor in phase 225 degrees.

Referring to Fig. 8, it will be seen that conductor 34^a of the auxiliary winding which starts at point 33 is located in phase 225 degrees and is an incoming conductor as required. To correspond to the turn 5, 12 of the main winding there should be either an outgoing conductor in phase 90 degrees, or an incoming conductor in phase 270 degrees, and in Fig. 8, an incoming conductor 34^c of the auxiliary winding is located in phase 270. Similarly, for the turn 7, 14 of the main winding, the corresponding auxiliary conductor should either be an outgoing conductor in phase 135 degrees, or an incoming conductor in phase 315 degrees. In Fig. 8, the conductor 34^b of the auxiliary winding is located in phase 135 degrees and is an outgoing conductor. The auxiliary winding comprising the conductors 34^a, 34^b and 34^c will therefore act to maintain the collector ring 6, to which it is connected, at a constant potential mid-way between the potentials of the positive and negative brushes of the machine. As the point of the main winding which is located 360 electrical degrees therefrom should be at the same potential as that of point 33, these two points are shown cross connected by the conductor 35, and if desired this auxiliary winding may be considered as starting from the point 36 which is cross connected to the point 33.

In Fig. 8 another auxiliary winding is shown which starts from point 37 of the main winding, 90 degrees from point 33, and which is the middle point of the turn 5, 12. We may therefore assume that the turn 5, 12 is taken care of, and we should locate the three conductors of this second auxiliary winding so as to correspond with the turns 7, 14, 9, 16 and 11, 18. Taking the turn 7, 14 of the main winding, this may be taken care of by an outgoing conductor in phase 135 or an incoming conductor in phase 315. The conductor 38^b of this second auxiliary winding is an outgoing conductor in phase 135 which answers the requirement. The auxiliary conductor for turn 9, 16 should be either an outgoing conductor in phase 180, or an incoming conductor in phase 360, and the conductor 38^c of the second auxiliary winding is an incoming conductor in phase 360. The auxiliary conductor for turn 11, 18 should be either an outgoing conductor in phase 225, or an incoming conductor in phase 45; the conductor 38^a of this auxiliary winding is an incoming conductor in phase 45, which answers the requirement. This second auxiliary winding will therefore also serve to maintain the neutral at the desired potential. Point 37, from which the second auxiliary winding starts, is cross connected to point 39, which point is 360 electrical degrees from point 37, and therefore of the same potential. It will therefore be seen that in Fig. 8, there are two auxiliary windings which begin at points in the main winding 90 electrical degrees apart, and that each of the auxiliary windings comprises only three conductors, and each of these three windings serve to maintain the desired potential of the collector ring 6 and of the neutral wire. It will also be noted that the conductors of the auxiliary windings are so located as to secure a substantially balanced armature. It will be understood from the diagram that the auxiliary conductors are intended to be located in the same slot of the core as the two adjacent conductors of the main winding. It will also be noted that the arrangement is such as to bring the collector ring 6 on the same side or end of the armature as the commutator.

It will be understood that any desired number of additional auxiliary windings may be added to the structure represented in Fig. 8 and connected at any desired point in the main winding provided the conductors of the additional windings are suitably located and connected. It will also be understood that the conductors of the auxiliary windings shown may be otherwise arranged, since each conductor of such winding may be placed in any one of four positions. It is evident that the general principles of these windings apply to any number of slots, and any number of conductors per slot. It will also be clear that in some instances better mechanical and electrical arrangements of conductors will occur with some numbers of auxiliary windings than with others, and the designer may select such number as to give the desired condition.

From the foregoing it will be understood that my invention may be applied to machines having a larger number of poles, and to various other forms of armature windings.

It will also be understood that my invention may be applied to machines having stationary armatures and revolving fields, instead of machines having rotating armatures as above described.

Fig. 9 is a diagram which shows the location of the conductors of Fig. 8 on the armature. The poles N, S are indicated in full lines, and the armature core is designated by the character 40, and is represented in sections. The core is indicated as being a slotted core, and the conductors of the main and auxiliary windings are designated by the same characters as in Fig. 8. It will be noted that the conductors of the auxiliary windings are shown as located in the bottom of the slots, and this location is preferable.

Fig. 10 illustrates my invention as applied to a machine having a larger number of conductors than that represented in Fig. 8, and having more than one turn per slot. The machine represented in Fig. 10 is the same as that of Fig. 8, except that there are two turns per slot per circuit instead of one, and each turn is provided with its corresponding commutator segment. There are therefore twice as many conductors or turns and twice as many commutator segments in Fig. 10 as there are in Fig. 8. With the 64 conductors in the main winding of Fig. 10, and four multiple circuits, there are 16 conductors per circuit from brush to brush bearing on the commutator, or eight turns per circuit and two turns per slot. Applying the rule above given that the number of turns per auxiliary winding shall be one-half the turns per circuit minus one-half the turns per slot, we find that this is equal to $\frac{8}{2}-\frac{2}{2}=3$ turns for each auxiliary winding or six conductors for each auxiliary winding. As already stated, the point of connection of the beginning of the auxiliary winding to the main winding should be the middle point of the turn or turns per slot selected. In Fig. 10, the turns selected for starting one auxiliary winding are made up of the conductors 5, 19, 6, 20. The middle point of these two turns is therefore point

41′, from which the auxiliary winding 42^a to 42^f starts. Assuming that these two turns are taken care of, the six conductors of the auxiliary winding should be located to correspond to the remaining conductors of this circuit of the main winding; that is, should correspond to the turns made up of conductors 9, 23, 10, 24, 13, 27, 14, 28, 17, 31, 18, 32. Taking the turns made up of conductors 9, 23, 10 and 24, the corresponding conductors of the balancing winding may be either an outgoing conductor in phase 90 and an incoming conductor in phase 270, or two outgoing conductors in phase 90, or if desired two incoming conductors in phase 270. In the auxiliary winding 42^a to 42^f, the conductor 42^c is an outgoing conductor in phase 90, and the conductor 42^b is an incoming conductor in phase 270, which answers the requirement. Now taking the turns made up of conductors 13, 27, 14 and 28, the corresponding auxiliary conductors may be an outgoing conductor in phase 135, and an incoming conductor in phase 315, or may be two outgoing conductors in phase 135, or two incoming conductors in phase 315. In the figure, conductor 42^b is an outgoing conductor in phase 135, and 42^e is an incoming conductor in phase 315, as required. The auxiliary conductors corresponding to the turns made up of conductors 17, 31, 18, 32 should be either an outgoing conductor in phase 180, and an incoming conductor in phase 360, or two outgoing conductors in phase 180, or two incoming conductors in phase 360. The conductor 42^a is an outgoing conductor in phase 180 and 42^f is an incoming conductor in phase 360. Consequently, the auxiliary winding 42^a to 42^f contains six conductors located in positions which answer the requirements and the winding will therefore serve to maintain ring 6 at the desired neutral potential. Point 41′ where the auxiliary winding starts, is shown cross connected to point 43′, located 360 electrical degrees therefrom, and which connection assists to improve the balancing effect.

Another auxiliary winding comprising the conductors 44^a, 44^b, 44^c, 44^d, 44^e and 44^f is shown in Fig. 10, which is connected to point 45′ of the main winding, 90 degrees from the beginning of the auxiliary winding already described. It will be seen by comparing the location of the conductors 44^a to 44^f, that they correspond to the proper conductors of the main winding and that they will serve to maintain the desired neutral potential of ring 6 constant. Point 45′ is cross connected to point 46′, which is the corresponding point of the same potential. It will be understood that the various conductors which are grouped together in Fig. 10, occupy the same slot as explained in connection with Fig. 8, and that the other general statements made in connection with Fig. 8 also apply to Fig. 10.

In the diagram Fig. 10, although I have shown the main winding with full pitch, it will be evident that with fractional pitch windings, the same general principles apply, the main feature to be observed being that in each auxiliary circuit, the algebraic sum of the electromotive forces from the collector ring to each brush shall be equal to half the electromotive forces between the positive and negative brushes, and also that the algebraic sum of the electromotive forces from the collector ring through any one auxiliary winding to its connection with the main winding and through any part of the main winding to the connection of any other auxiliary winding, and then through said winding back to the collector ring, shall be zero.

The diagrams shown herein refer to multiple windings, but the invention is equally applicable to series or two-path windings. For example, with a six pole machine having 59 slots and 2 turns per slot in the main winding, making the total number of turns equal to 118 and the turns per circuit equal to 59, we would have for the auxiliary winding $\frac{59}{2} - \frac{2}{2} = 28\frac{1}{2}$, for each auxiliary winding.

Although in modern machines, the number of conductors in the main armature winding is usually very much larger than the number represented in these figures, it will be understood by those skilled in the art how the conductors of the auxiliary winding or windings should be located in such machines, and also how they should be located for various other types of main windings. It will also be understood that my invention may be embodied in various forms of construction, and that I am not limited in the scope thereof to the particular form shown and described.

Having thus described my invention, I declare that what I claim as new and desire to secure by Letters Patent, is,—

1. The combination with a direct current generator, of a plurality of auxiliary dynamo electric generating windings wound on the armature core of said generator and electrically connected to points of different potential in the armature of said generator and also electrically connected to a common point, each of said auxiliary windings having less than one-half the conductors per circuit of the main winding, and certain conductors of said auxiliary windings being located unsymmetrically with reference to each other.

2. The combination of a winding having a commutator, a field magnet, and a dynamo electric generating winding connected to a point of varying potential in said first named winding, said second winding having less than one-half the conductors per circuit

of said first named winding, and located in core slots also containing conductors of said firs named winding.

3. The combination of a winding having a commutator, a field magnet, and a plurality of dynamo electric generating windings connected to points of different and varying potentials of said first named winding, each of said plurality of windings having less than one-half the number of conductors per circuit of said first named winding and located in core slots also containing conductors of said first named winding.

4. The combination of a field magnet, a main winding subjected to the magnetic field thereof and having a commutator and brushes, and a plurality of dynamo electric generating windings connected to points of different and varying potentials of said first named winding and subjected to the same magnetic field for generating a maximum electromotive force equal to less than one-half the electromotive force generated by said main winding, said plurality of windings being also connected to a common point, each of said plurality of windings having less than one-half the number of conductors per circuit of said first named winding and located in the same phase positions as certain conductors of said first named winding.

5. The combination of a winding having a commutator, a field magnet, and a dynamo electric generating winding connected to a point of varying potential in said first named winding, said second winding having a different number of conductors than one-half the conductors per circuit of said first named winding and located in core slots also containing conductors of said first named winding.

6. The combination of a winding having a commutator, a field magnet, and a dynamo electric generating winding, connected to a point of varying potential in said first named winding, said second winding having a number of conductors different from one-half the conductors per circuit of said first named winding and less than the number of conductors per circuit of said first named winding and located in core slots also containing conductors of said first named winding.

7. The combination of a winding having a commutator, a field magnet, and a plurality of dynamo electric generating windings connected to points of different and varying potentials of said first named winding, each of said plurality of windings having a number of conductors different from one-half the number of conducto.. per circuit of said first named winding and located in core slots also containing conductors of said first named winding.

8. The combination with a direct current generator, of an auxiliary winding for maintaining a fixed potential, said winding having its parts located under the influence of the magnetic field to correspond substantially with the phase location of the parts of a circuit of the main winding excepting the portion of the main winding to which the auxiliary winding is connected.

9. The combination with a direct current generator, of means for maintaining a fixed intermediate potential comprising an auxiliary winding on the armature core for dynamically generating a maximum electromotive force equal to less than one-half the electromotive force of said generator, and a collector ring to which said auxiliary winding is connected.

10. The combination with a direct current generator, of an auxiliary winding connected to a point of varying potential in the main winding for maintaining a fixed intermediate potential, said auxiliary winding having its conductors located on the armature to correspond substantially with the phase location of a part only of the conductors of a circuit of the main armature winding, certain conductors of the auxiliary winding being unsymmetrically located with reference to each other, and a collector ring to which said auxiliary winding is connected.

11. The combination with a direct current generator, of means for maintaining a fixed potential, said means comprising a winding having its parts located in the magnetic field and in armature core slots also containing conductors of the main armature winding to correspond substantially with the location of parts of the main armature winding and having a number of conductors equal to less than one-half the conductors per circuit of the main winding, and a collector ring to which said auxiliary winding is connected.

12. The combination with a direct current generator, of means for maintaining a fixed potential, said means comprising a winding for generating a maximum electromotive force equal to less than one-half of the electromotive force of said generator and having its parts located in the magnetic field to correspond substantially with the phase location of only parts of a circuit of the main armature winding, and a collector ring to which said auxiliary winding is connected.

13. The combination with a direct current generator, of an auxiliary winding for maintaining a fixed intermediate potential, said winding being connected at one terminal to a point in the main armature winding and having its parts located in the magnetic field to correspond substantially with the phase location of only a part of a circuit of the main winding for generating a maximum electromotive force equal to less than one-half the electromotive force of the generator, and a collector ring to which the

other terminal of said auxiliary winding is connected.

14. The combination with a direct current generator, of an auxiliary winding adapted to generate varying electromotive forces for maintaining a point of fixed potential, said auxiliary winding having less than one-half the conductors per circuit of the main winding and located in slots of the armature core which also contain conductors of the main armature winding.

15. The combination with a direct current generator, of an auxiliary winding adapted to generate varying electromotive forces for maintaining a point of fixed potential, said auxiliary winding having less than one-half the conductors per circuit of the main winding and located in slots of the armature core which also contain conductors of the main armature winding and the said conductors of the auxiliary winding being located at the bottom of said slots.

16. The combination with a direct current generator, of an auxiliary winding adapted to generate varying electromotive forces for maintaining a point of fixed potential, said winding being connected at one terminal to a point in the main armature winding and having its parts located in the magnetic field to correspond substantially with the phase location of a circuit of the main winding excepting that portion to which the auxiliary winding is connected and having its conductors located in the slots of the armature core which also contain conductors of the main armature winding.

17. The combination with a direct current generator, of an auxiliary winding adapted to generate varying electromotive forces for maintaining a point of fixed potential, said winding having its parts distributed with relation to the magnetic field to correspond substantially with the phase location of only a part of a circuit of the main armature winding and also to substantially balance the armature mechanically.

18. The method of deriving an additional point of fixed potential from a direct current machine, which consists in generating dynamically a resultant alternating electromotive force which continually equals and corresponds to the change in potential of a point in the armature from the potential of the said fixed point, said resultant electromotive force being attained by generating a plurality of electromotive forces in different phase relationship and in phases corresponding to the phase distribution of only a part of a circuit of the main armature winding.

19. The combination with a multipolar direct current generator, of an auxiliary winding distributed on the armature for dynamically maintaining an intermediate fixed potential, one terminal of said auxiliary winding being connected to a plurality of points in the main winding having the same potential approximately, said auxiliary winding having less than one-half the turns per circuit of the main armature winding, and a collector ring to which the other terminal of said winding is connected.

20. The combination of a multipolar direct current generator, of a plurality of auxiliary windings distributed on the armature for dynamically maintaining an intermediate fixed potential, one terminal of each of said windings being connected to a plurality of points in the main armature winding having the same potential approximately, the points of connection of one auxiliary winding being displaced less than 180 degrees electrically from the points of connection of the main armature winding of another of said auxiliary windings, each of said auxiliary windings having less than one-half the conductors per circuit of the main winding, and a collector ring to which one terminal of each of said auxiliary windings is connected.

21. The combination with a direct current generator, of an auxiliary winding for maintaining an intermediate potential, a collector ring to which one terminal of said winding is connected, the other terminal of said winding being connected to the main armature winding, and the number of turns of the auxiliary winding being one-half the number of turns per circuit of the main winding minus one-half the turns per slot of the main winding.

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

JAMES BURKE.

Witnesses:
L. K. SAGER,
GEO. N. KERR.