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PATENTED JULY 14, 1908.

G. S. DUNN.
DYNAMO ELECTRIC MACHINE.
APPLICATION FILED FEB. 11, 1905.

2 SHEETS—SHEET 1.

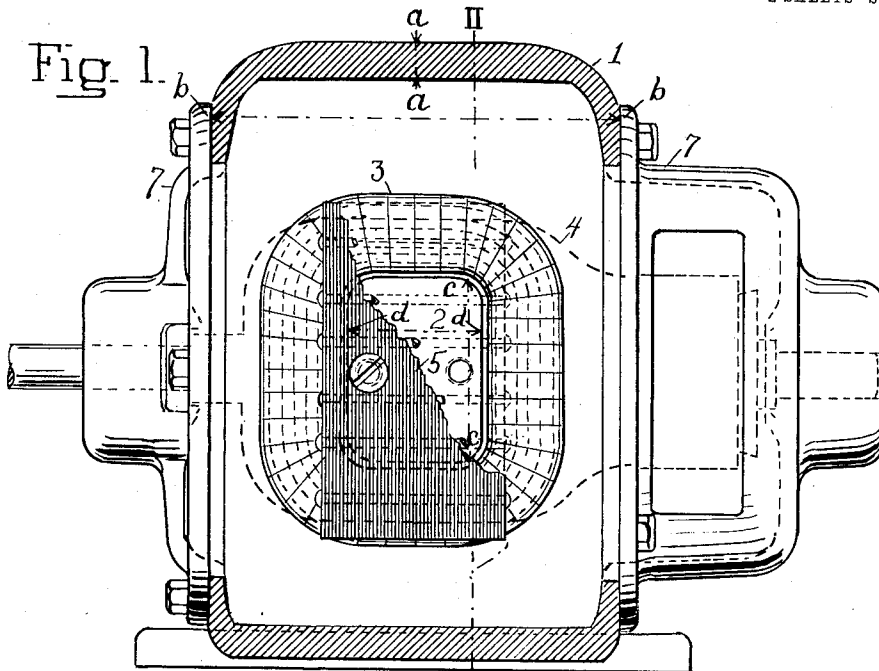
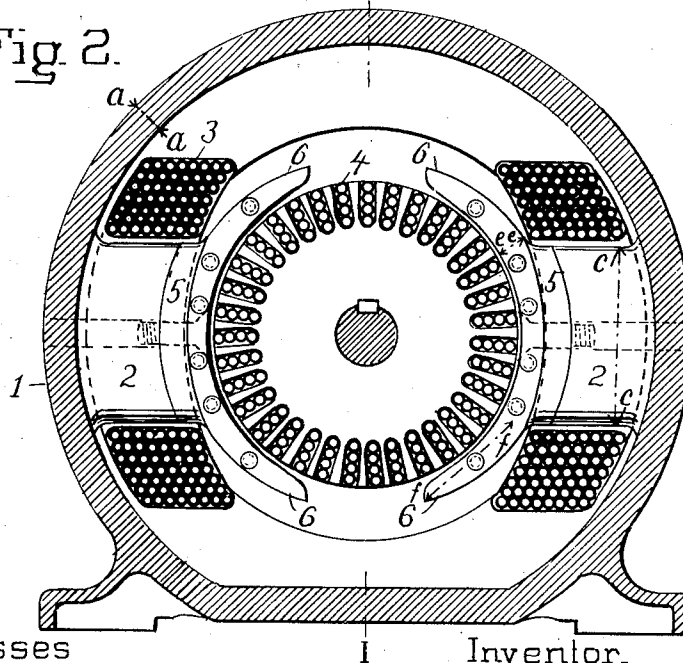


Fig. 2.



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2 SHEETS—SHEET 2.

Fig. 3.

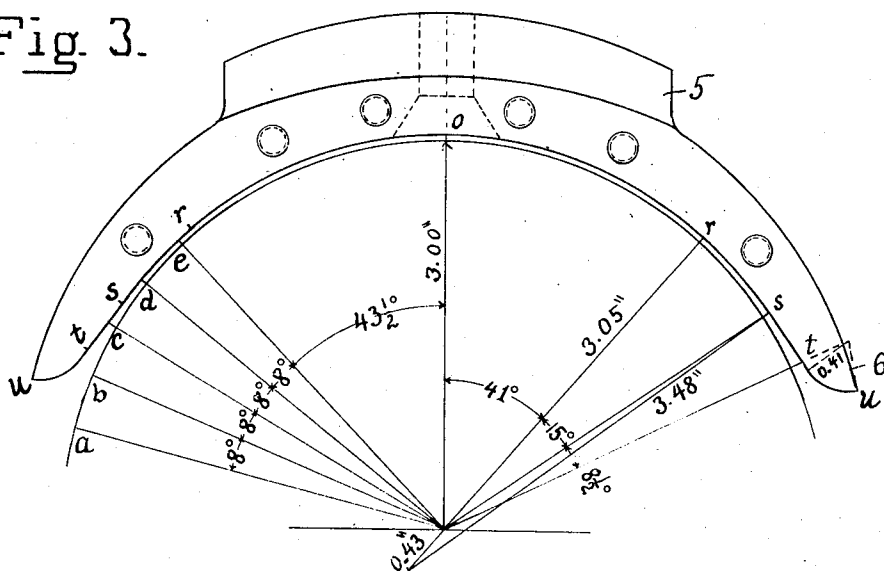
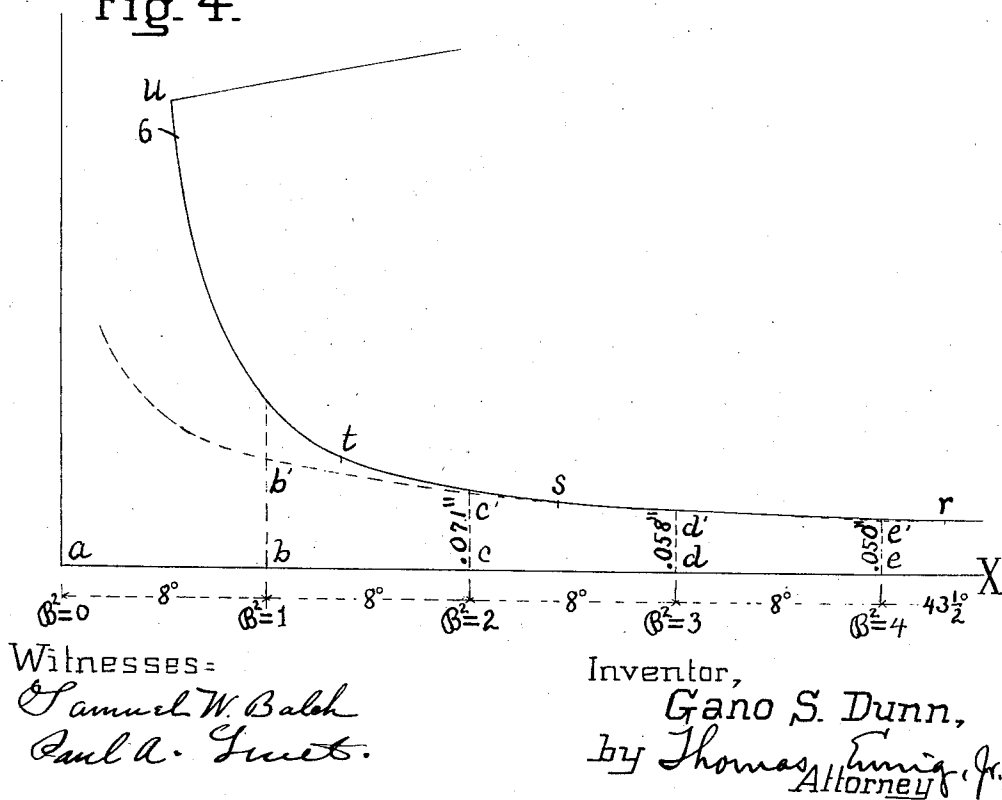


Fig. 4.



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UNITED STATES PATENT OFFICE.

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DYNAMO-ELECTRIC MACHINE.

No. 893,228.

Specification of Letters Patent.

Patented July 14, 1908.

Application filed February 11, 1905. Serial No. 245,185.

To all whom it may concern:

Be it known that I, GANO S. DUNN, a citizen of the United States of America, and a resident of East Orange, county of Essex, and State of New Jersey, have invented certain new and useful Improvements in Dynamo-Electric Machines, of which the following is a specification.

This invention relates to modifications introduced in dynamo-electric machines, and the method of introducing such modifications to reduce and prevent audible vibrations or humming, particularly in connection with those forms of machines wherein annular frames, or yokes support the cores for the field-magnets, and the yokes and pole-horns of the pole-shoes have for structural and electrical reasons been so modified that there is an increase in the tendency to vibrate audibly.

The object of this invention is to introduce such modifications in the dimensions, particularly of the cores of the field-magnets and of the air-gaps between the pole-shoes and armature, as will enable the parts to resist vibration and will reduce the cause thereof, and to avoid modifications which involve an addition to the material and weight of the machine.

In machines as usually constructed, the width of the yoke measured axially, and the thickness measured radially, are such as to give the requisite cross-section to carry the magnetic lines, and the thickness has usually approximated to that of the width, so that the yoke would possess considerable stiffness to resist vibration, or any deformation from its original circular form. I have found it desirable to depart materially from this type of machine with a thick and rigid yoke, in developing a closed or semi-closed type of machine, by extending the yoke in the direction of its axis, so that it will essentially shield the field-coils and armature, and be in this sense an inclosing yoke for the armature and fields, and the addition of end-shields of simple form will effect a complete inclosure of the electrical parts of the machine. In so doing, substantially the same cross-sectional area is preferably preserved, in order to avoid additional weight and material in the frame. This necessitates a material reduction in the thickness of the yoke, so that the yoke is, in effect, a comparatively thin annular shell or band, and it becomes

particularly thin when cast-steel is used. But, on using with and supporting from this type of yoke inwardly projecting poles with pole-shoes and pole-horns of the proportions heretofore used, the shell appears to have resonating properties, and vibrations are set up in the magnet-poles by reason of the insufficient stiffness of the yoke for the support of the cores of the magnet-poles and by the fluctuating mechanical action caused by the fluctuating magnetic flux between the armature teeth and pole-horns as the teeth approach and leave the horns. This results in a humming noise of such intensity as to render the machine commercially undesirable.

The thicknesses of the pole-horns of the pole-shoes which project over the edges of the cores have also been modified by making the pole-horns thinner, as this permits an equal reduction in the outside diameter of the machine with the consequent saving of weight and material. It is also carried to such an extent as to bring about, when the machine is running, a considerable degree of magnetic saturation which cannot be materially increased by any reactions of the armature. In this way distortion of the field under load is materially reduced, but reduction in thickness increases the susceptibility of the horns to vibration, and to vibrations at periods within the auditory range.

The objectionable audible vibrations which result from either or both of the above defined modifications, when other parts are preserved with the usual proportions, can, I find, be substantially eliminated, first, by increasing the dimensions of the cores in the circumferential direction of the machine, and, second, by so modifying the air-gaps that there will be extended arcs of approach and recession under the pole-shoes with suitably graduated increase or diminution of the magnetic flux between the pole-shoes and each armature tooth.

A machine modified as above pointed out, and embodying my invention, is illustrated in the accompanying two sheets of drawings which form a part of this application, and in which—

Figure 1 is a vertical section through the inclosing frame of a dynamo-electric machine on the line I—I of Fig. 2. Fig. 2 is a transverse section through the machine on the line II—II of Fig. 1, one of the pole-shoes and pole-horns being partly broken away.

Fig. 3 shows the outline of a pole-shoe and its relation to the armature face together with construction lines which accurately indicate its form and the theory of construction.

Fig. 4 is a curve diagram illustrating the modification in the air-gaps.

The invention herein claimed, is illustrated by drawings carefully made to scale of a direct-current machine rated at one horse power, and having an outside diameter of $12\frac{3}{4}$ inches, but machines have been developed in various sizes ranging from one-fourth to three horse power, and they are chiefly used as electric motors. A cast-steel or cast-iron annular inclosing shell or yoke 1, which also serves as a part of the magnet-frame, is of substantially cylindrical form with open ends and inwardly projecting cores 2 cast thereon. The yoke is of substantially sufficient width to cover the ends of the field-coils 3, and as illustrated is somewhat wider, with inwardly turned flanges, which to a certain extent cover the sides of the field-coils. The thickness of the yoke measured radially, as on the line $a-a$, is a comparatively small fraction of the width of the yoke measured in the direction of the axis of the machine, or on the line $b-b$. This is practicable so far as conductivity for magnetism is concerned, because the cross-section, which is requisite, is afforded by reason of the increased width. As an inclosing yoke of these proportions affords a less substantial support for the cores in a circumferential direction, which is the direction of greatest vibratory strains, I have found it necessary to materially modify the dimensions of the cores, particularly by an increase in the thickness of each measured in the direction of the circumference of the machine, as on the line $c-c$, and by having the bases of the cores cover a materially greater portion of the circumference of the yoke. The latter is thereby muffled and stiffened to such an extent as to destroy its resonance to vibrations within the auditory range. Vibrations of the cores in a plane perpendicular to the axis of the machine, which is the only plane in which the revolving armature would tend to set up such vibrations, are likewise prevented by the increase in base rigidity of the cores. With the increase of this dimension the thickness of the core in the direction of the axis of the machine as on the line $d-d$ is correspondingly reduced, so that the cross-section will not exceed what is required for magnetic conductivity for the sake of economy of material in the surrounding field-coils. This results in a core wherein the dimension in the direction of the circumference of the machine exceeds the dimension in the direction of the axis of the machine.

An armature 4, the coils of which lie between the teeth and in the slots of a lami-

nated armature-core, revolves between the pole-shoes 5 5 which are built up of sheet iron or laminated. Pole-horns 6 6 project laterally from the pole-shoes, and extend the faces of the pole-shoes and magnetic field in which the armature revolves, so that they will embrace such arcs as have been found practicable and desirable for the best results electrically, and the distance apart of the tips of the pole-horns of each pole-shoe is fixed by such considerations. The pole-horns overhang the feed-coils and whatever thickness is allotted to these pole-horns must be allowed for in the outside diameter of the machine. As this is expensive, the thickness is kept down as much as possible, for example, to the dimensions indicated by the line $e-e$. In adjusting this thickness, the magnetic conductivity is brought up to about the point of saturation to counteract the tendency to distortion of the field by armature reactions when the machine is running under load. But this weakens the pole-horns, and renders them subject to vibration. The distance apart of the tips and the thickness of the pole-horns being fixed by the electrical consideration above referred to, it follows that the length $f-f$ of each pole-horn is dependent on the width of the body portion of the field-core measured in the direction of the circumference of the machine, this being the same as the similar dimension of the core to which the pole-shoe is attached. Increase in this dimension of the core, above discussed with respect to the stiffening of the core and yoke, therefore, also results in a shortening and consequent stiffening of the pole-horns so that they will not vibrate audibly.

The field-coils are wound upon forms to the shape illustrated in Fig. 1, but the coil as originally wound is flat, each convolution being substantially in a plane for convenience in winding, as it is not practicable to give the coils the additional curvature or bowed form illustrated in Fig. 2, in the process of winding. If the field-cores had been of the usual proportions with their greatest dimensions in the direction of the axis of the machine and their dimensions in the circumferential direction of the machine kept as small as possible, the field-coils could be left straight instead of bowed, or bent but slightly. But with the dimensions of the field-cores modified as herein set forth, this additional curvature becomes necessary to save space and material at the base of the core. This curvature is given to the coils after winding by forcibly bending them to the bowed form shown in Fig. 2, before setting them in place on the cores in the machine.

In addition to the modifications above discussed in detail, the purpose of which is to overcome the tendency of the machine to respond to audible periods of vibration when

such are imposed, it is a further object of the invention to mitigate the cause of vibration so far as possible, which is due to the succession of impulses as the armature teeth come into or leave the magnetic field opposite the pole-shoes. This is accomplished by tapering the air-gaps at the pole-horns or terminal sections of the air-gaps, so that there will be extended arcs of approach and recession, particularly the latter, and, when one tooth is passing out of the field, another tooth will be entering the arc of recession and commencing to leave. Hence, two or more teeth will always lie along the path of recession at the same time, the number of teeth will not fluctuate, and it is of further importance that the rate of approach or recession as measured by the rate of change in the magnetic pull which is proportional to the square of the magnetic flux should be uniform, or that the sum of the pulls due to the magnetic flux to all of the teeth should be a constant quantity. This has been effected by suitable adjustment of the air-gap along this arc based on the principle that the magnetic pull is inversely proportional to the square of the air-gap.

In the specific example herein shown, it is intended to produce a field which embraces an arc of about 151 degrees, in which 32 degrees is an arc of approach, 87 degrees of the field is to be uniform, and about 32 degrees is an arc of recession. Three teeth always lie along the arc of approach and also along the arc of recession. In the illustrated example there are thirty-five teeth in the armature and three teeth subtend an angle of slightly less than 32 degrees, which is here assumed for convenience of subdivision and calculation. Since the grade of the tempered sections of approach and recession is slight at points immediately adjoining the uniform section, the discrepancy is negligible. The air-gap is made 0.050" over the uniform portion. The magnetic pull through the armature teeth commences or ends at the point *a*, where it is zero, and becomes uniform after passing the point *e*. If the magnetic pull at *e* be represented by 4, then the air-gap is graded to give at the equally spaced intermediate points *b c d* values in arithmetical ratio as 1 2 3. The relative air-gaps at *c d e* are respectively 0.071", 0.058", 0.050". The reciprocals of the squares of these numbers are in the proportional relations of 2 3 4. Hence the reciprocal of the square of the air-gap length bears a constant ratio to the distance along the armature periphery from the fixed point *a*.

In the curve diagram, the point *a* is placed at the origin. The axis *X* represents the surface of the armature, the curve is the developed face of that part of the pole-horn which is used as an arc of approach or recession, and the ordinates represent the air-

gap. The ordinates are drawn to an exaggerated scale to accentuate and better illustrate the peculiarities of the curve of inverse squares. The curve is represented by the equation

$$x = 0.08 \frac{1}{y^2}$$

In this equation *x* represents the angular distance from *a* in degrees, and *y* represents the theoretical air-gap in inches or decimals of an inch. This curve is represented by the line *b' c' d' e'*, and the pole-face *r s t u* conforms to this line except near the tip, where, since the lines of force are not approximately radial and do not lie along the ordinates, but scatter, an empirical modification by cutting back or turning up the nose of the tip from the curve or inverse squares is necessary in order to continue the uniform increase or diminution of magnetic pull or flux squared per degree of angle, or to so adjust the magnetic flux that the sum of the squares of the magnetic flux to all of the teeth will be a constant quantity as the armature revolves. For the convenience of the die-maker in constructing a die to cut out the blanks for the pole-shoe, this required curve has been very closely approximated by extending the circular arc *r o r* of uniform intensity which is struck from the armature center with a radius of 3.050" through 82 degrees, with tangent arcs of 3.480" radius which envelop the armature through arcs *r s* of 15 degrees each, thence continuing the surface with the tangents *s t* to the latter arcs till they meet reverse curves *t u* of 0.410" radius, the centers of which are on radial lines 8½ degrees further around the armature. This graduation of the air-gap, whereby audible vibration is overcome, is effective with machines of other types than that specifically illustrated herein, and I do not limit myself in this feature of the invention either to an inclosing yoke, or to the adaptation of the dimensions of the cores for the same purpose.

The open ends of the yoke have attached to them end-shields which complete the inclosure of the electrical parts and carry bearings for the armature-shaft and support the brushes and other parts, the details of which are fully set forth in my United States Patent No. 792,762, dated June 20, 1905. As the novel features of these parts are therein claimed, they are not herein set forth in detail.

Machines such as are herein set forth have been manufactured in large quantities and are found to be free from objectionable audible vibration.

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

1. A dynamo-electric machine having an air-gap section in which the reciprocal of the square of the air-gap length bears a constant

ratio to the distance along the armature periphery from a fixed point, substantially as described.

2. A dynamo-electric machine having an air-gap section at intermediate portions of which the reciprocal of the square of the air-gap length bears a constant ratio to the distance along the armature periphery from a fixed point, and near the wider end of which the gap is further increased to effect throughout a change in the square of the magnetic flux which bears a constant ratio to the distance along the armature periphery from said fixed point, substantially as described.

3. A dynamo-electric machine having a toothed armature and an air gap between the armature and field with graduated terminal sections wherein the reciprocal of the square of the air-gap length bears a constant ratio to the distance along the armature periphery from a fixed point, each terminal section being extended over an arc which is the same as that embracing several teeth, substantially as described.

4. A dynamo-electric machine having a toothed armature and an air gap between the armature and field with graduated terminal sections wherein the reciprocal of the square of the air-gap length bears a constant ratio to the distance along the armature periphery from a fixed point and wherein the gap is further increased near the wider ends to effect throughout each terminal section a change in the square of the magnetic flux which bears a constant ratio to the distance along the armature periphery from said fixed

point, each terminal section being extended over an arc which is the same as that embracing several teeth, substantially as described.

5. A dynamo-electric machine having an air gap with graduated terminal sections wherein the reciprocal of the square of the air-gap length bears a constant ratio to the distance along the armature periphery from a fixed point, and a pole the core of which is elongated in the direction of the circumference of the machine, substantially as described.

6. A dynamo-electric machine having an air-gap with graduated terminal sections wherein the reciprocal of the square of the air-gap length bears a constant ratio to the distance along the armature periphery from a fixed point and wherein the gap is further increased near the wider ends to effect throughout each terminal section a change in the square of the magnetic flux which bears a constant ratio to the distance along the armature periphery from said fixed point, each terminal section being extended over an arc which is the same as that embracing several teeth, and a pole the core of which is elongated in the direction of the circumference of the machine, substantially as described.

Signed by me at East Orange, New Jersey, February 10, 1905.

GANO S. DUNN.

Witnesses:

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