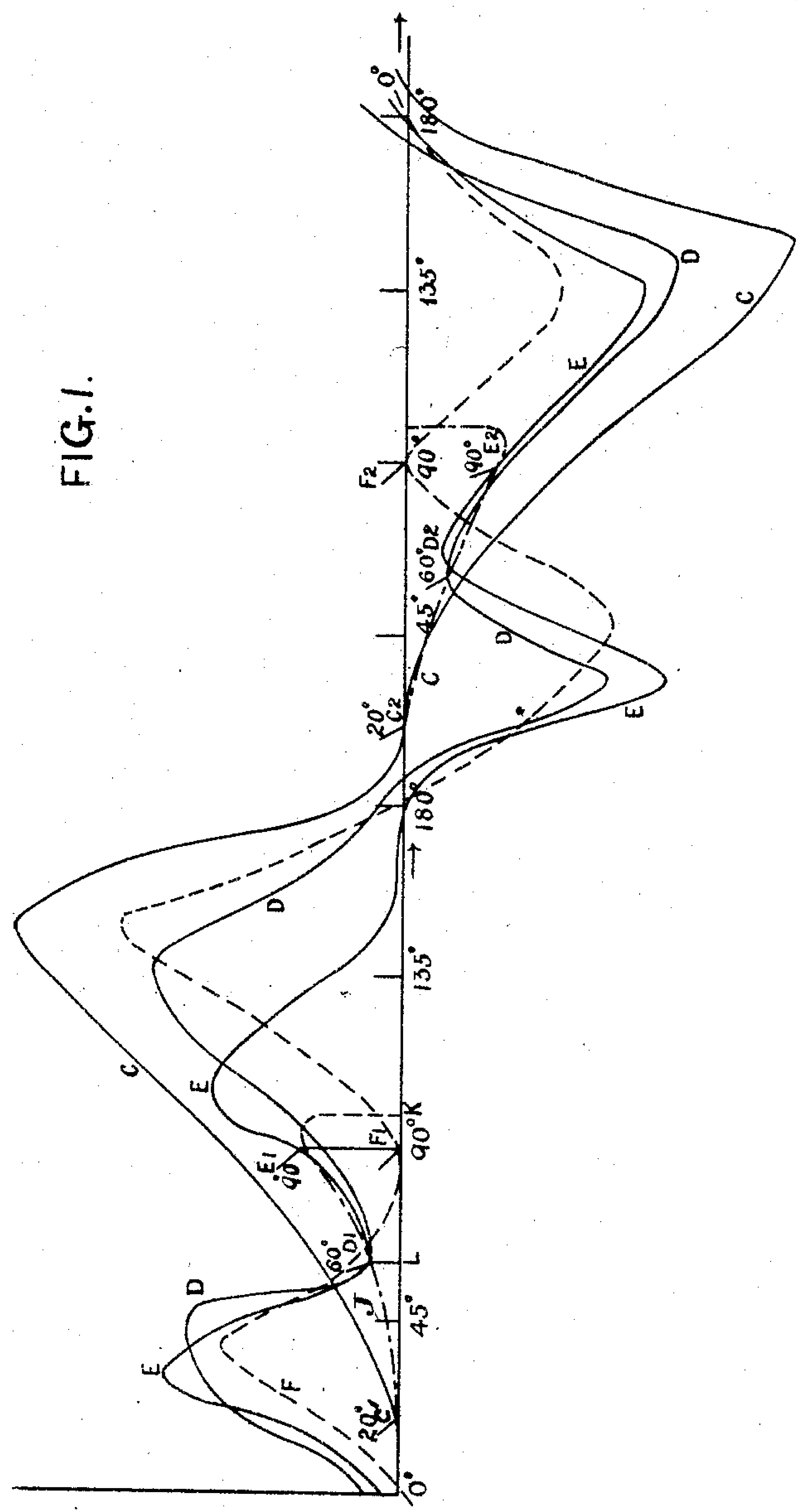
(No Model.) 3 Sheets—Sheet 1.

J. G. STATTER.

METHOD OF DETERMINING THE SHAPE OF POLE PIECES FOR DYNAMOS.

No. 410,656. Patented Sept. 10, 1889.

FIG. 1.



Witnesses.

James Green Lorrain

Charles John Howell Thomas.

Inventor

John Grice Statter

Atty.: A. C. Fowler

(No Model.)

3 Sheets—Sheet 2.

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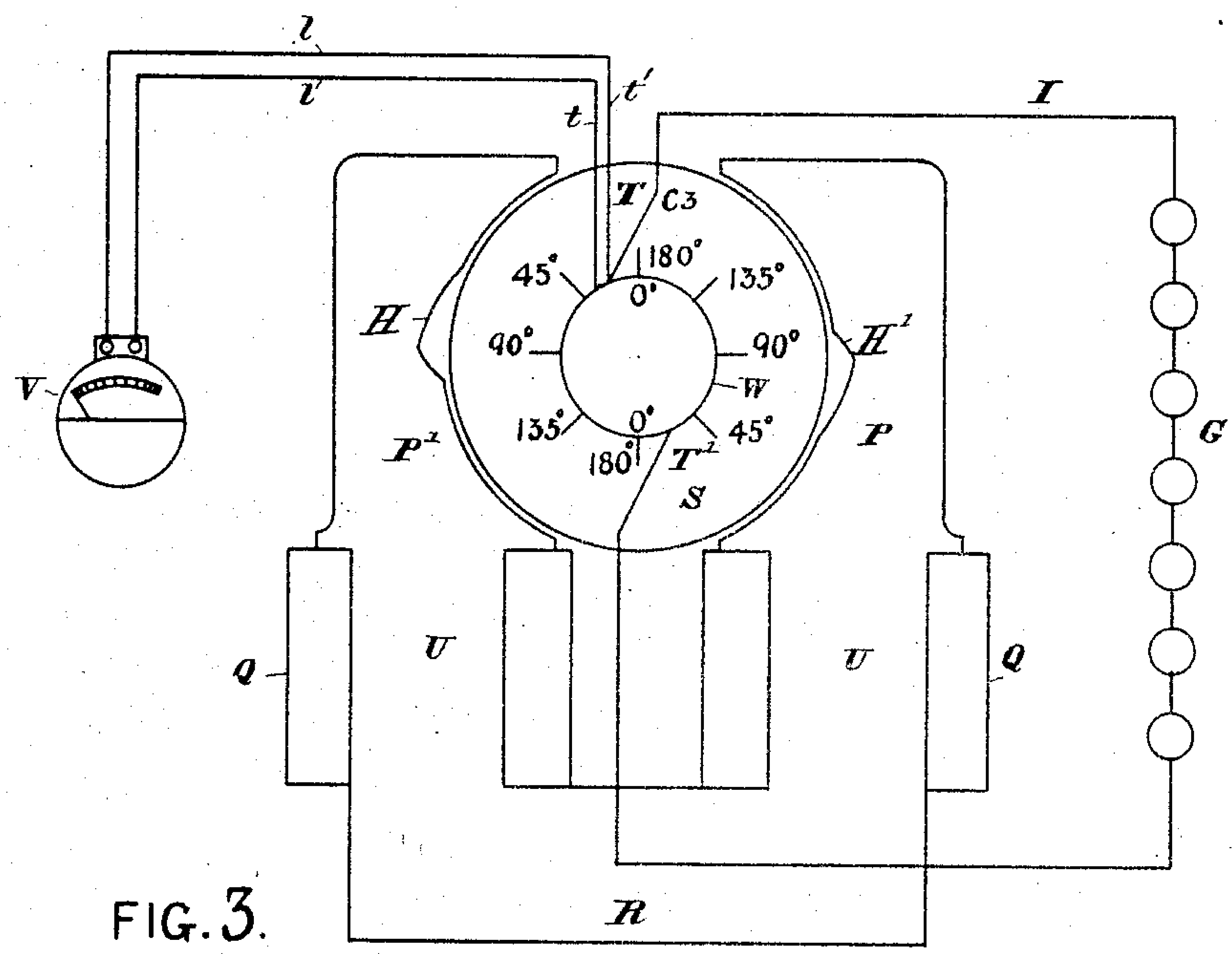
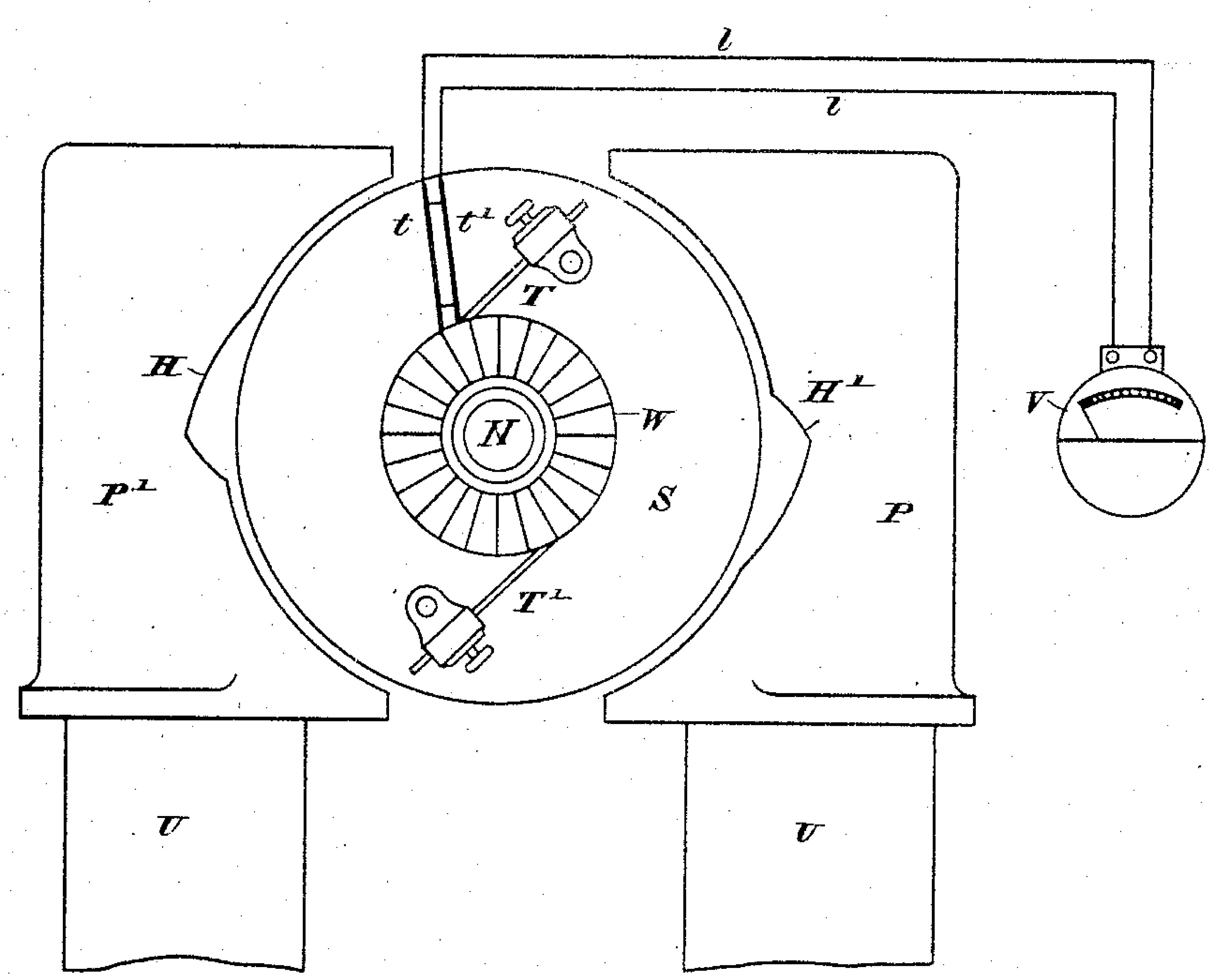


FIG. 3.



Witnesses
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FIG. 3a.

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(No Model.) 3 Sheets—Sheet 3.

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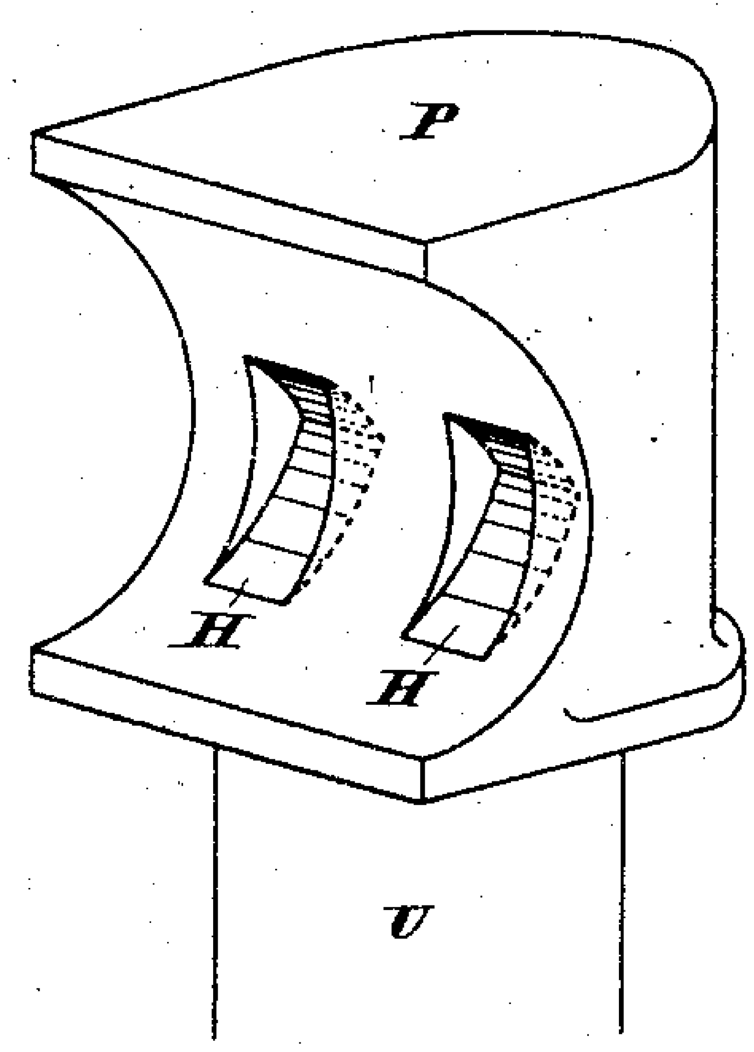

FIG. 4.

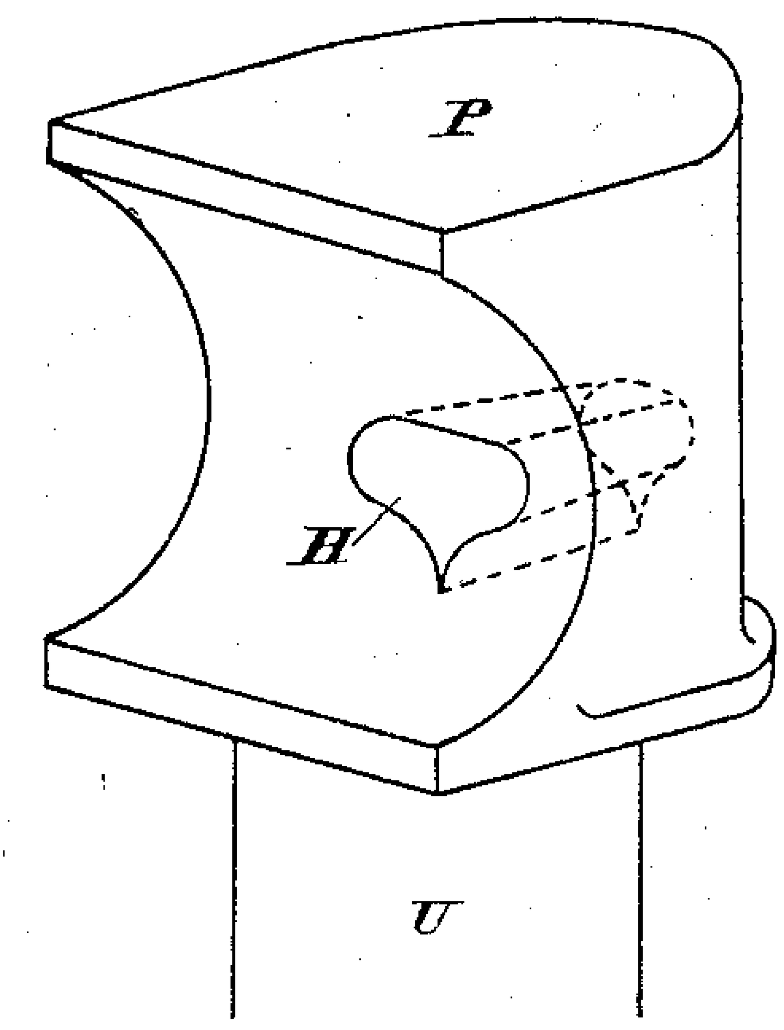

FIG. 5.

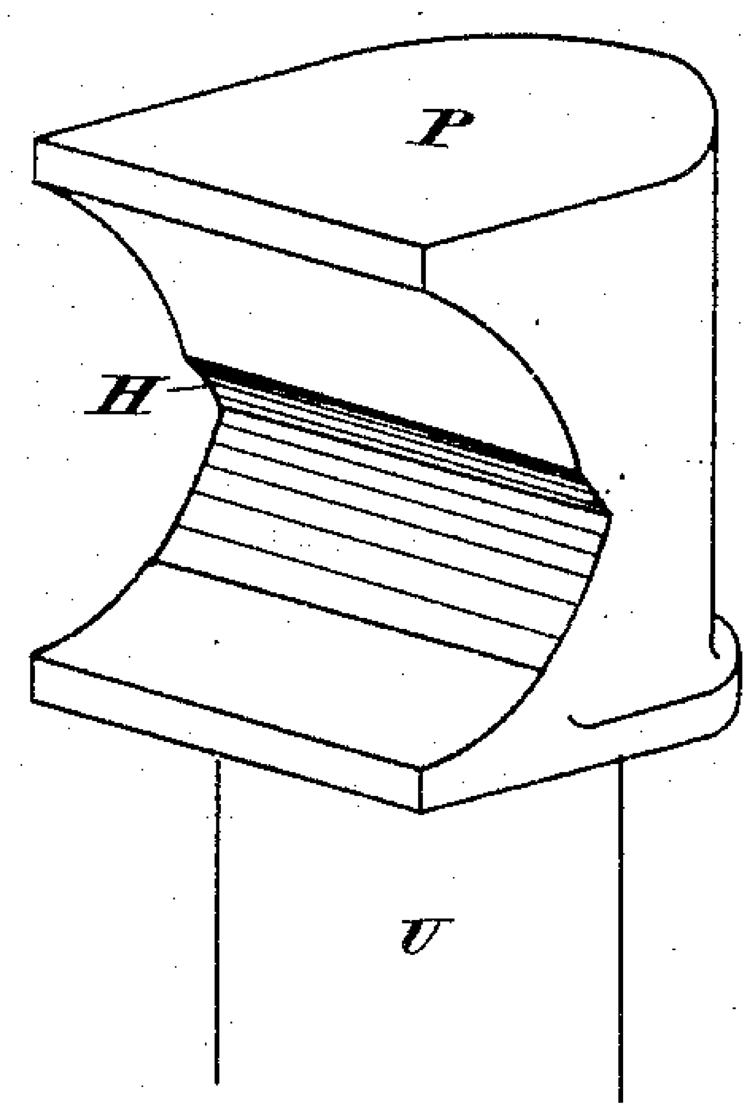

FIG. 2.

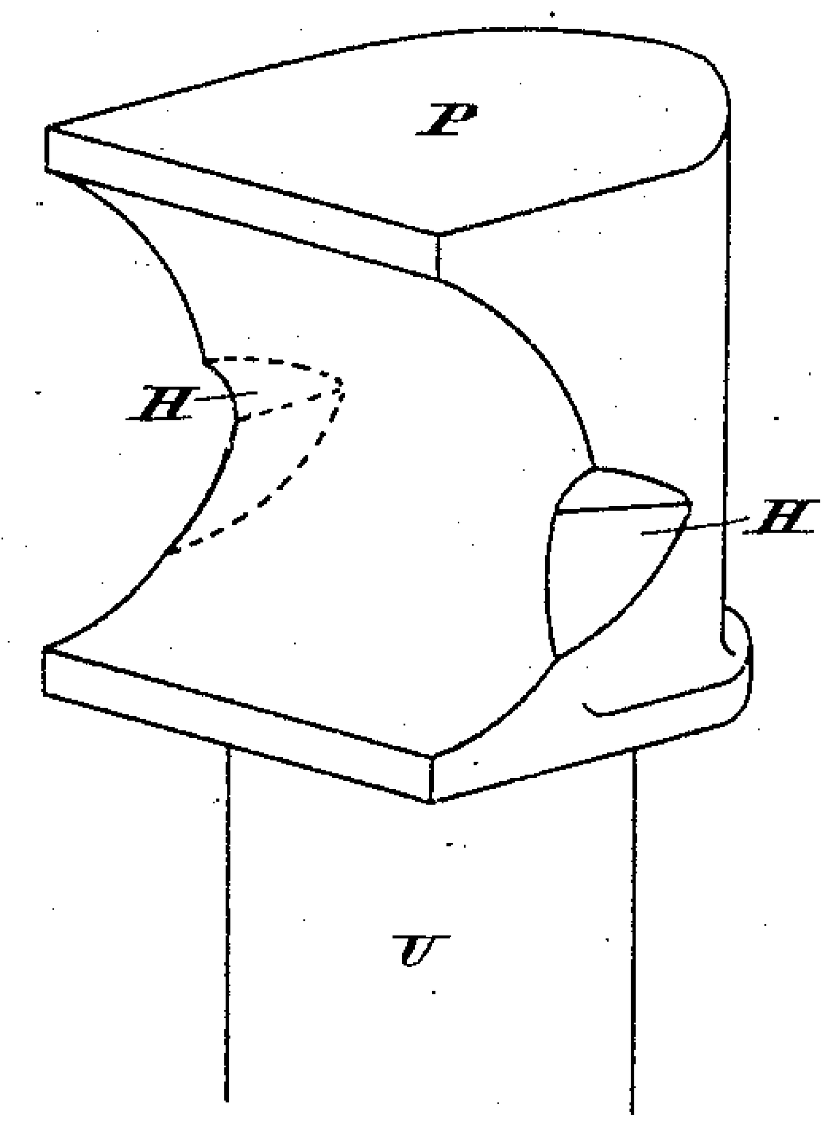

FIG. 6.

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UNITED STATES PATENT OFFICE.

JOHN GRICE STATTER, OF LONDON, COUNTY OF MIDDLESEX, ENGLAND.

METHOD OF DETERMINING THE SHAPE OF POLE-PIECES FOR DYNAMOS.

SPECIFICATION forming part of Letters Patent No. 410,656, dated September 10, 1889.

Application filed March 26, 1889. Serial No. 304,543. (No model.) Patented in England February 23, 1887, No. 2,825; in Belgium February 2, 1888, No. 80,487; in France April 13, 1888, No. 188,498, and in Spain May 14, 1888, No. 7,943.

To all whom it may concern:

Be it known that I, JOHN GRICE STATTER, a subject of the Queen of Great Britain, residing at London, in the county of Middlesex, England, have invented certain new and useful Improvements in Methods of Determining the Shape of the Pole-Pieces of Dynamo-Electric Machines, whether Generators or Motors, (for which I have received Letters Patent in Great Britain, No. 2,825, dated February 23, 1887; Belgium, No. 80,487, dated February 2, 1888; France, No. 188,498, dated April 13, 1888, and Spain, libro 6°, folio 243, numero 7,943, dated May 14, 1888;) and I do hereby declare that the following is a full, clear, and exact description of the invention, which will enable others skilled in the art to which it appertains to make and use the same.

These improvements have for their object, in the case wherein the machine is used as a generator, the maintenance of a constant current through a variable resistance, or a constant current or electro-motive force when the machine is driven at varying speeds, and, in the case wherein the machine is used as a motor, the varying of the mechanical energy given out. In obtaining such objects these improvements require the position of the brushes on the commutator to be altered, and they enable such brushes to be moved round the commutator through a large angular distance—say ninety degrees—without the production of sparking. I do not herein specify any particular means whereby the brushes are moved. They can be moved by hand or by any suitable known automatic device.

In carrying the principles of my invention into effect for the purpose of obtaining a machine capable of acting as above mentioned, I find it necessary to maintain constant the product of the magnetic intensity affecting those coils of the armature which are at any moment passing under the brushes expressed in any suitable units—such, for example, as gram, centimeter, second units — and the length of the conductor of such coils as is directly acted upon by the field-magnets expressed, say, in centimeters. This magnetic intensity must be of a certain value, as the following explanation will show. For the purpose of this explanation I shall assume that I employ an armature of the drum or ring type and field-magnets such as those shown in the accompanying drawings, it being understood that the accompanying drawings show ordinary pole-pieces modified according to the present invention, as will be hereinafter described. A coil on the armature in passing from a position immediately behind to one immediately in front of the brushes experiences a sudden reversal of the current which it is carrying. This causes a momentary electro-motive force of self-induction to take place in the said coil, which, if not neutralized, will cause a current to leap between that plate of the commutator connected to the coil which has just passed from under a brush and the brush which the plate has just left—in other words, sparking is produced. By so placing the brushes that the magnetic intensity of the field-magnets shall affect this coil to a suitable extent this electro-motive force is neutralized by the electro-magnetic induction on this coil.

In order to be able to move the brushes through a large angular distance—say ninety degrees—around the commutator without producing sparking, it is necessary that the inductive effect of the field-magnets upon that part of the armature upon which the coils passing under the brushes are wound shall be constant throughout such angular distance, and shall be sufficient to neutralize the electro-motive force of self-induction hereinbefore referred to.

In order that my invention may be more readily understood, I shall refer to the accompanying drawings, making a part of this specification, and shall first describe how I carry it into effect in the case of a dynamo-electric machine or generator; and thereafter I shall describe how I carry it into effect in the case of an electro-dynamic machine or motor. I am now using the words "dynamo-electric" and "electro-dynamic" in their narrow and specific sense.

Figure 1 is a diagram of the current curves generated in the armature under the conditions set forth. Fig. 2 is an isometric view of a pole-piece incised in accordance with my invention. Figs. 3 and 3a are end views of a dynamo made in accordance with my invention, showing also a diagram of the means for testing the same. Figs. 4, 5, and 6 show modified forms of pole-pieces made in accordance with my improved method.

In constructing my improved machine to act as a generator, say, for the production of a high-tension current of ten ampères, at a maximum electro-motive force of two thousand volts, I employ a quantity of iron relatively large to the quantity of wire in both the field-magnets Q U and the armature S, and having a depth of armature-core, say, three to four times the depth of the external winding on the same, and having in the field-magnets a mass of iron (preferably wrought-iron) considerably in excess of the mass of the iron in the armature S. Having constructed such a machine with a ring-armature S in the usual way—that is, so as to have the pole-pieces P P′, which are united by a yoke R, solid and concentric with the armature and with just sufficient clearance between the pole-pieces and the armature—I put it into operation, and close the circuit I through such a resistance—for instance, the lights G G—as will enable the machine to give out its normal current, and I set the brushes T T′ at the position where no sparking occurs. I now take an apparatus, which I may for convenience term an "exploring apparatus," and which consists of a voltmeter V of any convenient type, with flexible conductors l l attached thereto, which flexible conductors terminate at their other extremities in two small brushes or plates t t′ of metal, insulated from one another and suitably distanced apart. With this apparatus I obtain relative indications of the electro-motive force of the current (which are also relative indications of the resultant magnetic intensity produced by the mutual action upon each other of the field-magnets and the armature) flowing through the coils, whose circuit I complete by means of the exploring apparatus; and this I do by bringing the brushes of the exploring apparatus (hereinafter for the sake of convenience termed the "exploring-brushes") in contact with adjacent segments of the commutator W, which, it must be understood, is revolving at the time and the machine giving out its normal current. The object of obtaining such indications is to enable me to alter the shape of the pole-pieces P P′ in such a way that when the pole-pieces are so altered the product of the magnetic intensity affecting those coils of the armature which are at any moment passing under the brushes into the length of the conductor of such coils as is directly acted upon by the field-magnets shall be constant. This alteration I effect by incising or boring the pole-pieces, so as to produce orifices or cavities H H′ of certain definite shape and size, such shape and size being determined in the manner following: I determine the shape by plotting out the electro-motive forces indicated by the voltmeter V of the exploring apparatus. I set out such electro-motive forces as ordinates, and as abscissæ I set out the angular distances corresponding with the positions which the exploring-brushes t t′ at the time of a reading being obtained upon the voltmeter occupy upon the commutator. These angular distances are set out from a vertical line midway between the poles, and are diagrammatically represented in Fig. 3, where it will be seen that angular distances equal to forty-five degrees are marked passing in the direction of the arrow. It will be noticed that these angular distances are represented as angles from 0° to 180° on one side of the said vertical line, and repeated as 0° to 180° on the other side. In this figure the exploring-brushes t t′ are shown in connection with the voltmeter V and in contact with commutator-segments W at an angle of twenty degrees from the part where the said vertical line cuts the top of the armature S, the main brushes T T′—that is, the brushes connected with the external circuit I fed by the machine—being one at this point, and the other at the corresponding angular distance from the part where the vertical line cuts the bottom of the armature and diametrically opposite, these being the positions which the brushes would naturally occupy in a machine as usually constructed. In the immediately preceding sentence I mention that the exploring-brushes tt′ are at the same point as the main brushes T T′. This is not strictly correct, since no reliable readings can be obtained by the exploring apparatus when the exploring-brushes are exactly in line with the main brushes, on account of the continual short-circuiting of adjacent sections of the commutator by the main brushes. I therefore take readings with the exploring-brushes immediately behind and immediately before the main brushes, and am able to draw the curve hereinafter described with sufficient accuracy without having taken a reading exactly under the main brushes. The electro-motive force at this angle is thus obtained, and electro-motive forces are similarly obtained at all parts, the whole of the commutator being explored for this purpose, and the indications obtained plotted out in curves, as shown in Fig. 1, the main brushes in connection with the external circuit remaining in the same position during such exploration, and the speed at which the machine is driven and the resistance of the said external circuit being maintained constant.

Referring to Fig. 1, it will be seen that C C C C show a curve of electro-motive forces as obtained by exploring the whole commutator. It will be seen that the curve, when the main brushes are at an angle of twenty degrees, is thus displayed. I then change the position of the main brushes to sixty degrees, and in the same manner plot out the curve D D D D. Again, I shift the main brushes to an angle of ninety degrees and obtain the indications which enable me to plot out the curve E E E E. Upon the curves, as shown in Fig. 1, C′ C^2 on the curve C C C C represent the positions of the main brushes when they are at an angle of twenty degrees. The points D′ D^2 on the curve D D D D represent the positions of the main brushes when they are at an angle of sixty degrees, and the points E′ E^2 on the curve E E E E represent the positions of the main brushes when they are at an angle of ninety degrees. It will be seen that when the main brushes are in the positions shown on the curve C C C C there is no sparking. When in the positions shown on the curve D D D D, it will be seen that there is sparking, the electro-motive force in the coil short-circuited by the main brushes being represented by the length of the ordinate L, (this ordinate being obtained as hereinbefore described,) which electro-motive force represents the excess of the inductive effect, as hereinbefore mentioned, over the self-inductive effect in the coil passing under the brushes at the time of observation. Similarly in the case of the curve E E E E, it will be seen that there is sparking at the brushes, the ordinate K (this ordinate being obtained as herein described) representing this, as described in the last case.

In Fig. 1 I have only plotted out three curves, these being representations of results obtained during explorations with the brushes in three different positions. In practice, however, instead of making three explorations, I make a considerable number—say ten or twelve—and plot the curves obtained by this means in the same manner as are those shown in Fig. 1. These curves I shall call, for the purpose of this specification, "exploration-curves." These exploration-curves I utilize to obtain a new curve, which, for convenience, I shall hereinafter refer to as the "shaping-curve." The shaping-curve is obtained as follows: On the horizontal line (see Fig. 1) and at the point corresponding with the angle at which the main brushes are at the time when the exploration-curve C C C C is obtained, I set up an ordinate cutting the said exploration-curve C C C C. On the horizontal line, and at the point corresponding with the angle at which the main brushes are when the exploration-curve D D D D is obtained, I set up the ordinate L, cutting said exploration-curve D D D D. On the horizontal line and at the point corresponding with the angle at which the main brushes are when the exploration-curve E E E E is obtained, I set up the ordinate K, cutting the said exploration-curve E E E E. These three points C′, D′, and E′, I join by a line and so obtain the shaping-curve J desired, it being of course understood that to obtain such a shaping-curve as would be desirable in practice, instead of having only three curves, (the result of explorations in three positions of the main brushes,) I should, as before mentioned, plot out a large number of curves and so obtain additional points, by the connection of which I would obtain my desired shaping-curve. This shaping-curve represents the excess of the inductive effect, as hereinbefore mentioned, over the self-inductive effect in the coil passing under the main brushes at different positions of these with respect to the before-mentioned vertical line. This curve also indicates where and to what extent the magnetic intensity of the field exceeds the definite value hereinbefore referred to. I therefore utilize such indications as are shown by the shape of this curve to guide me in determining the shape of a part of the metal of the pole-pieces to be removed, as hereinbefore mentioned.

To determine the amount of metal to be removed or the size of the cavities or orifices to be made, I have recourse to experiment, as I know of no definite method approaching accuracy by which I can obtain this information. A rough guide, however, exists in the length of the ordinates which represent the excess of the inductive effect over the self-inductive effect, as before mentioned.

I shall now proceed to explain how I employ the information yielded by the shape of this shaping-curve to guide me in altering the form of my pole-pieces. For this purpose I shall first of all refer to one form of modified pole-piece—namely, that in which a groove is cut parallel to the armature-shaft N—and thereafter I shall refer to other forms of modified pole-pieces which may be constructed according to my invention. Having obtained the shaping-curve, as before mentioned, I proceed to cut out grooves H H′ in the pole-pieces P P′ of a shape resembling that of the shaping-curve and in a direction parallel to the armature-shaft N. Such a groove is represented in Fig. 2, the position of the said groove being indicated by the shape of the curve and corresponding with the angles, as shown in Figs. 1 and 3. Having cut out this groove as aforesaid, I replace the armature and run the machine again, using the exploring apparatus and again plotting out curves, as before. In order not to confuse the diagram shown in Fig. 1 by having too many curves, I represent only one exploration-curve, obtained after the removal of some of the iron from the pole-pieces, and this exploration-curve, which is taken with the main brushes at an angle of ninety degrees with the vertical line above referred to, is shown in the dotted line F. It will be seen that this new exploration-curve cuts the ordinate K corresponding with the angular position of the brushes on the horizontal line, and that there is no excess of electro-motive force, as before mentioned, when the main brushes are in this position, and therefore no sparking. Such cutting of the ordinates on the horizontal line and consequent absence of sparking at all positions of the brushes would show that the shape and size of the groove is of sufficiently approximate accuracy in order to obtain the desired purpose. If, however, it had not been so, it would have been necessary to alter the groove in accordance with this second shaping-curve, and then to obtain another shaping-curve, and so alter the groove as to make it correspond therewith, and so on, shaping-curves being obtained and the grooves altered in accordance therewith until it were found that the machine could be run as before mentioned and curves be taken which should cut on the horizontal line the ordinates corresponding with the positions of the main brushes at all angular positions.

Figs. 2, 3, and 3^a illustrate pole-pieces modified in the manner just described—that is, so as to have grooves cut in them in a direction parallel to the armature-shaft and incised in accordance with the form of the shaping-curve.

Having now described my method of determining the shape of one form of modified pole-piece—namely, that in which a groove is cut parallel to the armature-shaft—I shall proceed to describe some other forms of modified pole-pieces—that is to say, pole-pieces modified by the formation of cavities or orifices differing from the form just described. A large number of such modifications could be made, and I desire it to be understood that I do not limit myself to any particular form of cavity or orifice H H′, as the essence of my invention consists in the modification of the pole-pieces by the formation of cavities or orifices, for the purpose either of varying the magnetic intensity or of varying the length of conductor acted upon, as previously mentioned, and in accordance with what is shown to be necessary by the form of the shaping-curve.

Figs. 4, 5, and 6 illustrate pole-pieces modified in different manners. Fig. 4 illustrates a case closely resembling that hereinbefore described with reference to Figs. 2, 3, and 3^a, the difference being that instead of the groove being cut across the whole face of the pole-piece, as shown in Figs. 2, 3, and 3^a, it is cut in an interrupted manner. In the figure—namely, Fig. 4—it will be seen that two cavities H H are cut; but if the metal between and at the sides of these cavities were cut away, it will be seen that cavities of the same form would be obtained as in Figs. 2, 3, and 3^a. Fig. 5 shows another modification. In this case an orifice H is bored right through the pole-piece in a direction at right angles to the armature-shaft, and the resemblance between this form of orifice as it would be shown in cross-section with the shaping-curve or a groove such as is shown in Fig. 2 will be apparent. At the angular distance with reference to the commutator where the ordinate is highest (see Fig. 1) or the cavity is deepest (see Fig. 2) the orifice of Fig. 5 is broadest. It is not necessary that the orifice should be bored the whole way through, as shown in the figure. It may be merely a cavity of a shape similar to the orifice shown. Fig. 6 illustrates another form of pole-piece modified in accordance with my invention. It will be seen that this form of modified pole-piece differs from that shown in Fig. 4 chiefly in the fact that the cavities H H, instead of being incised at or near the central part of the pole-pieces, are incised at the ends thereof. It will be noticed that of these figures illustrating modified forms of pole-pieces, Figs. 2, 3, and 3^a are the best illustrations of the case wherein the magnetic intensity, as previously described, is varied; whereas Fig. 6 illustrates probably in a better manner than the other figures the case wherein the length of conductor acted upon by the field-magnets is varied. Figs. 4 and 5 may be taken as being good illustrations of cases which are, as it were, a compromise between those illustrated in Figs. 2 and 6, respectively. Such compromise might be introduced still further in making other forms of modified pole-piece. For example, a form of pole-piece might be made differing from that shown in Fig. 2, in that the grooves might be shallower toward the center than at the ends of the said grooves, or vice versa, and other modifications will readily suggest themselves.

Having now described the carrying out of my invention as applied to a dynamo-electric machine or generator, I shall proceed to describe the carrying out of my invention with regard to its application to an electro-dynamic machine or motor. I commence, as in the case of a generator, by constructing an electromotor after the ordinary manner, and then I proceed to run it and obtain shaping-curves in the same manner as I have already described with regard to carrying out my invention in the case of a generator, but with this difference, that instead of running the machine as a generator I run it as a motor—that is to say, I keep the feeding-current constant, and alter the position of the main brushes, so as to maintain the speed of revolution constant under a varying load. Having obtained such shaping-curves, I use them for the purpose of guiding me in modifying the pole-pieces exactly as hereinbefore described in speaking of the pole-pieces of a generator.

Inasmuch as it is generally necessary to obtain more than one shaping-curve, and as modifications in the cavity or orifice H have to be made in accordance with each additional shaping-curve obtained after the first one, I find it expedient, in incising the metal of the pole-pieces for the purpose of obtaining cavities or orifices H, to incise the metal to a less extent than the shaping-curve would appear to warrant, and so leave myself a margin of metal to work upon.

I would remark that hitherto I have assumed that the commutator-plates are at the same angular position on the armature as the coils with which they are in connection; but this is not always the case, for in some armatures the coils, instead of being connected to commutator-plates at the same angular position, are connected to commutator-plates at a different angular position. This is the case with the well-known Edison armature; and when my invention is applied to machines having such armatures I cut away my pole-pieces at the places indicated with respect to the coils, and not at the places indicated with respect to the commutator-plates with which such coils are connected.

I have hereinbefore described my invention as applicable to a machine having a single horseshoe field-magnet and a ring-armature. My invention is not, however, restricted to such a machine, but is applicable to other types of machine—namely, to any two or four pole machine whose field is capable of suitably acting upon an armature of the ring or drum type, and having many coils (say twelve or more and a corresponding number of commutator-plates) connected up in a single circuit, as is, for example, the well-known Gramme armature. It is to be understood, however, that though my invention is not applicable to machines having many poles, still, should the diameter of the armature be large, the number of such poles might be increased to, say, six or eight. In the case of such types of machine as I have just indicated I proceed as hereinbefore described—that is, I take readings enabling me to plot out shaping-curves, and afterward remove the metal as shown to be necessary by such shaping-curves.

In order to explain more clearly the application of my invention in the case of other known types of machine, as aforesaid, I shall proceed to consider what the action of single horseshoe-magnets must be upon a ring-armature in order that there may be no sparking at the brushes whatever may be their position on the commutator. It will be understood that in a single horseshoe field-magnet as usually constructed the magnetism of the pole-pieces at the part nearest the field-magnet coils is stronger than at the part most remote therefrom; therefore, as the current is taken off the armature at different positions with respect to the two pole-pieces—in one of them nearer the field-magnet coils and in the other farther away from them (see Fig. 3)—the shaping-curves indicated with respect to the two pole-pieces will differ from one another, as will the shape of the part to be cut away from each pole-piece. This will be readily seen by reference to the two shaping-curves shown, respectively, above and below the horizontal line in Fig. 1, where they will be seen to differ. In a drum-armature, as is well known, each coil is simultaneously acted upon by both pole-pieces, so that in exploring after the manner hereinbefore mentioned round one half of the field I would in reality have explored both halves of the field, and the diagram I would take would only be one-half of such a one as is shown in Fig. 1. The shaping-curve would indicate the resultant effect of both pole-pieces on one coil; and in carrying my invention into effect I might either cut away one pole-piece only or cut away both to such an extent that the sum of the grooves cut in them would equal the groove cut in one pole-piece only.

By the employment of pole-pieces cut away or incised, as hereinbefore specified, together with a suitable device for altering the position of the brushes, I am able, when the machine is used as a generator, to maintain a constant current through a variable resistance, or a constant current or electro-motive force when the machine is driven at varying speeds, and when the machine is used as a motor to vary the mechanical energy given out.

It is not necessary that separate shaping-curves should be obtained for every individual machine constructed, for one shaping-curve will apply to all machines made to one pattern; but any alteration of pattern that would sensibly alter the strength of the field, such as an alteration in the winding of the field-magnets or armature, would entail the obtaining of a new shaping-curve and the cutting away or incision of the pole-pieces in accordance therewith.

Having thus specified the nature of my invention and the best manner of carrying it into effect with which I am acquainted, I would add that modifications of a mechanical nature may be introduced without departing from the essence of my invention. For example, one might bore a number of small holes through or to a certain depth into the pole-piece or cut a number of horizontal channels or grooves along its face, the said holes or channels being deepest or widest or most numerous at the part from which the shaping-curve shows that the largest amount of metal has to be excised. Modifications of such a nature would readily suggest themselves to an ingenious mind; but they would be mere self-evident variations of the invention hereinbefore set forth.

I am aware that before this date pole-pieces have been modified in form for various purposes. For example, modified forms which may be looked upon as pole-pieces of ordinary type cut away or incised have been described by Houston and Thompson, by Trouvé, by Wissendanger, by Weston, by Joel, by Lever, and by E. and J. Hopkinson, and J. Platt; but such modified forms of pole-piece as they describe differ essentially from mine and have different objects in view. I therefore desire it to be understood that I make no claim to the methods of modifying pole-pieces which they describe.

I desire it to be understood that in this specification I make no claim to the generic or specific forms of pole-piece embodying my invention, as I claim such in the specification accompanying a separate application for a patent, which application was filed at the United States Patent Office on February 9, 1888, and received the Serial No. 263,453.

Having fully described my invention, what I claim, and desire to secure by Letters Patent, is—

1. The method of determining the shape of the pole-pieces of dynamo-electric machines or motors, consisting of exploring the armature at various points around the same under different positions of the commutator-brushes to determine the electro-motive forces at various points around the armature and under different positions of the brushes, plotting out the curves of the electro-motive forces so obtained, and from these exploration-curves determining the excess of the inductive effect over the self-inductive effect in the coils passing under the brushes in the various positions of said brushes.

2. The method of determining the shape of the pole-pieces of dynamo electric machines or motors, consisting, first, in obtaining a curve which represents the excess of induction over self-induction, then removing experimentally less metal than required from the pole-pieces at the point indicated by the curve so obtained, then replotting the curve, and again experimenting until sufficient correction be obtained to make the inductive effect equal to the self-inductive effect.

3. The method of determining the shape of the pole-pieces of a dynamo-electric machine or motor to prevent sparking when the brushes are shifted, which consists in plotting out exploration-curves obtained in substantially the manner described, setting up ordinates corresponding to the various positions of the commutator-brushes in their several positions, and joining by a line the points where these ordinates cut their respective curves.

4. The method, as hereinbefore set forth, of determining the shape of the pole-pieces of a dynamo-electric machine or motor to vary the magnetic effect of said pole-pieces upon said armature and render the magnetic effect of said pole-pieces on said armature equal to the self-induction generated in the coils of the armature passing under the brushes at the time to prevent sparking, which consists in running said dynamo or motor under normal conditions, placing the brushes at several points around the commutator and measuring the differences of potential between adjacent coils around the armature for each position of the brushes, plotting the curves of said differences of potential by setting out the angular distances around the commutator as abscissæ and the differences of potential as ordinates for every position of the brushes, erecting ordinates corresponding to the angles at which the brushes are located in the several positions, noting the points where these ordinates cut their curves and joining the points so located by a line the angular position, size, and form of which will indicate the position, shape, and proportionally the amount of metal to be cut from the pole-pieces.

5. The method of determining the shape of the pole-pieces of dynamo-electric machines or motors to prevent sparking when the brushes are shifted, which consists in running said dynamo or motor with a constant current and resistance, or a variable load, respectively, changing the position of the brushes around the commutator, measuring the difference of potential between the adjacent coils around the commutator to correspond with each position of the brushes, plotting the curves of said differences of potential, setting out ordinates corresponding with the various positions of the brushes and noting the points where the said ordinates cut their corresponding curves, joining the points so located by a line and constructing the pole-pieces to correspond with the position and shape of this line and substantially in proportion to the area inclosed by said line, then running the dynamo under normal conditions again and shifting the brushes as before, measuring the differences of potential between the adjacent coils around the armature as before, and shaping the pole-pieces until the curves representing the differences of potential in adjacent coils cut the zero-line of said curves at points corresponding to the location of said brushes.

JOHN GRICE STATTER.

Witnesses:
JAMES GRIEVE LORRAIN,
CHARLES JOHN HOWELL THOMAS.