(No Model.) 2 Sheets—Sheet 1.

W. LANGDON-DAVIES.

ELECTROMAGNET HAVING ROTATING FIELDS.

No. 604,055. Patented May 17, 1898.

Fig. 1.

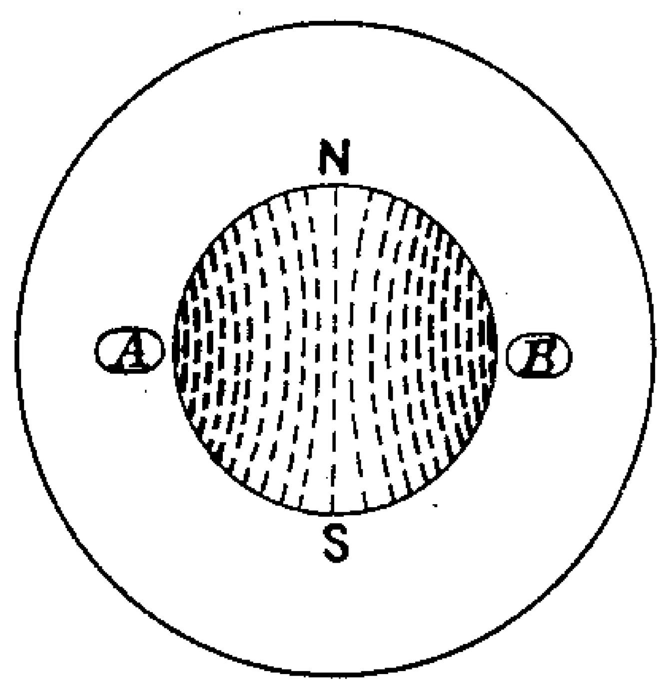


Fig. 2.

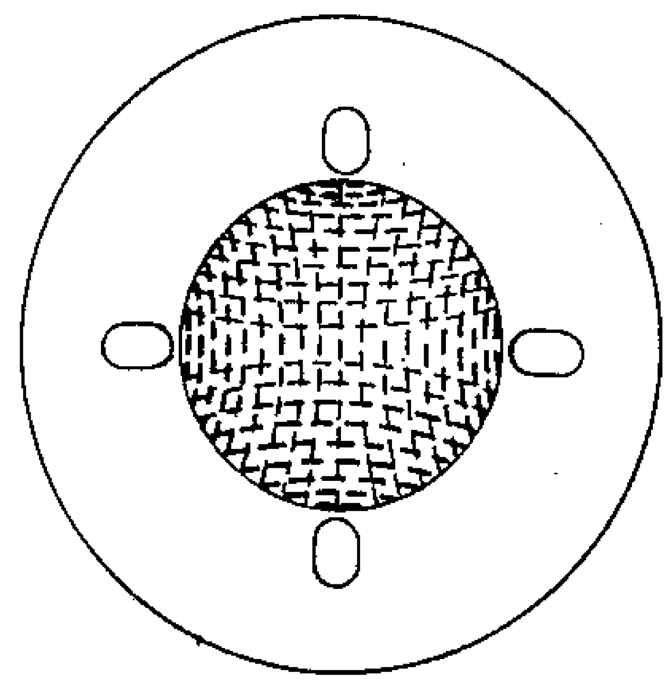


Fig. 3.

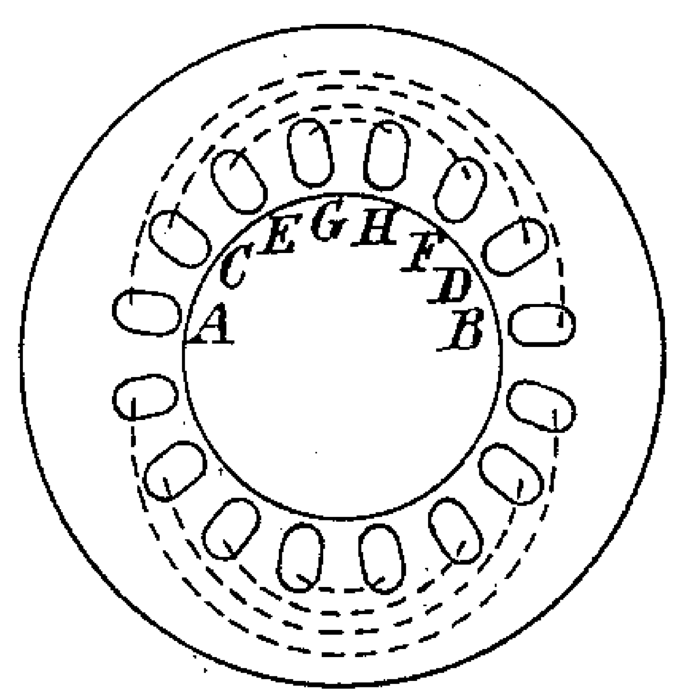


Fig. 3ª.

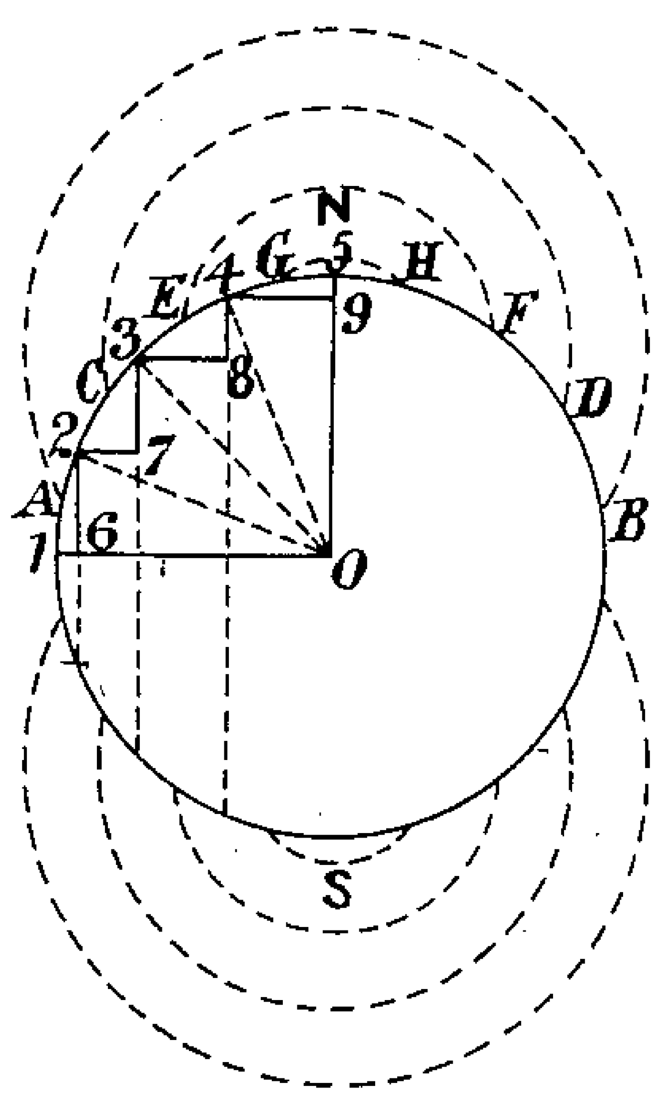


Fig. 4.

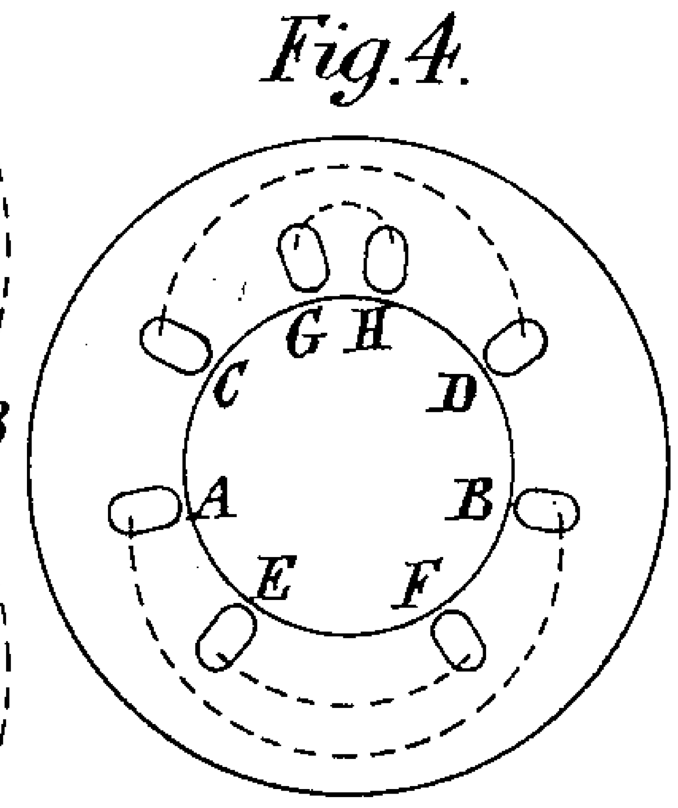


Fig. 5.

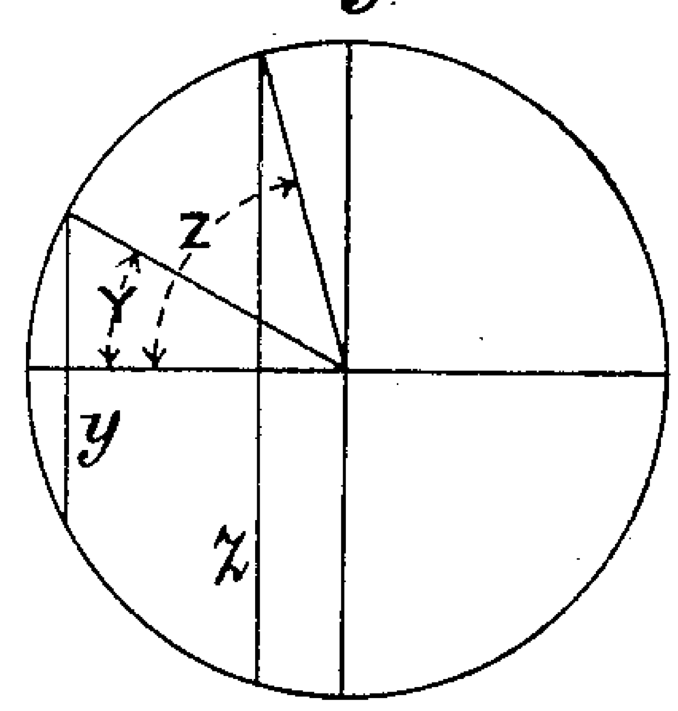


Fig. 7.

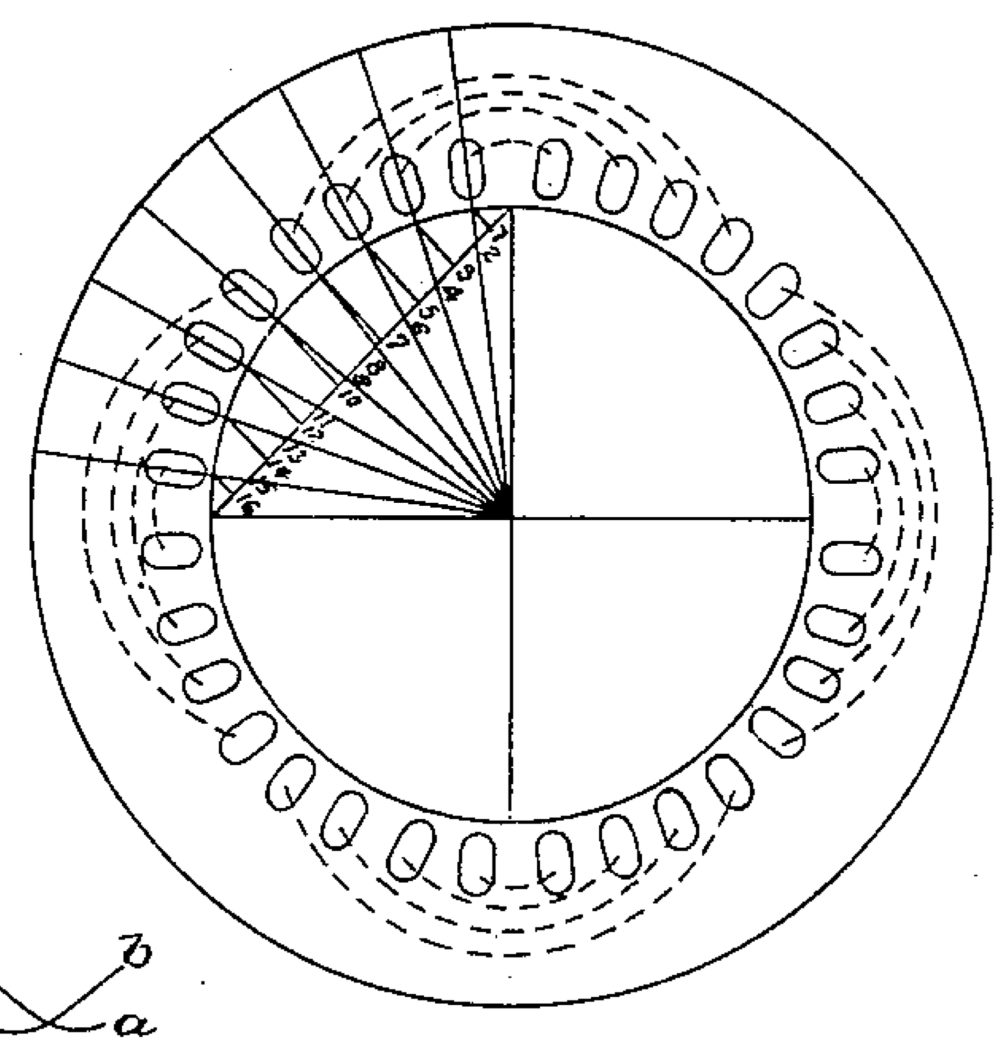


Fig. 6.

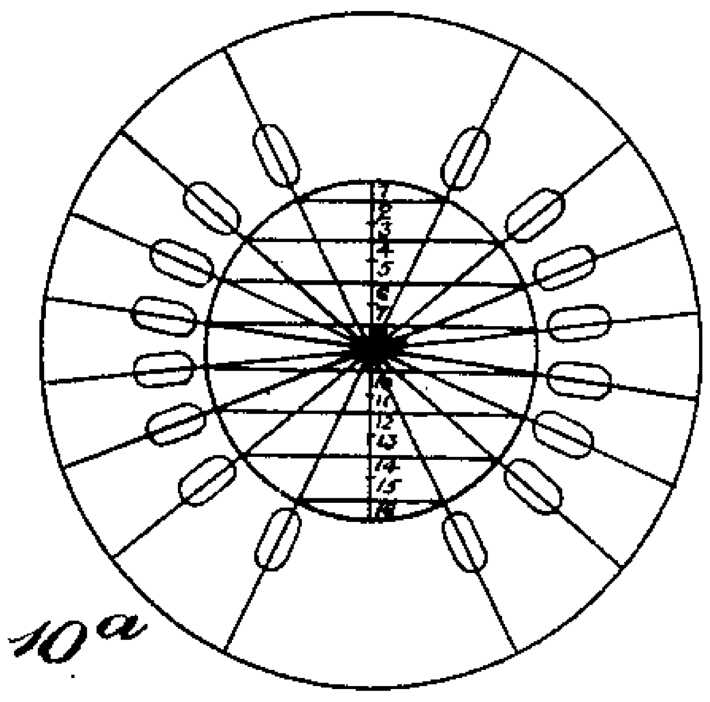
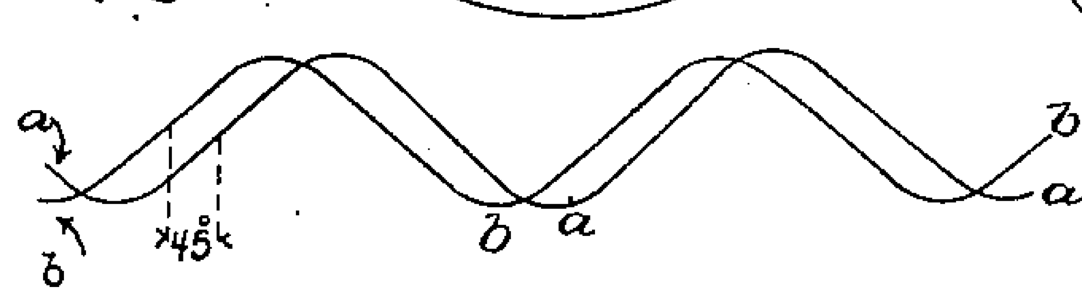


Fig. 10ª



Witnesses
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(No Model.) 2 Sheets—Sheet 2.

W. LANGDON-DAVIES.

ELECTROMAGNET HAVING ROTATING FIELDS.

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Fig. 7a.

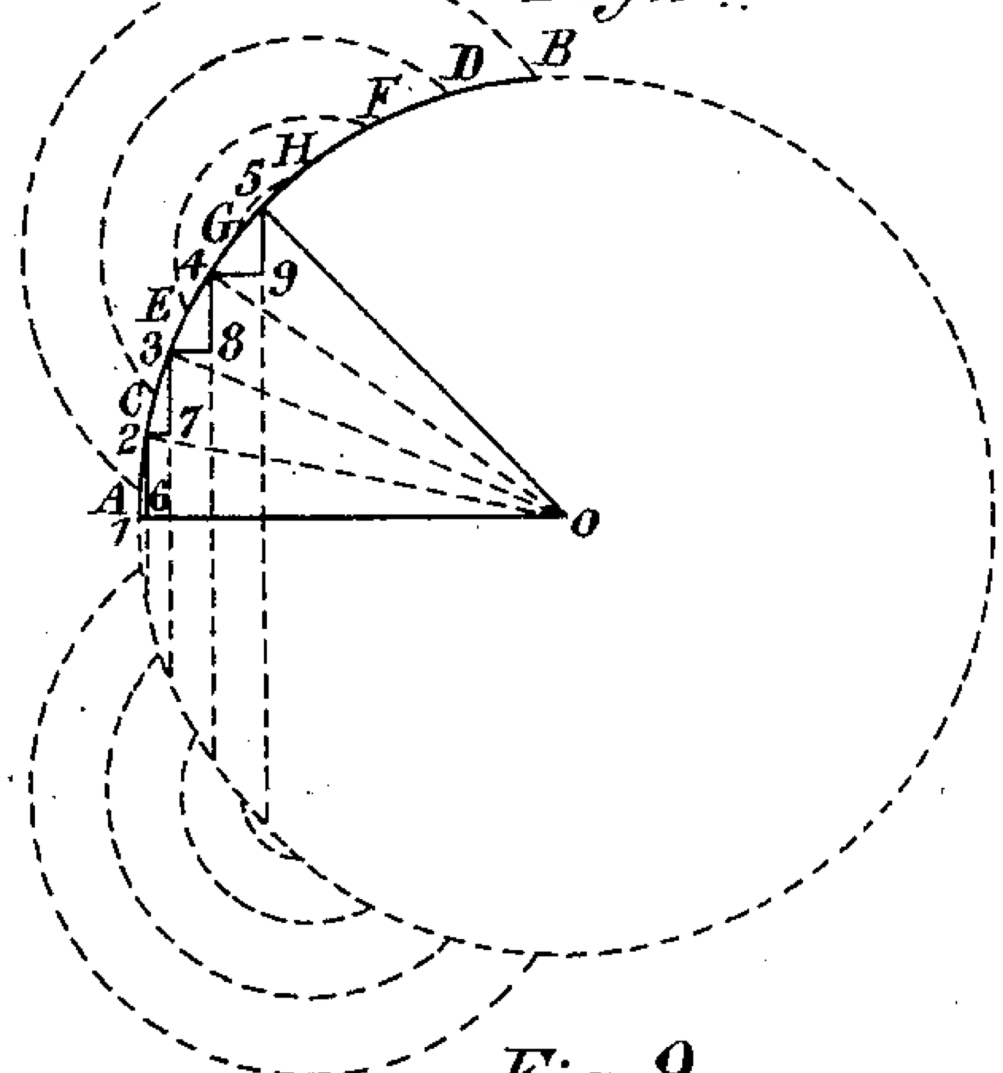


Fig. 8.

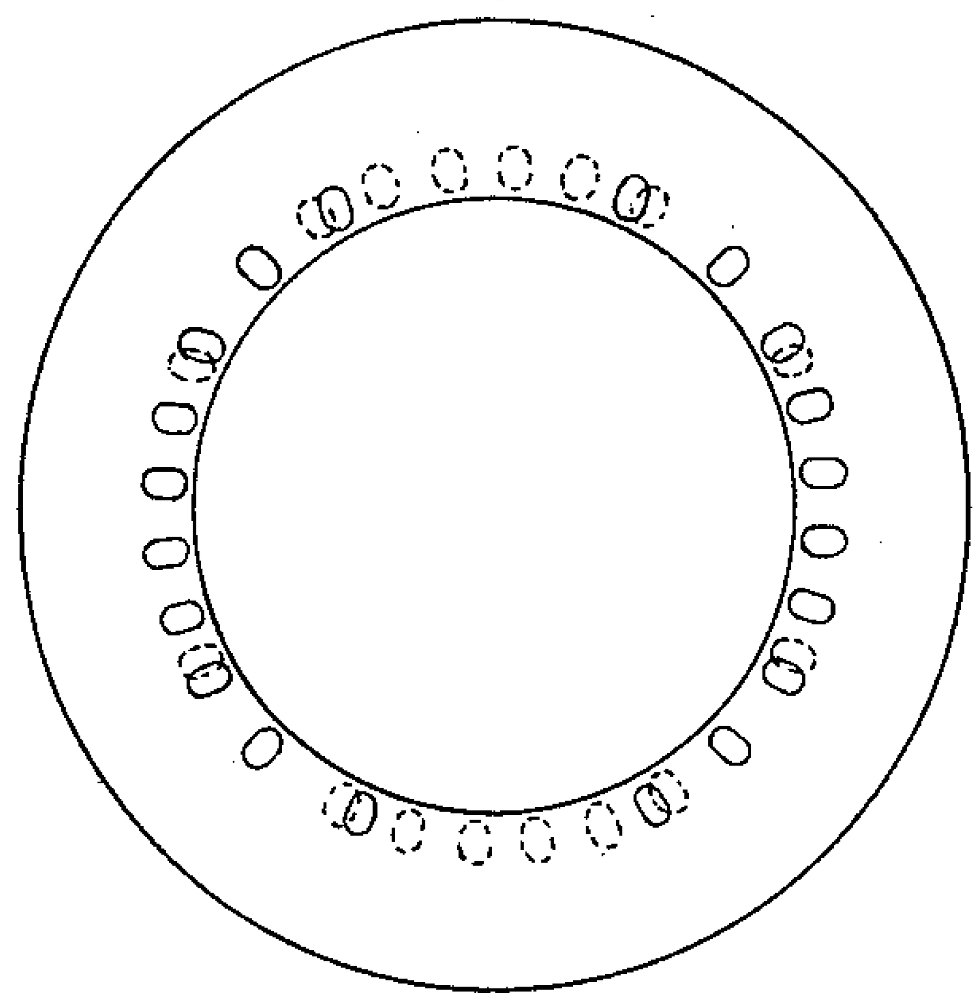


Fig. 9.

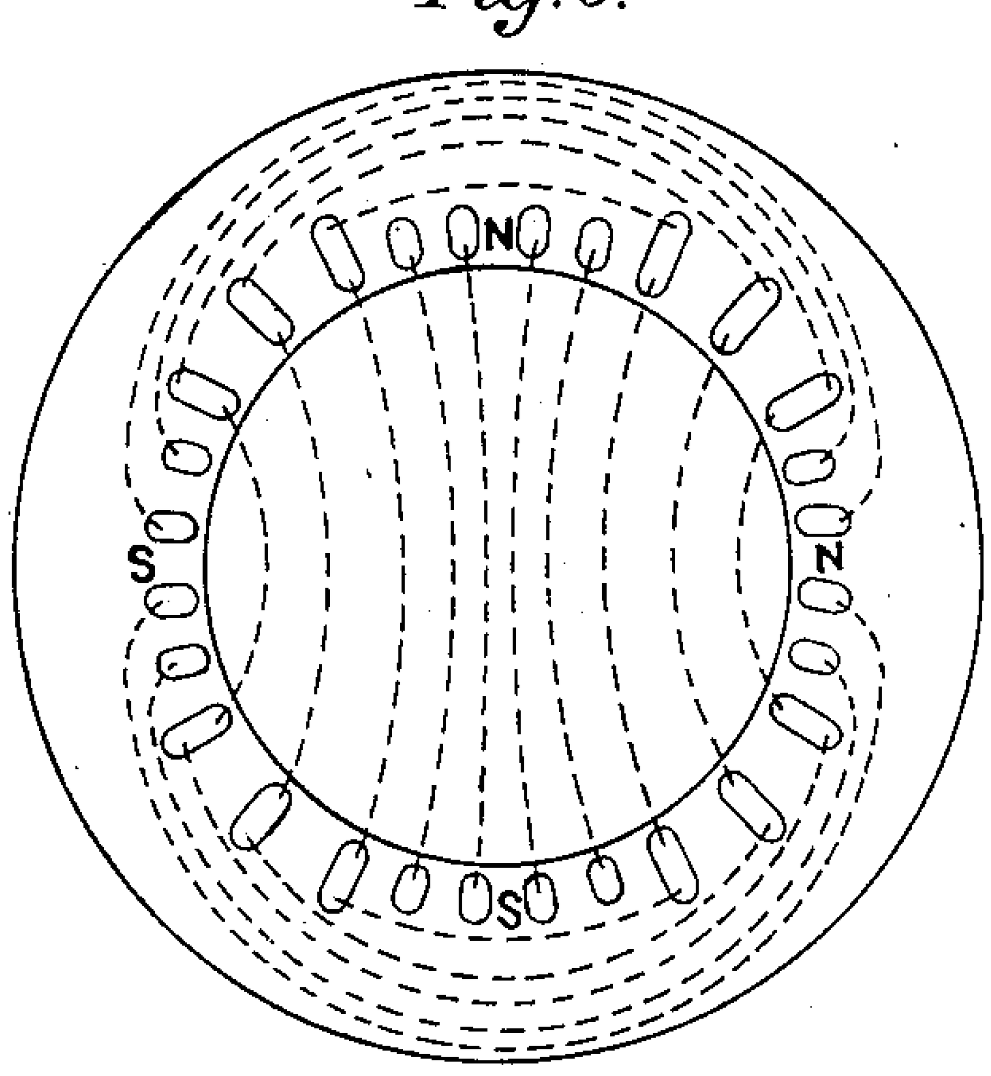


Fig. 10.

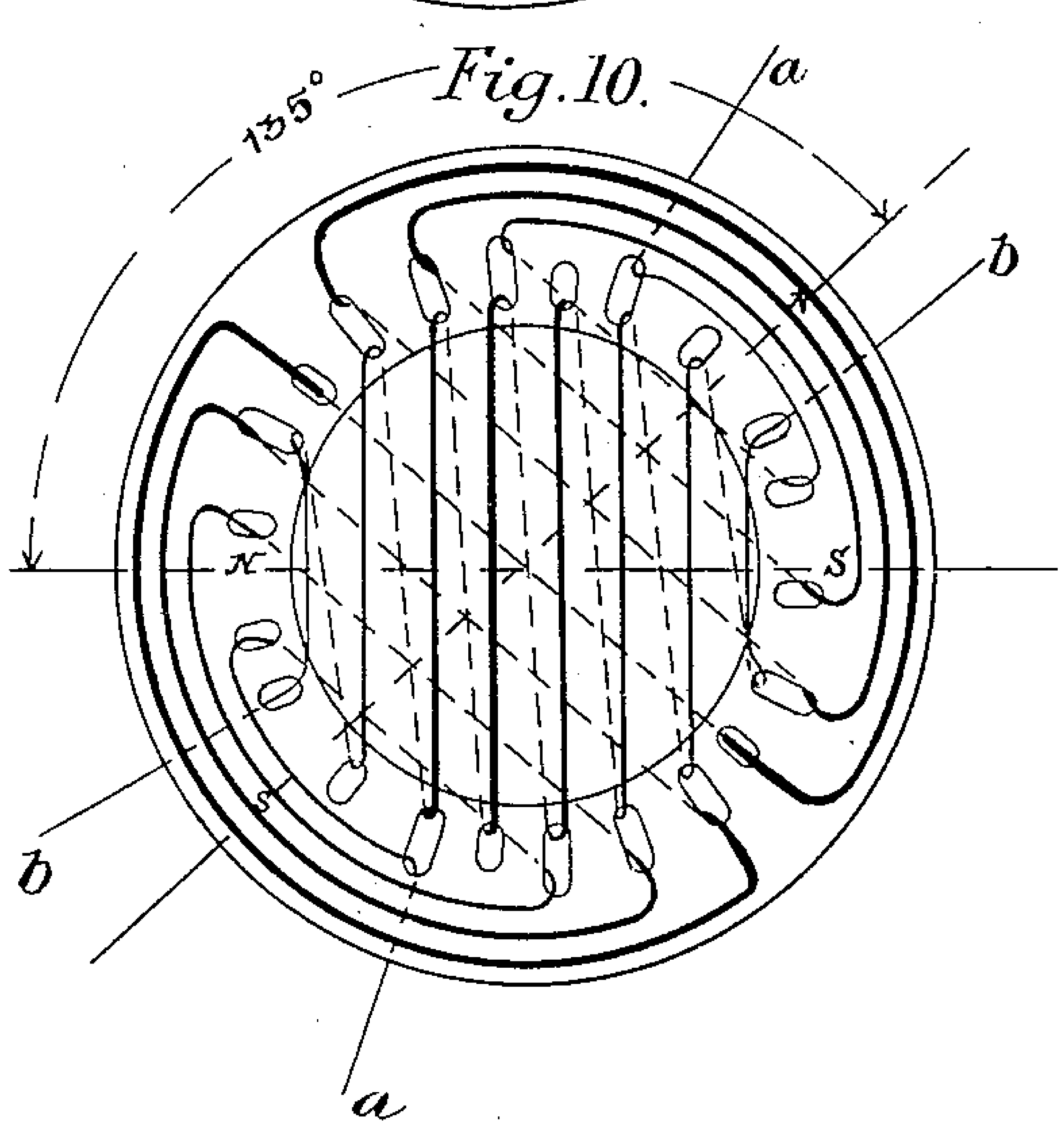


Fig. 11.

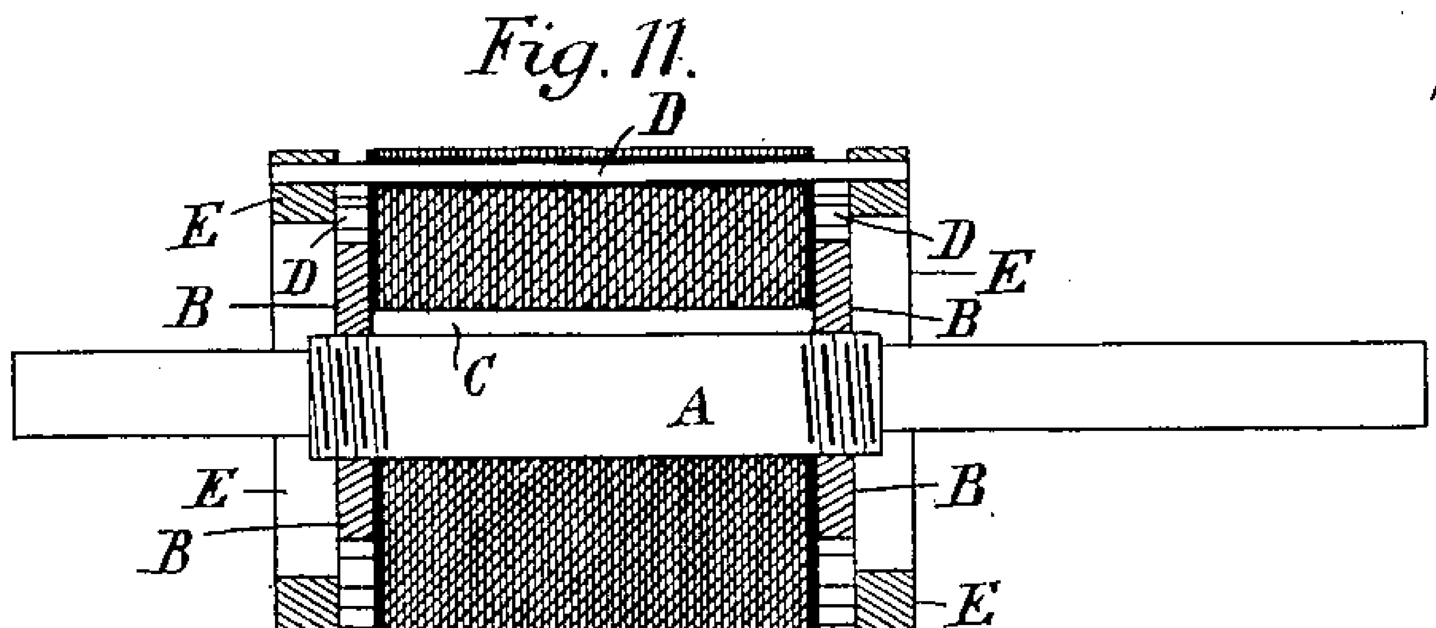


Fig. 12.

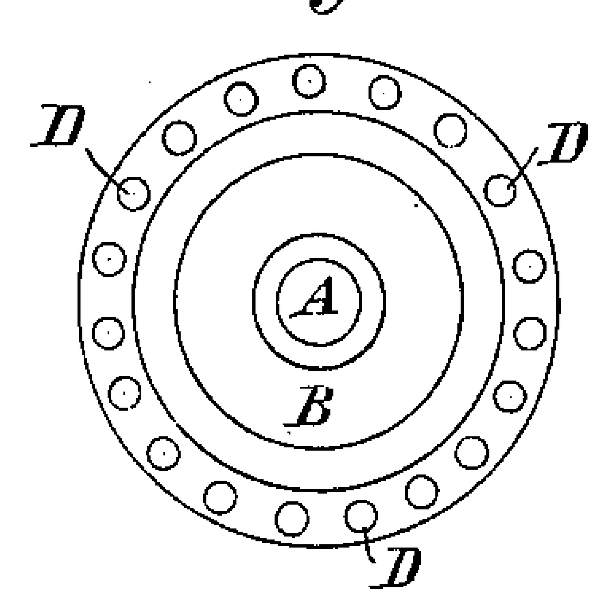
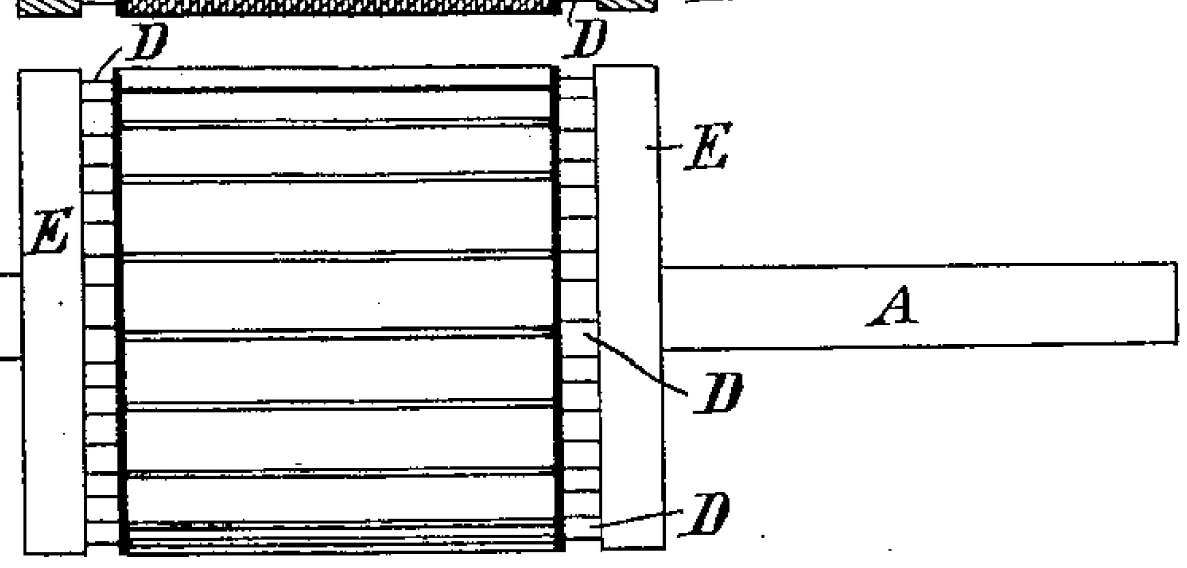


Fig. 13.



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E. A. Balloch.

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By his Attorneys
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UNITED STATES PATENT OFFICE.

WALTER LANGDON-DAVIES, OF LONDON, ENGLAND, ASSIGNOR, BY MESNE ASSIGNMENTS, TO THE DAVIES MOTOR COMPANY, LIMITED, OF SAME PLACE.

ELECTROMAGNET HAVING ROTATING FIELDS.

SPECIFICATION forming part of Letters Patent No. 604,055, dated May 17, 1898.

Application filed May 23, 1896. Serial No. 592,831. (No model.)

To all whom it may concern:

Be it known that I, WALTER LANGDON-DAVIES, a subject of the Queen of Great Britain, residing at 57 Comeragh road, West Kensington, London, in the county of Middlesex, England, have invented certain new and useful Electromagnets Having Rotating Fields, of which the following is a specification.

In my prior application, filed November 7, 1895, Serial No. 568,201, there are described means by which an alternating single-phase current may be made to produce a rotary magnetic field suitable for a self-starting alternating-current motor and suitable also for a transformer which is required to transform a single-phase current into two approximately equal currents differing from one another in phase. For these purposes, whether it be to obtain the greatest starting moment in an electromotor or the greatest efficiency in a transformer, the magnetic field should rotate as uniformly as possible and should not vary in strength. The means described in the said specification approximately satisfy these conditions, but greater uniformity may be obtained.

I have demonstrated that when two fields are used to produce the rotating field the coils should be so set that the axes of the two fields producing the resultant rotating field are inclined to each other at an angle which is the supplement of that angle by which the currents in the two coils differ in phase. Thus, supposing the phase difference of the currents in the coils to be forty-five degrees, (which is about the maximum difference of phase which is suitable and is readily obtained from one electromotive source,) the coils should be so set upon the core that the north pole of one field is one hundred and thirty-five degrees from the north pole of the other field. Thus two equal fields having simple harmonic variations which are not in phase with one another are combined to produce a rotary field of which both the strength and the velocity of rotation are constant.

The law is general that when the axes of two equal simple harmonic fields are inclined to one another at an angle which is the supplement of the phase angle between the fields they produce a uniformly-rotating resultant of constant strength.

I have also found that when the axes of any two simple harmonic fields differing in phase are inclined one to the other at an angle which is the supplement of the phase angle between the fields they will produce the closest approximation to a uniformly-rotating resultant field of constant strength. It is therefore correct to place the axes of these fields at ninety degrees when the phase difference is ninety degrees between the two fields. I have discovered, however, that when the difference is not ninety degrees the axes of the fields should be inclined to each other at an angle which is the supplement of that angle by which the magnetization of the two fields differ in phase. In general the difference of phase to be taken into consideration for the above purpose will be that which exists initially; but if it is intended that the motor shall run asynchronously, as well as to be thus set in motion, it may be found advantageous to take the difference of phase when the motor is at or about its normal work. It is also important that the magnetic flux should be as evenly distributed over the polar surfaces as possible. Now, supposing an annular field-magnet and a cylindrical rotor mounted within it, the axis of the field generated by the field-magnet through the rotor being vertical, then this field may be represented by a number of vertical lines drawn across the annular field-space, and these lines, which will decrease in length from the center line or diameter to either side, will approximately represent the reluctances of the magnetic paths across the various elements of the field. If now the same magnetomotive force be applied over the whole field by surrounding the field-space with a single coil, a stronger magnetic field will be generated through the regions of lesser reluctance, and as a result the field generated by the above-described field-magnet will be considerably denser at the two sides than in the center.

Figure 1 illustrates the usual method of applying a winding to a cylindrical field-magnet and indicates the nature of the magnetic field so obtained. Fig. 2 illustrates the usual method of applying two windings when a rotating field is required. Fig. 3 illustrates the new method of winding as applied to the production of a single alternating field. Fig. 3^a is a diagram by the aid of which the proper distribution of the winding is ascertained. Fig. 4 is a modification of Fig. 3. Fig. 5 is an explanatory diagram. Fig. 6 illustrates another modification, in which the winding is divided into equal sections and the holes to receive it are not equally spaced. Fig. 7 illustrates the winding of a four-pole field-magnet, the winding being divided into equal sections. Fig. 7^a explains the winding of a four-pole field-magnet, the holes being equally spaced. Figs. 8 and 9 illustrate the winding for a rotating field, in which the two component fields are at right angles, and the difference between the phases of the currents is also ninety degrees. Fig. 10 illustrates the winding for a rotating field where the difference between the phases of the currents is forty-five degrees. Fig. 10^a represents the currents in the two field-windings displaced forty-five degrees in phase. Figs. 11, 12, and 13 show the rotor which I employ.

Fig. 1 shows an end view of an iron cylinder such as would be used in a motor wound with a single coil to produce a field perpendicularly across the interior diameter. The conductors are wound through the holes at the sides of the cylinder, say up in a direction parallel with the axis through the hole on the left-hand side A, across the end of the cylinder in a semicircle, and down through the right-hand hole B, again in a direction parallel with the axis. Now with such a winding when the current passes polarities N and S are obtained, but the field is not at all uniformly distributed for the reason already given—namely, the different reluctances of the paths—and the field is very dense at the two sides near A and B and diminishes very considerably toward the center, as is indicated by the figure. Now it is a fact (as might, indeed, be anticipated) that a uniform rotating field cannot be obtained by superposing, as in Fig. 2, two fields, such as Fig. 1 indicates, which are not individually uniformly distributed.

Fig. 3 illustrates my method of winding, by which I obtain approximately uniform distribution in each of the individual component fields. I distribute the winding so as to compensate the different reluctances of the paths. A portion only of the winding is threaded through the holes A B, while another portion is threaded through holes C D, and, it may be, a third portion through holes E F, and a fourth portion through holes G H. Then the windings C D E F G H will successively reinforce the magnetomotive force in those sections of the field which need reinforcement in consequence of the progressive increase in the reluctance. The dotted lines indicate the directions taken by the winding wires in pass-from hole to hole.

The number of the sections into which the winding is divided may be varied. Three will be sufficient for the smallest class of two-pole motors, and four or more sections will be used in two-pole motors of larger size.

The cylinder is built up of thin disks of soft iron, having sixteen holes in each, and is adapted to receive two similar windings, one above and the other below the horizontal diameter of the cylinder as it appears in the figure, each winding being in four sections and similarly situated. These windings above and below may be regarded as parts of a single coil. It is not essential, however, that the windings should be thus arranged. There need be no winding on the lower part of the cylinder, or the lower part of the cylinder may be reserved to receive a winding for a current differing in phase to produce with the first winding a resultant field of different phase from the first, or, again, the winding on the lower half may be omitted and the upper winding may be then redisposed, as in Fig. 4, partly on the upper and partly on the lower half of the cylinder.

The rule by which I apportion the turns in the several sections for a cylinder such as Fig. 3 is the following: Draw a figure such as Fig. 3^a, in which the points A B C D E F G H on the circumference of a circle correspond to the equally-spaced holes similarly lettered in Fig. 3. Bisect the intervals between the holes in points 1, 2, 3, 4, and 5, marked on the circle. From the neutral point 1 draw a radius, and from the point 5 at the center of the polar surface draw another radius. They meet at the center 0 in a right angle. Draw a line 2 6, so that the angles at 6 are right angles. Draw right angles 6 2 7, 2 7 3, 7 3 8, 3 8 4, and 8 4 9. Then the lengths of the lines 2 6, 3 7, 4 8, and 5 9 represent and are proportional to the numbers of turns which should be wound through the holes A B, C D, E F, and G H, respectively. Thus I find, for example, that if I wind through A B nineteen turns I should wind through C D sixteen turns, through E F ten turns, and through G H five turns, these being the nearest whole numbers. I give to the winding G H the advantages of fractional parts. Similarly I calculate when the number of sections is less or greater than four.

The rule given above is readily deduced from the fact that the reluctance of two paths (represented in Fig. 5 by lines y and z) varies approximately as the sines of the angles Y and Z. I therefore apply a proportionately greater magnet-motive force about z than along y.

It will be observed that neutral intervals occur between the upper and the lower windings. It is expedient to provide in this manner for neutral areas between the polar surfaces.

When the total number of turns to be wound on is but small, sufficient accuracy cannot be obtained with equally-spaced holes. I then prefer to wind an equal number of turns in each section and to vary the distances between the holes. Such a field-magnet may be set out in the manner shown in Fig. 6. The diameter of the armature-space coinciding with the axis of the field is divided into twice as many equal parts as there are coils to be wound, (in this case sixteen.) At right angles to the axis of the field are drawn parallel lines through the points 2 4 6 8 10 12 14 16, cutting the diameter of the armature-space. Through the points where these lines cut the diameter are drawn radii, and the holes for winding are punched upon these radii. As shown, these holes are bisected by the radii. I can in a similar manner wind a cylindrical magnet-core so as to obtain four or more poles. Fig. 7 shows a cylinder prepared to receive a four-pole winding.

In the case of a four-pole magnet when the holes are equally spaced and the number of turns on the coils differ from one another, as in Fig. 3, I ascertain the proportions to be given to the several sections of the windings by drawing a diagram such as Fig. 7ᵃ. It is very similar to Fig. 3ᵃ; but now the radii 5 0 and 0 1 meet in an angle of forty-five degrees. In other respects the description of Fig. 3ᵃ applies.

I have up to this point assumed that the air-space between the polar surfaces of the magnets was free from iron. It is, however, at once obvious that the introduction of the iron rotor or armature will alter the problem only in degree and not in method of solution. The presence of the iron rotor does not alter the conditions except by lessening the total amount of the magnetic reluctance. Whether in iron or in air the longer course has the greater reluctance.

I have so far described the winding for obtaining one uniform field. To yield a rotating field, a second winding is required, separated from the first winding by an angular distance dependent on the difference of phase in the two windings, as already explained. I can apply the second winding over the first, using the same holes, or some of them, to accommodate both the windings. Thus in Fig. 8 the full lines show a cylinder set out with holes for winding, as in Fig. 6, except that in this case the windings are to be each in five sections. The dotted lines show the holes repeated at ninety degrees distance from the holes represented by the full lines. The phase difference between the currents in the coils is in this case assumed to be ninety degrees. It is obviously impracticable to punch the double set of holes as they occur in this diagram. Fig. 9 shows the arrangement of holes suitable to receive two windings, the one over the other and at right angles. The dotted lines crossing the central space represent diagrammatically one pair of windings and the dotted lines outside the central space represent the other pair of windings.

Fig. 10 shows the arrangement which is suitable for a motor in which the difference of phase in the two component fields is forty-five degrees and in which the current in the two coils is derived from the same source, the coils being adjusted to equal ampere-turns in the manner described in my before-mentioned application. The winding having terminals *a a* is placed, as shown, with its magnetic axis inclined one hundred and thirty-five degrees to the winding having the terminals *b b*. The variation in the number of turns is indicated by the varying thickness of the lines representing the windings.

Fig. 10ᵃ shows the currents in the two field-windings displaced forty-five degrees in phase. Thus the magnetic axes of the two windings are inclined to each other at an angle, (one hundred and thirty-five degrees,) the supplement of the angle (forty-five degrees) representing the difference in angles of lag of the currents in the two windings.

Figs. 11, 12, and 13 show a rotor which is suitable for use with field-magnets such as herein described. It consists of a series of iron disks threaded upon a shaft A and clamped fast between screw-nuts B. A feather C prevents the disks from turning on the shaft. A series of copper rods D are passed through the disks and at their ends are fixed into massive copper rings E. Saw-cuts are made in the edges of the disks parallel to the axis and penetrating into the holes which receive the copper rods. These slits are seen in Fig. 13. The thick black lines in Fig. 11 indicate insulating material.

Field-magnets in accordance with this invention are also applicable to transformers.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is—

1. An electromagnet energized from a single source of alternating electromotive force comprising two component fields of equal rates of alternation but with different phase angles of magnetization, having their magnetic axes inclined one to the other at an angle other than ninety degrees and equal to the supplement of that angle by which the currents in the two component windings differ in phase, thus producing a rotary field.

2. An electromagnet energized from a single source of alternating electromotive force, for an electric motor or transformer, comprising two component fields of equal strength and equal rates of alternation, but with different phase angles of magnetization, having their magnetic axes inclined one to the other at an angle other than ninety degrees and equal to the supplement of that angle by which the currents in the two component windings differ in phase, so as to produce a resulting rotary field of constant strength and of uniform rate of rotation.

3. A field-magnet for an electric motor or transformer, consisting of a substantially cylindrical magnetic core, wound with coils of wire encircling varying amounts of the cylindrical field-space, the coils being distributed upon the cylinder in due proportion to the magnetic reluctance to be overcome in the central field-space, so as to produce a field of substantially uniform density, substantially as described.

4. A field-magnet for electric motors or transformers consisting of a substantially cylindrical magnetic core, wound with two component windings, with their axes of magnetization inclined one to the other, each winding being composed of coils of wire encircling varying amounts of the cylindrical field-space, the coils being distributed upon the cylinder in due proportion to the magnetic reluctance to be overcome in the central field-space, so as to produce a resultant field of substantially uniform density, substantially as described.

5. A field-magnet for electric motors or transformers, consisting of a substantially cylindrical magnetic core, wound with two component windings, carrying currents of different phase, the magnetic axes of the two component fields being inclined one to the other, each winding being composed of coils of wire encircling varying amounts of the cylindrical field-space, the coils being distributed upon the cylinder in due proportion to the magnetic reluctance of the central field-space, so as to produce a rotary field of substantially uniform density, substantially as described.

6. A field-magnet for electric motors or transformers consisting of a substantially cylindrical magnetic core, wound with two component windings, carrying currents of equal magnetizing effects and rate of alternation but of different angles of lag, the magnetic axes of the two component fields being inclined one to the other at an angle equal to the supplement of that angle by which the currents in the component windings differ in phase, each winding being composed of coils of wire encircling varying amounts of the cylindrical field-space, the coils being distributed upon the cylinder in due proportion to the magnetic reluctance to be overcome in the central field-space, so as to produce a resultant rotary field of uniform density, constant strength, and uniform rate of rotation.

7. An electromagnet having a rotating field resulting from two windings carrying currents differing in phase asymmetrically arranged upon the core and inclined the one to the other at an oblique angle which is the supplement of the angle by which the current in the two windings differ in phase.

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