May 5, 1964 W. I. MACFARLANE 3,132,272

DYNAMO-ELECTRIC MACHINES

Filed Nov. 21, 1961 4 Sheets-Sheet 1

FIG. 1.

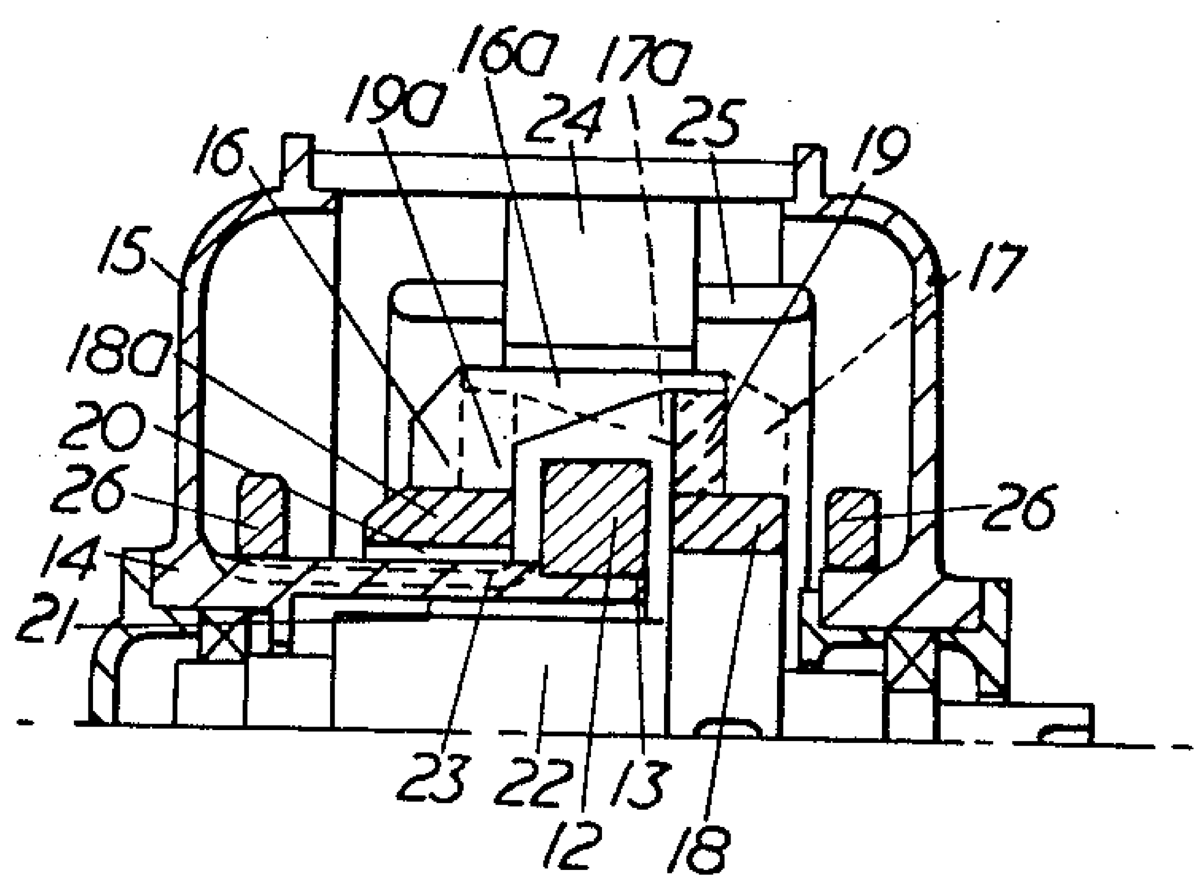


FIG. 2.

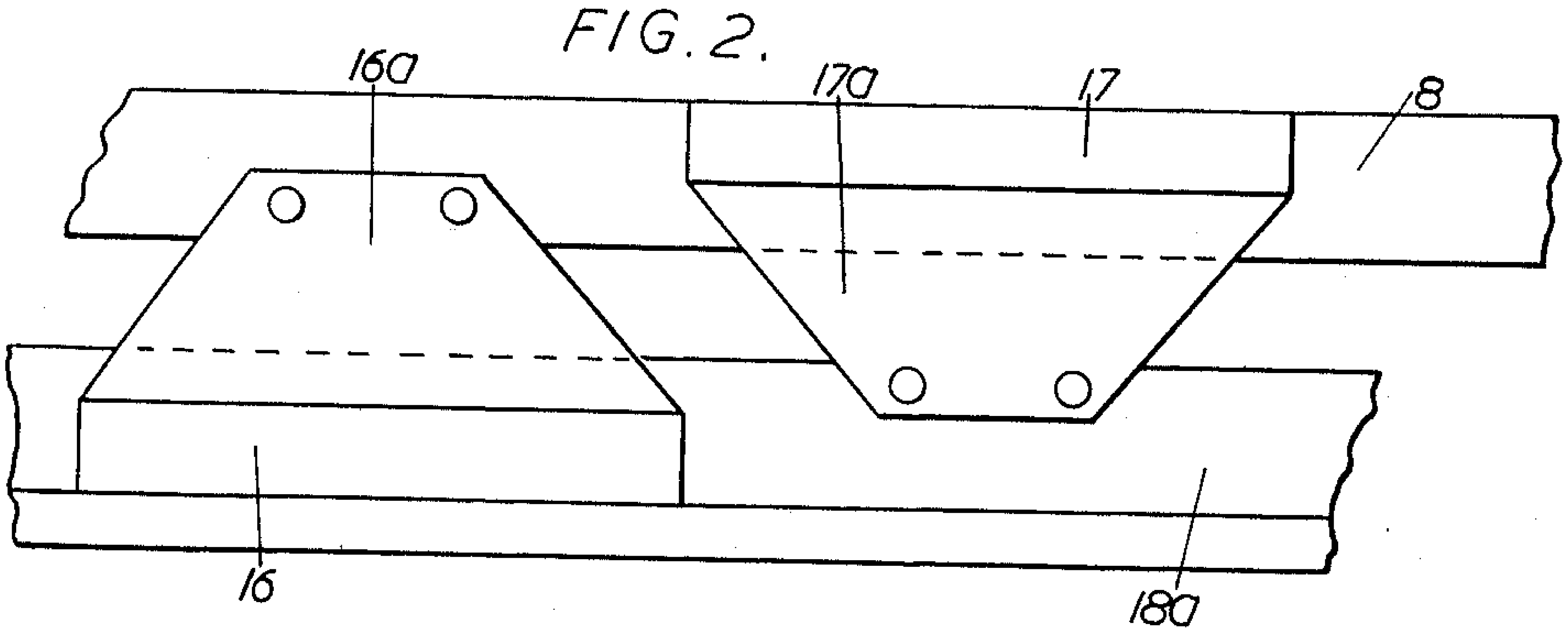
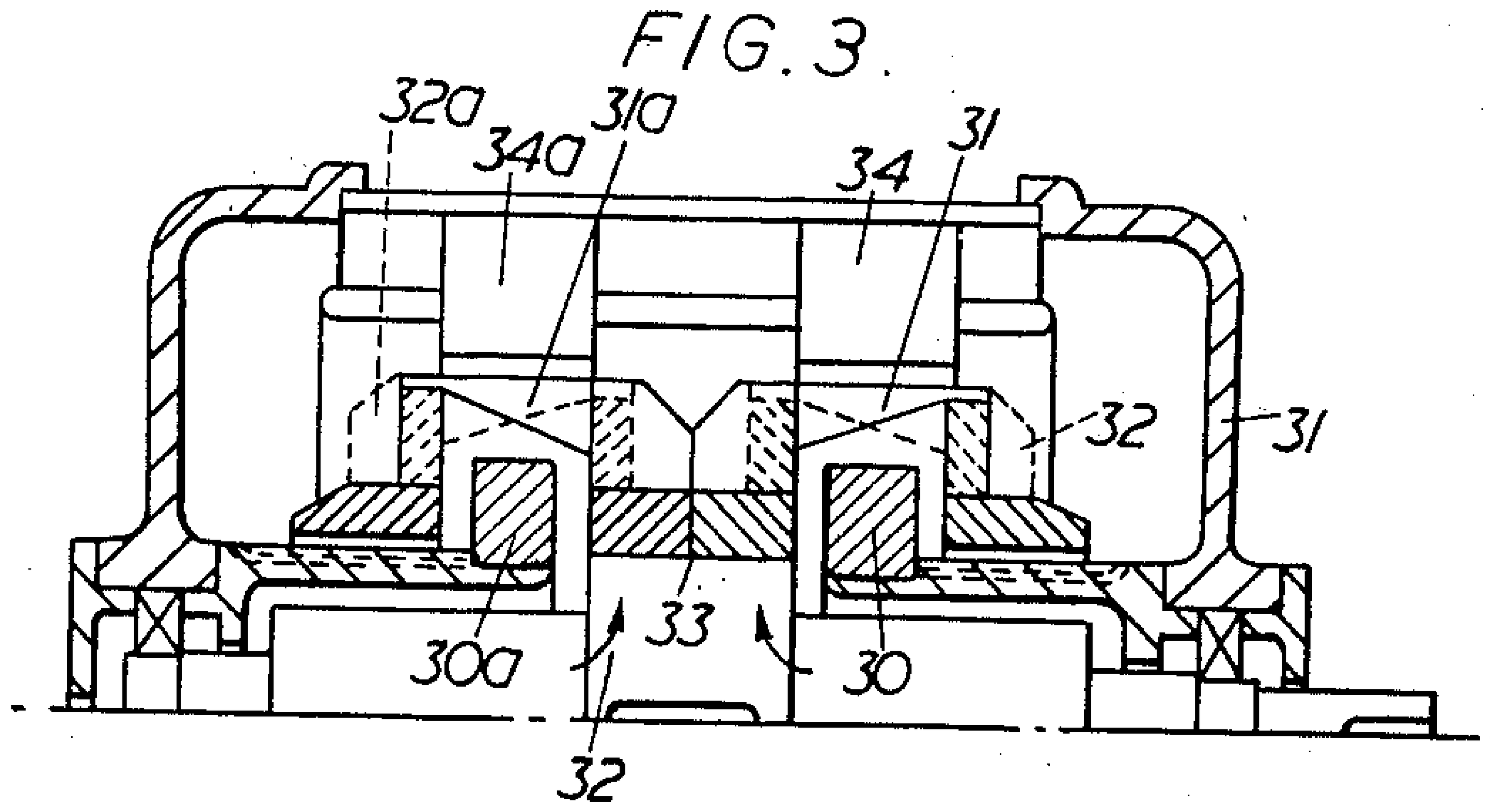


FIG. 3.



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Filed Nov. 21, 1961 4 Sheets-Sheet 2

FIG. 4.

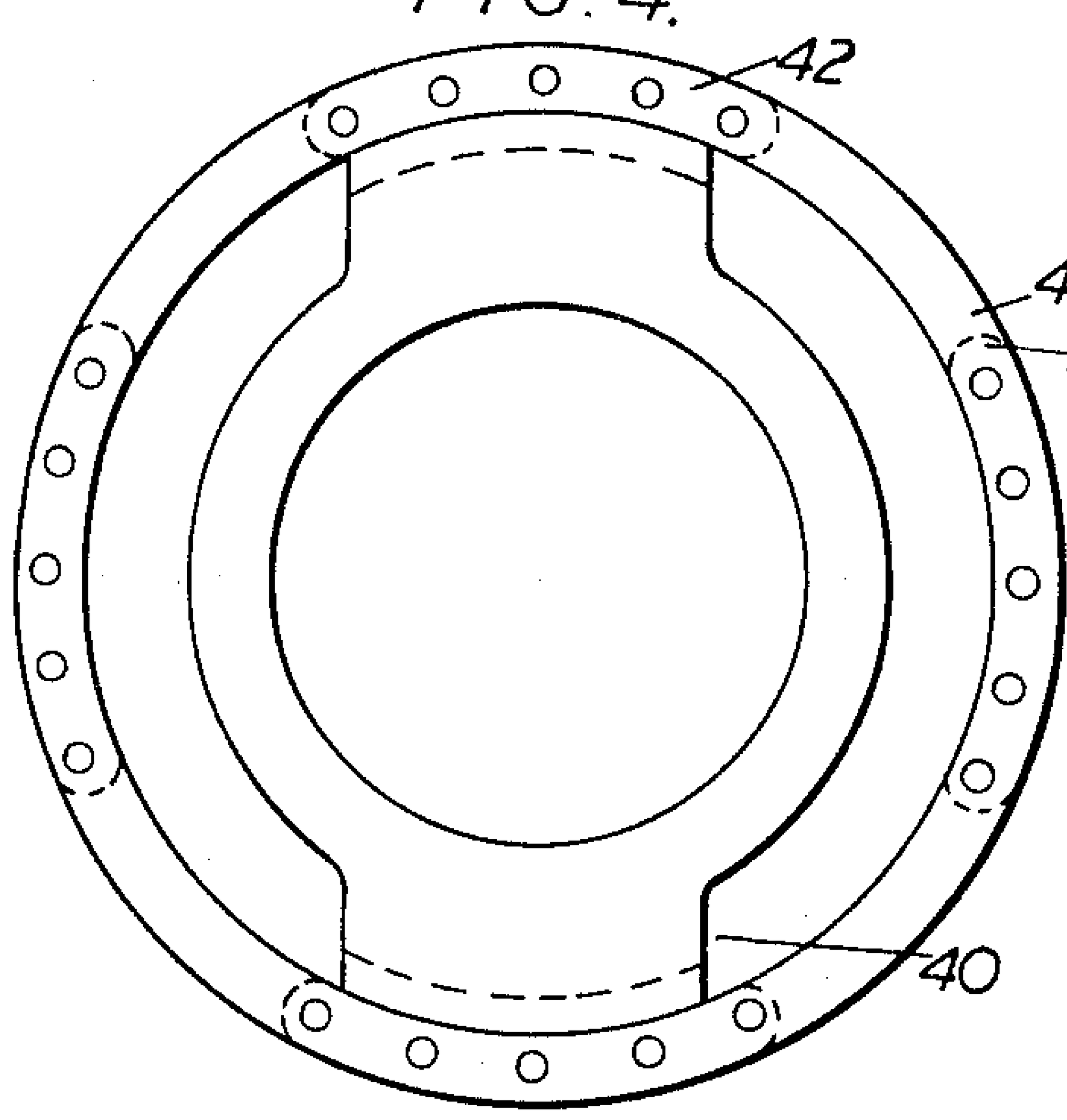

FIG. 5.

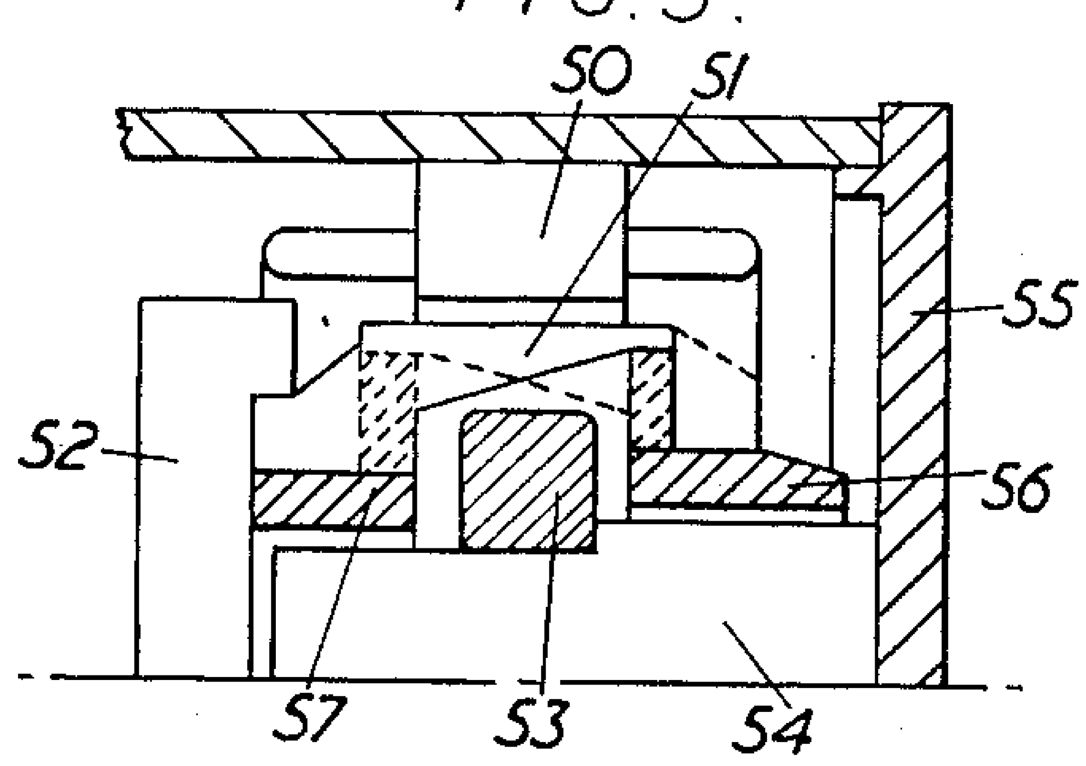

FIG. 6.

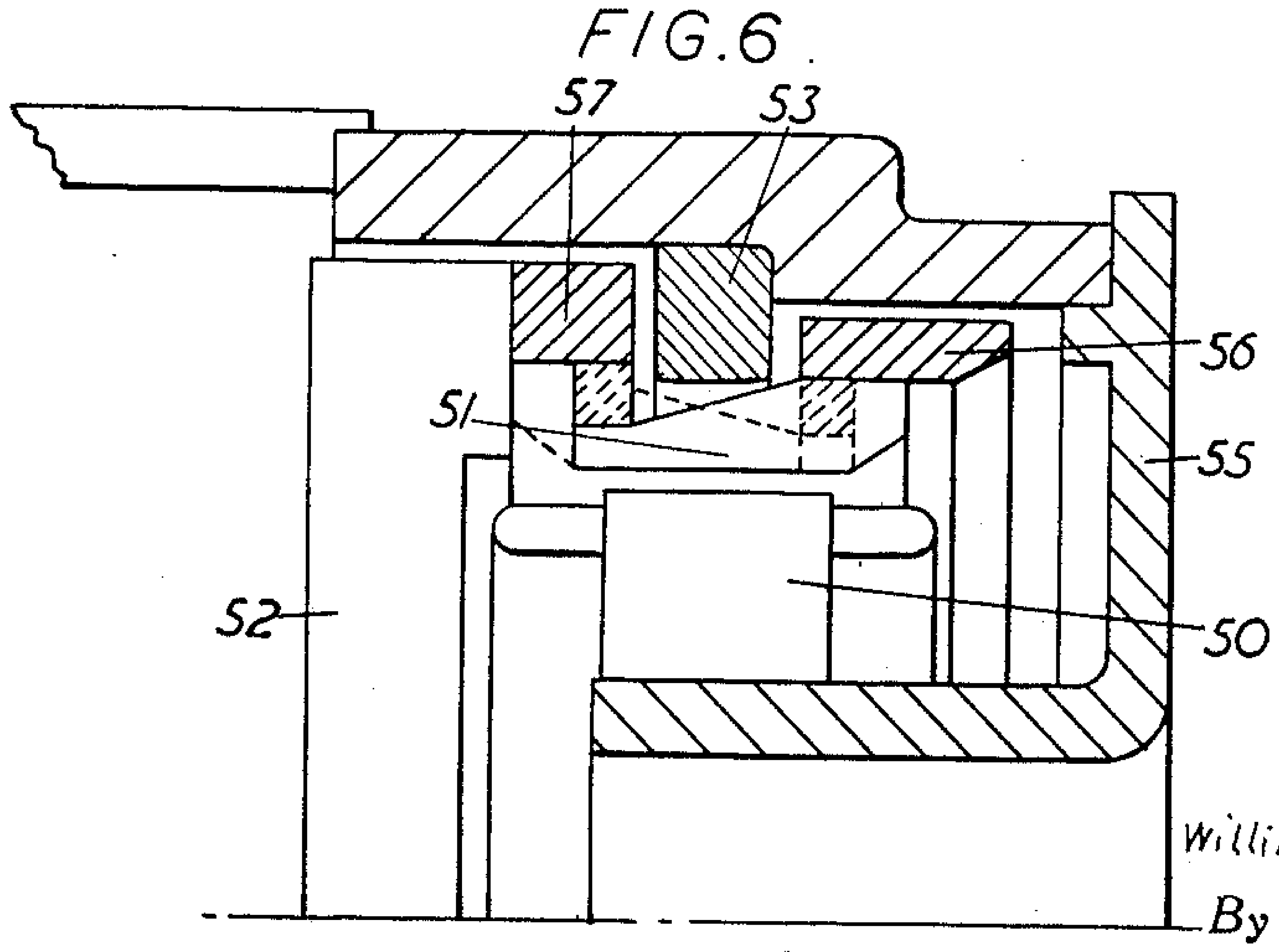

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FIG. 7.

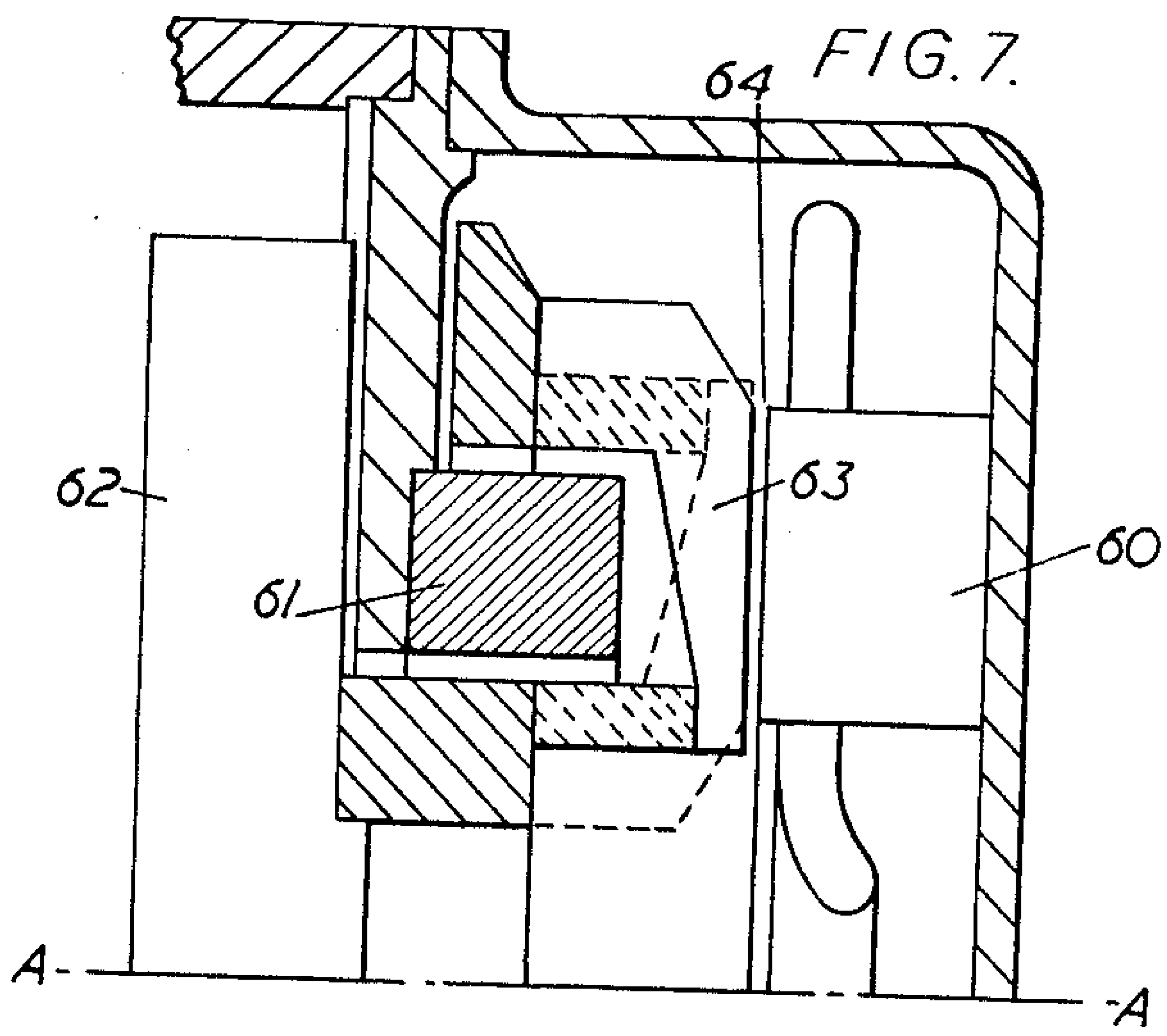


FIG. 8.

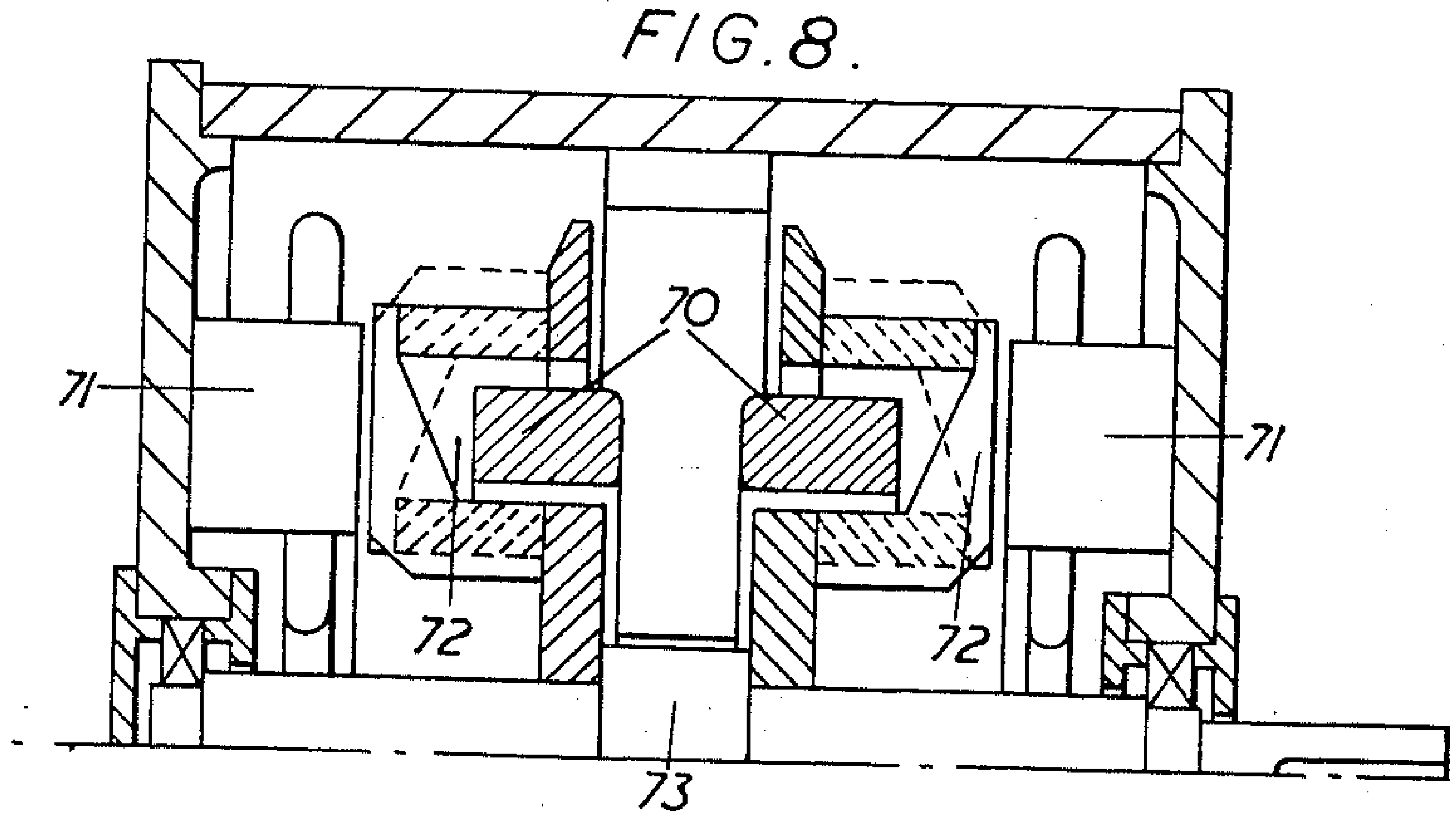
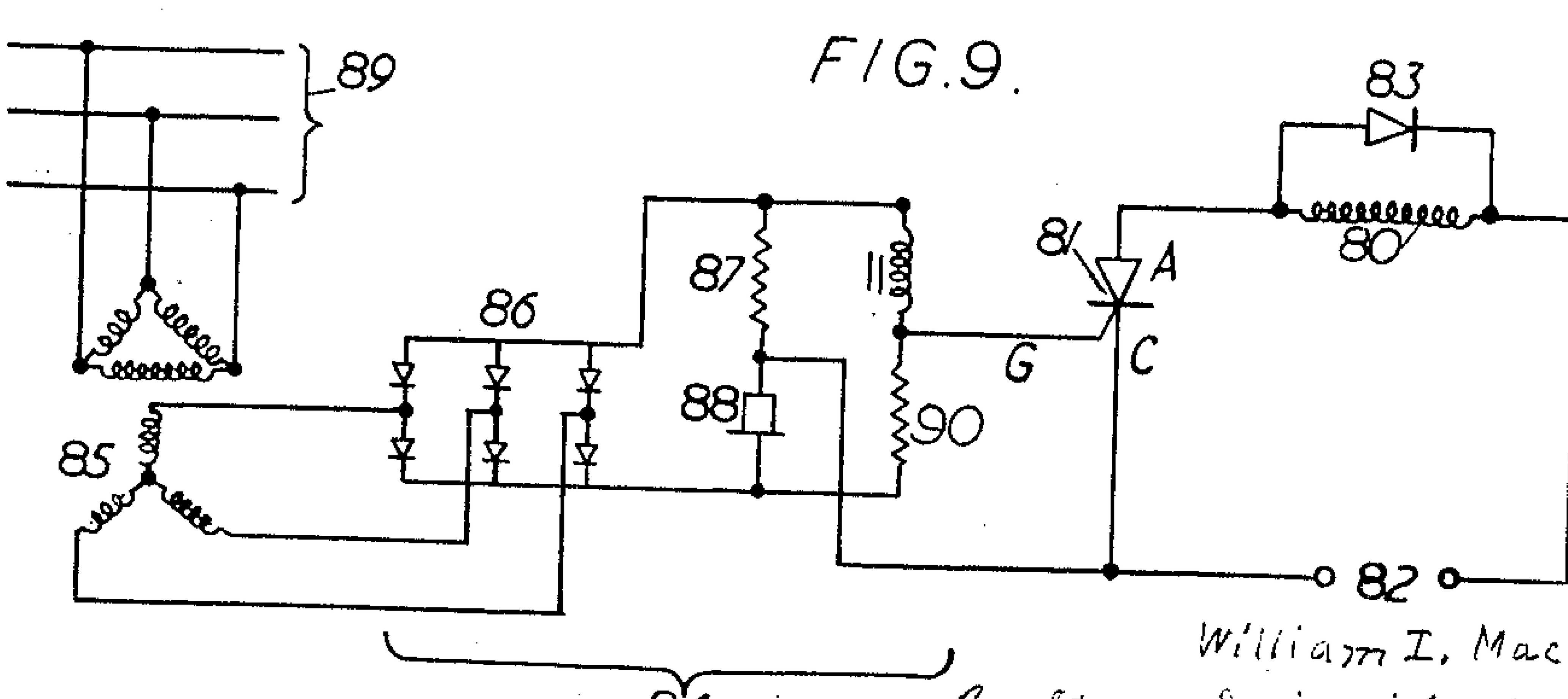


FIG. 9.



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May 5, 1964 | W. I. MACFARLANE | 3,132,272

DYNAMO-ELECTRIC MACHINES

Filed Nov. 21, 1961 | 4 Sheets-Sheet 4

FIG. 10.

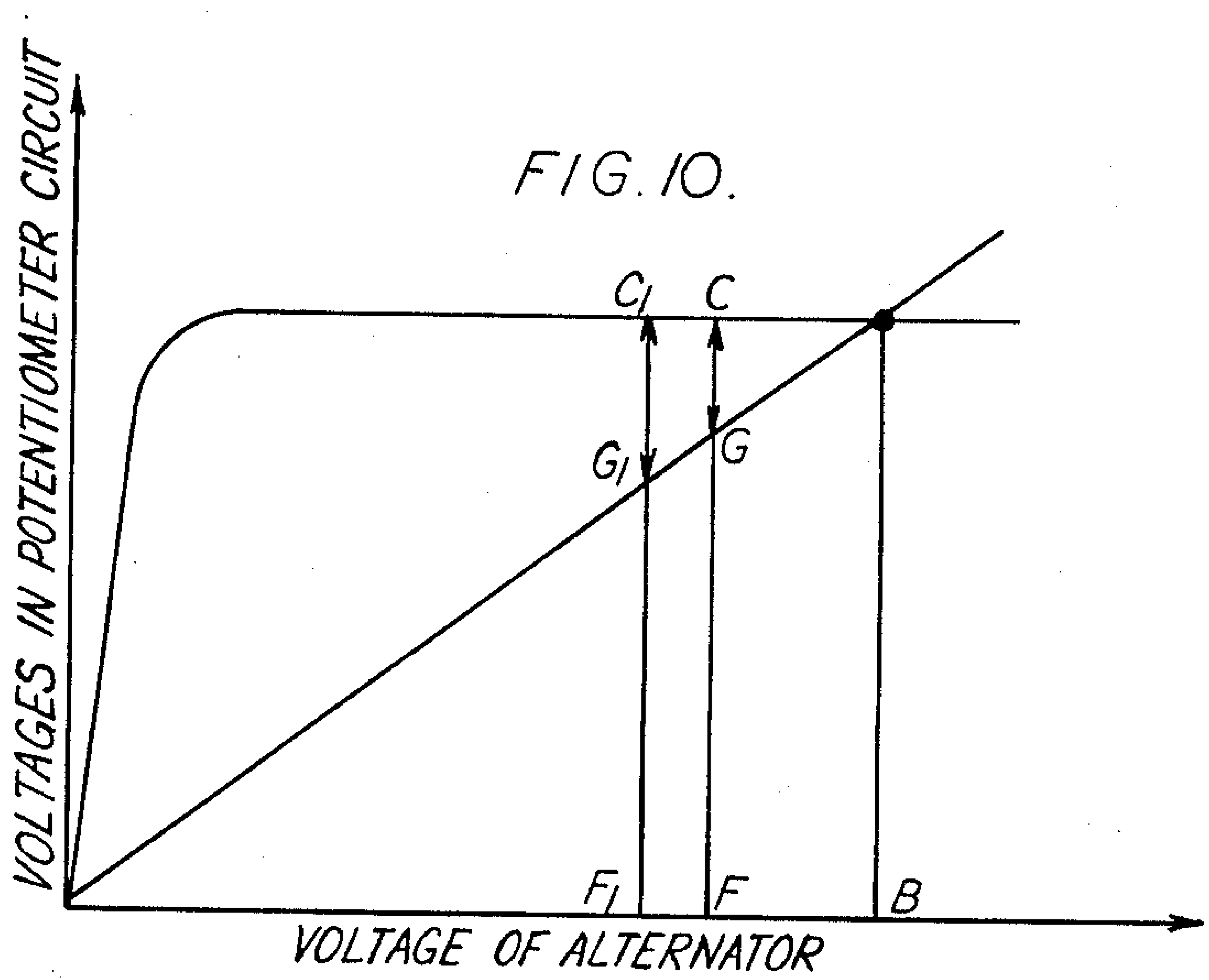
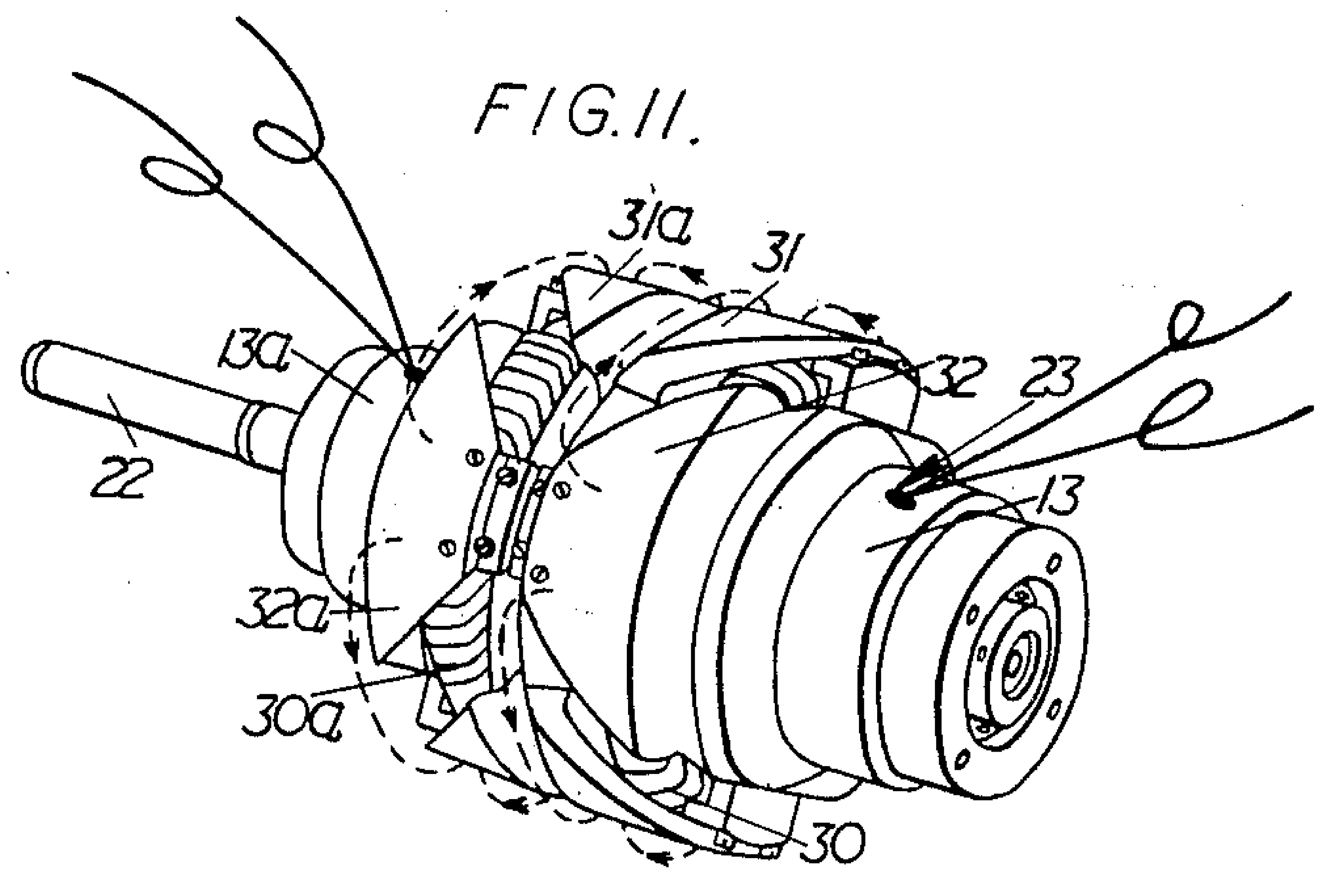


FIG. 11.



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DYNAMO-ELECTRIC MACHINES

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Claims priority, application Great Britain Dec. 1, 1959
12 Claims. (Cl. 310—168)

This invention relates to dynamo-electric machines.

In dynamo-electric machines of the polar type it is normally necessary to have sliding electrical contacts in the form of brushes and either slip rings or commutators to supply current to, or take current to, or take current from, the rotating electrical winding. It is well known that such sliding contacts can be a source of trouble in such machines due to wear, damage due to sparking for various electrical and mechanical reasons very rapid destruction of the brushes at high altitudes and in dry atmospheres, and so on.

It is an object of this invention to obviate or mitigate these disadvantages.

According to the invention we provide a dynamo-electric machine, comprising field pole shoes rotatable about the machine axis, a driving element for example a shaft or flywheel for rotating said pole shoes, a wound stator opposite said pole shoes on one side thereof and cooperating electromagnetically therewith, and stationary field coils opposite said pole pieces on the other side thereof and for exciting same, a magnetic core within said field coils, magnetic pole parts rising alternately on opposite sides of said field coils and carrying said pole shoes, alternate pole shoes extending across in opposite directions between said field coils and the stator, and non-magnetic material uniting the respective shoe tips on each side with the roots of the adjacent alternate poles, so that the whole pole assembly may be driven through one side thereof.

Advantageously said magnetic core is an axial driven shaft which rotatably mounts the pole and pole shoe assembly from one side thereof, the oher side thereof being separated from the core by an air gap, and coil mounting means are provided for mounting the field coils fixedly from the other end, the coil mounting means passing through said air gap, the field coil flux passing through said shaft and the alternate poles and pole shoes on one side to the stator and back through alternate poles on the other side.

In a modification said magnetic core is stationary and mounts the field coils from one end of the machine, and comprising a flywheel at the other end of the machine and which rotatably mounts the pole and pole shoe assembly from that side.

These arrangements may conveniently be duplicated axially.

Embodiments of the invention will now be described merely by way of example with reference to the accompanying drawings, in which:

FIGS. 1, 3, 5, 6, 7 and 8 are axial half-sections through machines in accordance with the present invention,

FIG. 2 is a diagrammatic view of a development of an outlet,

FIG. 4 is a diagrammatic view illustrating a design with laminated pole shoes and amortisseur windings,

FIG. 9 is a circuit diagram suitable for supplying the field winding of a self-regulating alternator in accordance with the invention,

FIG. 10 is a graph showing the variation of voltage across a control circuit of the alternator with variation in alternator output voltage, and

FIG. 11 is a perceptive view of the rotor system of a machine according to the invention.

In FIG. 1 we support the field coil 12 on a static tubular support tube 13 which surrounds the shaft and which projects to one end 14 and is there held by e.g. the frame 15. The polar projections 16, 17 (the latter in ghost view) are made integral at their roots with a ring 18, 18*a* so that they project first radially from the ring and then axially in opposite directions at 16*a*, 17*a* outside the coil. One pole-ring assembly 18 is firmly fixed to the shaft, and the other is driven by means of the first assembly through spacer pieces of non-ferrous metal 19, 19*a* and by non-ferrous bolts. The inner diameter of the ring of this assembly is arranged to have a small airgap 20 between it and the coil support tube, and similarly, the coil support tube is arranged to have a small airgap 21 between it and the shaft 22 which runs inside it.

The electrical connections to the coil 13 are made through wires carried in a passage 23 in the support tube which runs axially through the tube from the coil and then radially into the interior of the machine beyond the rotating assembly. The armature is at 24 and its conductors 25.

It will be evident that the polar projections which act as pole pieces or shoes are inter-digitated with each other, each alternate one rises from an opposite side and bridges across coil 12 axially between 18 and 18*a*, and the tip of each is separated from mounting ring 18, 18*a* by non-magnetic spacers 19, 19*a*. This polar assembly is rotated from one end 18 by shaft 22. The flux path is through 22, 18*a*, 16, 16*a* or 22, 18, 17, 17*a* to the armature. The return flux path in each case is via the oppositely disposed pole pieces and back to the shaft. Coil 12 is within and in line with armature 16*a*.

The effect of the two extra airgaps at the coil support tube 13 is quite small; since they are complete cylindrical surfaces the density of the flux in these gaps may be easily made very small and the gaps themselves need only be mechanical clearances. In addition, the excitation coil 12 being round has an ideal ampere turns per watt relationship. The extra gaps add only about one-fifth to the magnetising M.M.F. turns required, and with the small coil mean length (as compared to a set of coils on individual radial pole bodies) it is found that the magnetising power required for this type of design may even be less than that of a conventional machine.

The pole shoes take the form of approximate half sine waves on their radially developed faces. A suitable approximation is the trapezoidal form shown developed in FIG. 2. This gives the necessary incerasing section for flux at the root and a good wave shape.

The simple arrangement shown in FIG. 1 suffers from two disadvantages. Firstly, all the flux of the machine is required to pass along the shaft, and as the cross sectional area of this part of the path is limited this tends to increase the diameter of the machine beyond that which would be economically desirable. In the case of a machine having a great many poles, however, the normal economic design requires a very large diameter in comparison to the length of the stator core. In such a machine the simple arrangement shown in FIG. 1 can be quite satisfactory. The second disadvantage is that the coil produces an M.M.F. along the shaft which could cause the circulating currents in the bearings aforementioned. This disadvantage can be overcome either by the use of non-ferrous end shields and frames, or by the use of compensating coils is at 26 mounted on the end shields and producing an M.M.F. of equal and opposite amount to that of the field windings.

These disadvantages can be overcome by a second embodiment of our invention illustrated in FIG. 3. In this embodiment the machine is similar to that of FIG. 1, but is divided into two half machines, each of which has the form of field shown in FIG. 1. Each field system has a coil 30, 30*a* supported from the frame 31 of the machine at the end nearest to it. The two pole projection-ring assemblies 31, 31*a* at the centre of the machine are fixed rigidly to the shaft 32 and the two outer pole projection-ring assemblies 32, 32*a* are driven from the fixed assemblies at 33. The stator core of the machine is divided into armature cores 34, 34*a* each of which is centrally placed on the appropriate field arrangement with the field coil within and in line with the armature. The stator winding, however, is wound through both of these cores as in a single machine. The field coils 30, 30*a* are arranged so that M.M.F.'s are in opposition along the shaft so that there is no resultant M.M.F. to drive flux through the bearing. In addition, the flux to be carried by the shaft section is halved since it flows in two separate circuits. This enables machines of normal diameter to length relationship to be designed without limitation from the flux carrying capacity of the shaft.

When such a machine is compared with a conventional polar type alternator it is found that the field leakage is slightly worse, since the M.M.F. of the field winding acts at a rather greater distance from the main airgap than does those of the conventional machine. Consequently, the size of the magnetic core of a machine according to this invention will be slightly larger than that of a conventional machine. However, as a conventional machine requires brushgear, slip rings or commutators, which are unnecessary in our invention, overall sizes and costs will if anything tend to be favourable to our invention.

In addition, our machine will have lower leakage and more effective use of its magnetic circuits than either of the two stationary field machines mentioned above and will have the advantage over the rotating rectifier type brushless machine in that rotating rectifiers and a rotating exciter are not required.

When our machine is used as a synchronous motor rotating short circuiting devices to protect field supply rectifiers are also unnecessary. If rectifiers are used to supply the stationary field any protection apparatus will, of course, be static.

While the above construction will be suitable in most cases, it may be necessary for particular designs to have laminated pole shoes and amortisseur windings. Such cases would be special single phase alternators and high starting torque synchronous motors. A useful form of construction for this is shown in FIG. 4; here the pole projection-ring assemblies 40 are made smaller in outside diameter. Laminated pole shoes 41 of conventional types are built up complete with amortisseur bars 42 in slots through the pole shoes and amortisseur end rings 43 suitably raised to the bars; the whole assembly is then pushed over the polar projections and bolted to them. In smaller machines and machines which do not have to run at too high a speed the amortisseur winding may, in fact, be used to support the pole-ring assembly which is driven from the other member without additional supports.

It is obvious that the types of construction shown in the above examples do not exhaust the possibilities of the invention as applied to inter-digitated polar construction, modified to have a stationary coil and designed so that minimum field and armature leakage compatable with the arrangement is obtained. Further examples are shown in FIGS. 5, 6, 7 and 8 which illustrate the application of the single inter-digitated polar construction to direct engine drives where the rotating parts may be mounted directly on the flywheel of the engine and significant simplification of the overall arrangement can be obtained.

In FIG. 5 the armature 50 of the machine is made in the form of a normal stator. The polar assembly 51 similar to that of FIG. 1, is, however, driven directly from the engine flywheel 52 and the exciting coil 53 mounted on a stationary bracket 54 suspended from the end shield 55 of the machine. This shaft is continued under both rotating pole-ring assemblies 56, 57 and is separated from them by airgaps as before. The rotating polar parts will, of course, act effectively as part of a flywheel which may consequently be reduced in size.

In FIG. 6 an inverted form of the FIG. 5 arrangement is shown to illustrate another form which the invention may take, the same references indicating like parts.

In FIG. 7 an axial airgap machine is used in which the stator core 60 is made in the form of iron tape wound into a spiral core (similar to those used on transformers) about axis AA. The field coil 61 is suspended next to the flywheel 62 and the polar arrangement 63 is as before, but with the inter-digitated poles co-operating with the stator across an axial gap 64. This arrangement gives a smaller overhang for the field poles from the flywheel and a mechanically more robust unit.

Two machines of the type illustrated in FIG. 7 can be mounted back to back as shown in FIG. 8 so that the field coil M.M.F.'s oppose. Such a machine will have properties similar to that of FIG. 3.

The field coils are shown at 70 on a common support, armatures at 71, pole shoes at 72, and driving shaft at 73.

When machines of the present invention are used as alterantors, to preserve the brushes effect, the excitation will be supplied from static circuits. In the case of an unregulated alternator the alternator output may be rectified and supplied directly to the field. In the case of self-regulating alternators any suitable static circuit may be used to supply the field. For example, magnetic amplifiers may be used which are supplied by the alternator output and which are arranged to give a D.C. output to the field. Control of the magnetic amplifier may be by any of the well known voltage sensitive control circuits.

FIG. 9 illustrates a simple circuit which is well suited to supply the field of our machine when used as a self-regulating alternator. Here the alternator field 80 is fed from a rectifier 81 of the controlled silicon type which, in turn, is supplied at 82 either from a transformer across the output terminals of the alternator, or preferably, from an auxiliary winding in the face of the alternator armature slots. The alternator output is at 89. The controlled rectifier is one of the silicon type which works basically in a similar manner to that of a Thyratron or gas filled valve. It has the property of rectifying in both directions up to full breakdown voltage when operating with no control supply. When, however, a voltage is applied across the gate G and cathode C terminals of the device, and when this voltage exceeds a certain minimum value the device allows current to flow in the direction from A to C in an avalanche fashion. When the field circuit is supplied with an alternating voltage, current will continue to flow through the rectifier until the voltage or current through it falls to a low enough value at the end of the cycle to cause cut-off. It will be seen that by varying the voltage across CC relative to the cathode, that the device can be made to fire at different parts of the cycle and thereby vary the current through the alternator field. On the reversed half cycle of the wave in this simple device current is prevented from flowing from C to A by the rectifier, but may be continued in the alternator field in a discharge fashion through a freewheel rectifier 83 as shown.

The control voltage applied between G and C is obtained from a potentiometer circuit 84 which is fed from the alternator output terminals via a transformer 85 rectifier 86 combination. The potentiometer circuit consists of two limbs, one of which contains a resistor 87 and a zener diode 88, and the other a choke and resistor. The zener diode is a silicon rectifier operated in the reverse direction and has the characteristic that at a certain voltage its reversed resistance suddenly breaks down in avalanche form to a very low value. Accordingly, after the voltage reaches the firing amount, the current very rapidly increases through the zener diode for a very small increase of voltage. The diode thus makes an excellent reference device and, as the alternator voltage increases, when the voltage across the diode reaches the firing point, any further variation of the alternator voltage would make little or no difference to the voltage across the zener diode. The other limb of the potentiometer is made up of linear parameter components 89 and accordingly the voltage of the tapping point in this limb of the potentiometer rises linearly with alternator voltage. It will be obvious that when the potentiometer is properly designed the voltage applied between G and C represents the small difference of alternator voltage from a set (zener diode) value. Consequently this circuit can be arranged to vary the field of the alternator rapidly with small changes in alternator output from a set value; it acts, therefore, as a very effective voltage regulator.

This simple circuit is illustrated as typical of the types of circuit which can be used to control the alternator field in our invention. Such a circuit can be developed to work in a multi-phase manner. As aforesaid, the supply to the alternator field may be from an auxiliary winding in the face of the alternator slots; the use of such a winding is desirable since the faster response of the alternator field is obtained.

The action of the circuit of FIG. 9 will be better understood by reference to FIG. 10 which shows the variation of voltage across the diode 88 and the resistor 90 of the potentiometer control circuit when the voltage of the alternator is varied as the voltage of the alternator at 89 is raised. To start with only a very tiny current circulates in circuit 87, 88 because of the high impedance of the zener diode 88. Consequently practically all the applied voltage from residual magnetism of the alternator appears across diode 88. On the other hand since the components in the other limb of the potentiometer are linear the voltage drops across resistor 90 follows a straight line characteristic as shown on FIGURE 10. After the zener diode 88 has fired, as described above, the voltage across it remains substantially constant; therefore, as the voltage of the alternator increases a point is finally atttained where the voltage cross resistor 90 balances that across diode 88. The resultant voltage applied across points G and C of the controlled rectifier is then zero. The rectifier will not fire and no field will be produced for the alternator. In fact this condition is not attained, the voltage of the alternator rises until a point F (FIG. 10) is reached which just supplies a sufficient voltage to fire the controlled rectifier 81 and provide the necessary field. The voltage GC is of course the difference of voltages between the diode voltage 88 and the resistor voltage 90 and is shown in FIG. 10. Should the voltage of the alternator fall to F1 (FIG. 10) due to an increase of load or for any other reason the rate of firing of the rectifier will increase and a greater average field current will be applied to the alternator to restore the voltage to its original value. Similarly should the voltage of the alternator rise the controlled rectifier will cut off and the smaller rectified current will be applied to field 80, this in turn will cause a reduction of alternator voltage 89 to the controlled value.

It has been found that the performance of a dynamo-electric machine according to the invention is affected primarily by the magnetic leakages round the field coil and internal to the field itself and those created by the armature conductors in the magnetic circuit of the field. To obtain maximum output and best performance of these machines it is desirable to restrict these leakages to the smallest possible value in any given design. Since the leakage of flux takes place between the positions of the opposing M.M.F.'s of armature and field it is desirable to have these M.M.F.'s as near the main air gap as possible. It is desirable, therefore, that the field coil 12 should be mounted symmetrically with relation to the armature 24, and also that the field coil 12 should lie as near to the main air gap of the machine as is possible. Owing to the shape of the pole faces 16A, 17A and the necessity to carry flux from the pole face back to the pole bodies 16 and 17 (FIG. 1) it is not possible to have the coil 12 as close to the main air gap as would be desired but it should in fact be as close as the pole faces 16A and 17A admit.

In addition the internal leakage of the interdigitated pole arrangement is increased if the annular rings 18 and 18A which carry the poles lie close to the tips of the pole faces 16A, 17A as the M.M.F. of the field coil will drive flux across the intervening gaps. Consequently for good performance it is desirable to keep the rings 18 and 18A as far from the pole faces 16A, 17A as possible. As the pole faces are fixed in position by the internal diameter of the armature 24, for optimum design the rings 18, 18A should be as small as possible in diameter. This requirement is in opposition to the necessity to keep the inside diameter of the field coil as large as possible in order to obtain an adequate area for flux. In a modification of the invention, not illustrated, the coil support tube has two portions of different diameter, the field coil being mounted on the larger diameter portion of the coil support tube to allow flux to pass axially through this enlarged portion so as to maintain sufficient area for flux under the coil and still reduce the end leakages of the field, and the annular rings being positioned around the smaller diameter portion of the tube.

The invention is applicable to a variety of dynamo electric machines including alternators, A.C. motors, synchronous machines and D.C. machines.

I claim:

1. A dynamo-electric machine, comprising field pole shoes rotatable about the machine axis, a driving element for rotating the pole shoes, a wound stator opposite the pole pieces on one side thereof and co-operating electromagnetically therewith and stationary field coils opposite the pole pieces on the other side thereof and for exciting same, magnetic pole parts rising alternately on opposite sides of the field coils and carrying the pole shoes, alternate pole shoes extending across in opposite directions between the field coils and the stator, and non magnetic material uniting the respective shoe tips on each side with the roots of the adjacent alternate poles, so that the whole pole assembly may be driven through one side thereof.

2. A dynamo-electric machine as claimed in claim 1, in which a magnetic core is provided within the field coils.

3. A dynamo-electric machine as claimed in claim 2, in which said magnetic core is an axial driven shaft which rotatably mounts the pole assembly from one side thereof, the other side thereof being separated from the core by an air gap, and coil mounting means are provided for mounting the fields coils fixedly from the other end, the coil mounting means passing through said air gap, the field coil flux passing through said shaft and the alternate poles on one side to the stator and back through alternate poles on the other side.

4. A dynamo-electric machine as claimed in claim 3, in which the arrangement comprising the pole assembly, the field coils and the stator is duplicated axially on the driving shaft, the two pole assemblies being mounted together at their adjacent sides on the shaft.

5. A dynamo-electric machine as claimed in claim 2, in which the magnetic core is stationary and mounts the field coils from one end of the machine, and comprising a flywheel at the other end of the machine and which rotatably mounts the pole assembly from that side.

6. A dynamo-electric machine as claimed in claim 5, in which the stator winding is surrounded by the pole shoes, and the field coils in turn surround the pole shoes, an outer part of the stator replacing the magnetic core and carrying the field coils.

7. A dynamo-electric machine as claimed in claim 1, in which the stator, the rotary pole shoes, and the stationary field coils are all disposed around a machine axis which is normal to the plane of the airgap between stator and pole shoes, and comprising a rotary part of the machine rotatably mounting the pole and pole shoe assembly from the axis or inner side thereof and means for stationarily mounting the field coils from the outer part of the machine.

8. A dynamo-electric machine as claimed in claim 1, including a means for controlling the machine field comprising a control energised in accordance with variation of a characteristic of the machine being controlled and which may be electrically represented in said control circuit, means for amplifying the signal in the control circuit, and a field supply circuit including an auxiliary winding in the armature slots of the machine for energising the machine field directly, the control circuit being connected with the field supply circuit and controlling the current therein as a function of the control signal.

9. A dynamo-electric machine as claimed in claim 8, in which the machine is an alternator and the control circuit is energised by the alternator output.

10. A dynamo-electric machine as claimed in claim 1, in which the non-magnetic material is in the form of annular rings positioned to support the pole parts.

11. A dynamo-electric machine as claimed in claim 10, in which a coil support tube is provided and is mounted around a pole-rotating shaft, said supporting tube having at least two portions of different diameter, said coils being mounted on a portion of lesser diameter and said ring or rings being positioned around a portion of greater diameter, whereby flux leakage is diminished.

12. A dynamo-electric machine comprising field pole shoes rotatable about the machine axis, a driving element for rotating the pole shoes, a wound stator opposite the pole shoes on one side thereof and cooperating electromagnetically therewith and for exciting same, magnetic pole parts rising up on opposite sides of the field coils and carrying the pole shoes, alternate pole shoes being secured at their roots to a pole part and extending across in opposite directions between the field coils and the stator to terminate in a tip, and nonmagnetic material uniting the respective shoe tip on each side with a pole part at the roots of the adjacent poles, so that the whole pole assembly may be driven through one side thereof.

References Cited in the file of this patent

UNITED STATES PATENTS

588,602	Rice	Aug. 24, 1897
2,817,029	Jaeschke	Dec. 17, 1957
2,928,963	Bertsche	Mar. 15, 1960