

Oct. 4, 1955

W. KOBER

2,719,931

PERMANENT MAGNET FIELD GENERATORS

Filed March 17, 1951

4 Sheets-Sheet 1

Fig. 1.

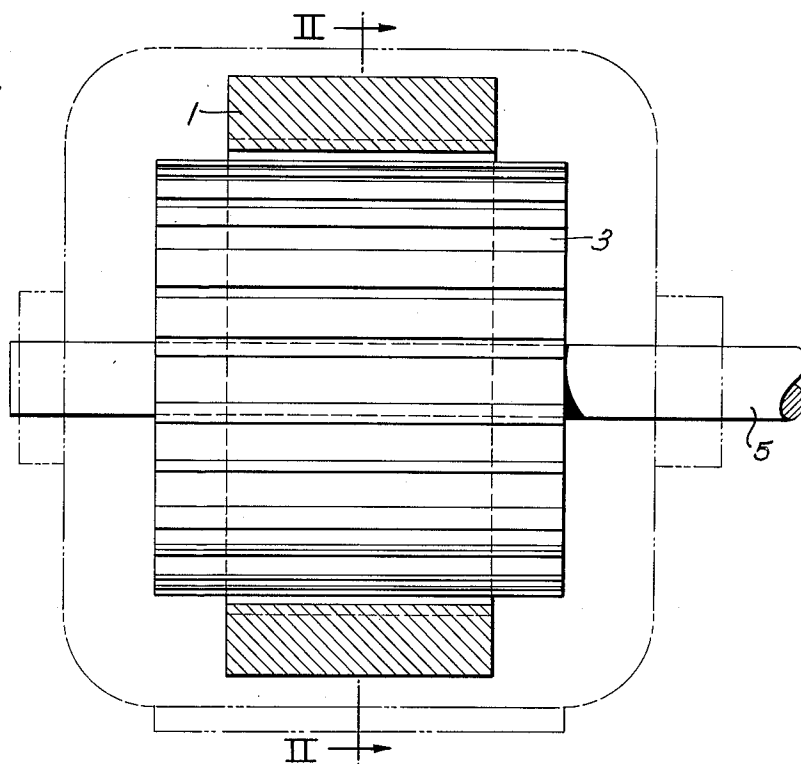
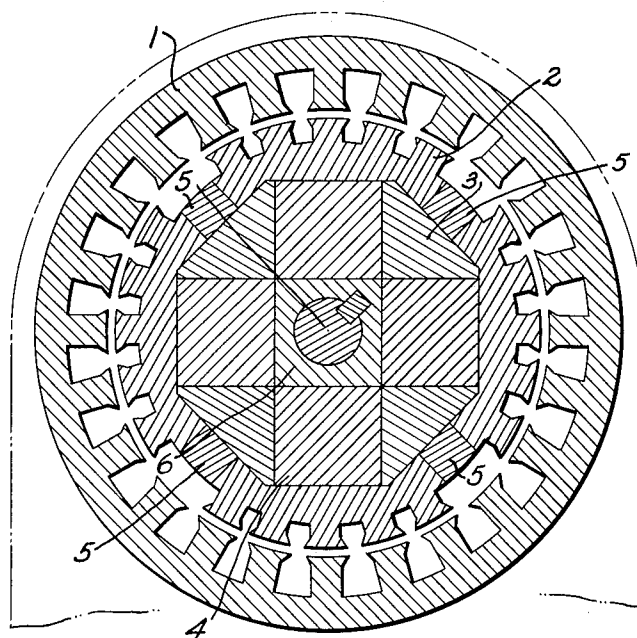


Fig. 2.



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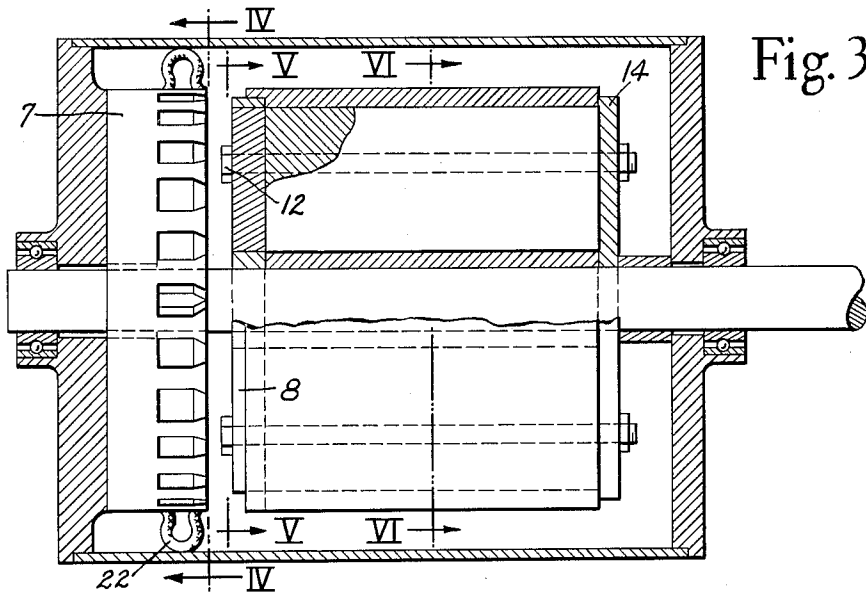


Fig. 3.

Fig. 4.

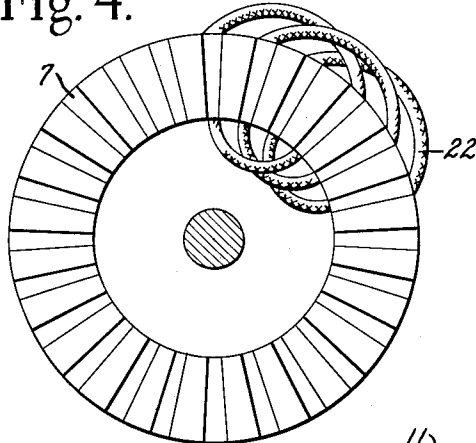


Fig. 5.

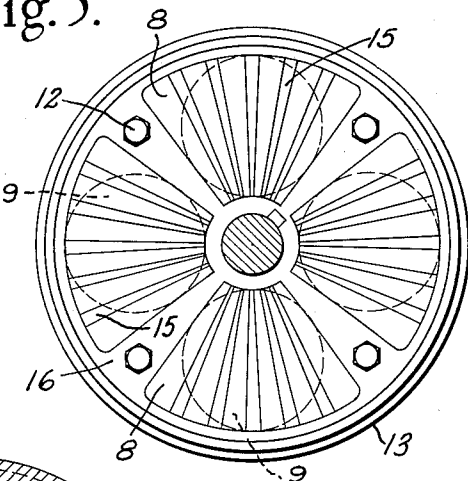
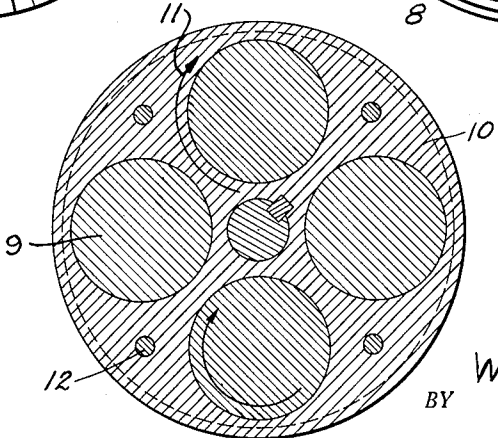


Fig. 6.



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Fig. 7.

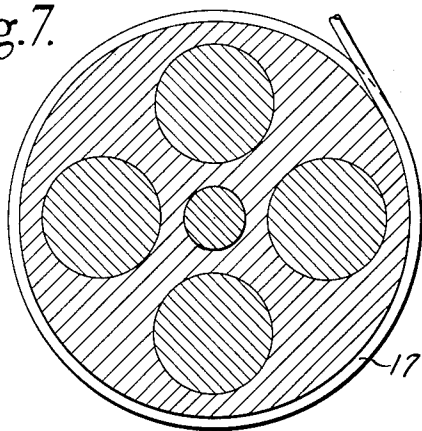


Fig. 8.

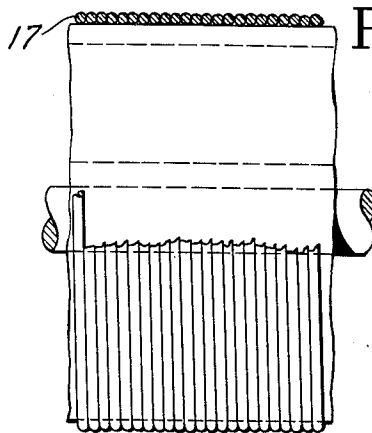


Fig. 9.

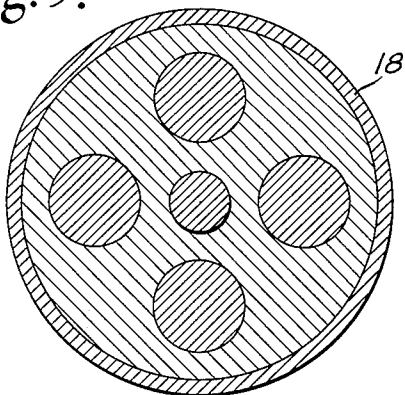


Fig. 10.

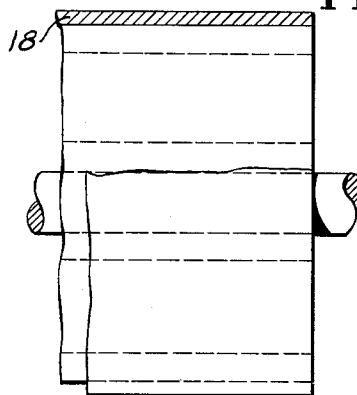
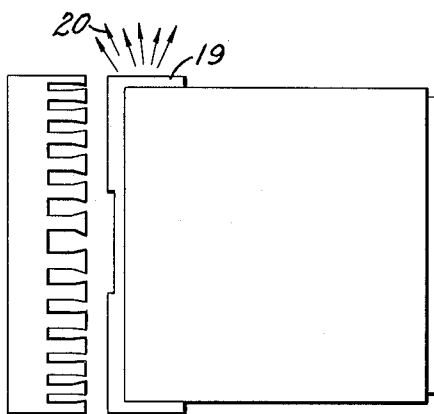


Fig. 11.



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Fig. 12.

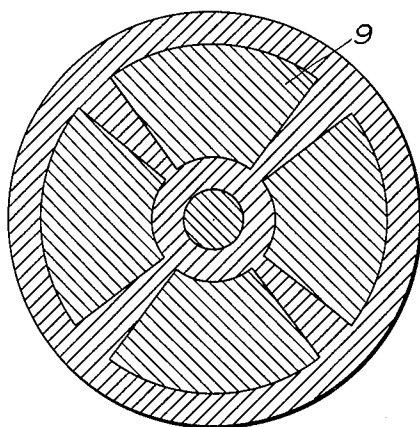


Fig. 13.

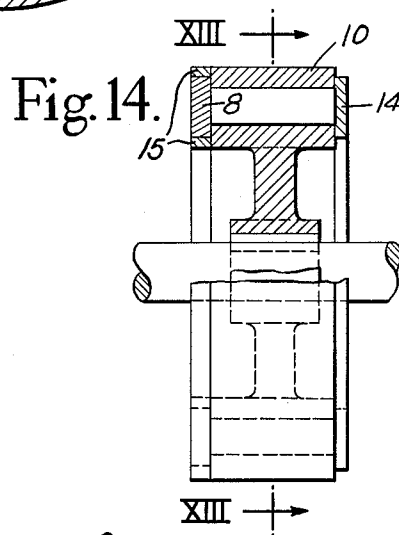
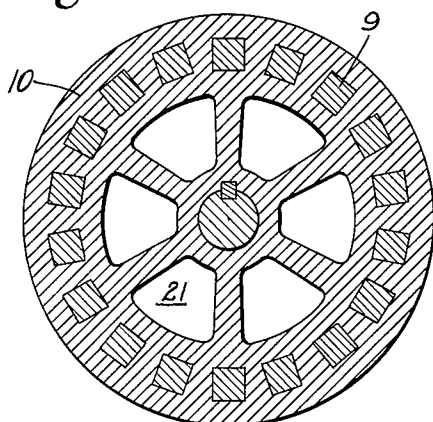
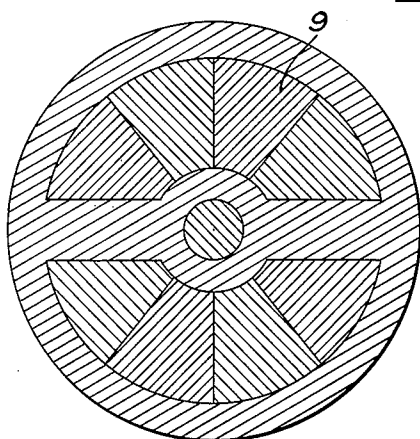


Fig. 15.



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PERMANENT MAGNET FIELD GENERATORS

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Application March 17, 1951, Serial No. 216,185

10 Claims. (Cl. 310—156)

The object of the invention is to obtain a type of rotor construction for use in rotating permanent magnet field generators having a number of special advantages.

One advantage is that a very strong structure, suitable for very high speeds of rotation is produced.

Another is that wrought, forged or other special mechanical or heat treated material may be used as the main mechanical support and also as the principal element of the conducting shield for the magnets.

Another advantage is that no casting need be made around the magnets, with possible danger of heat damage to the magnet material.

Another advantage is that very strong materials not producible by casting may be used in the mechanical structure and conducting shield.

Another advantage is that necessary by-pass magnetic circuits required for proper magnetic structure design are more readily constructed and have reduced weight.

Another advantage is that short-circuit leakage paths have a greater free space to develop, thus reducing the magnetic shock on short circuit.

Another advantage is that the magneto-motive force per pole, which depends on the length of the magnets, can be chosen for optimum value without interference with other design factors.

These and other advantages are described in the following specifications and drawings. In the drawings, Figs. 1-2 represent a conventional or "radial air gap" permanent magnet generator for purposes of comparison. Figs. 3-15, inclusive, show embodiments of the invention.

For a number of well known reasons, the usual structure of a motor or generator makes use of a rotor and stator in which the magnetic field flux flows from the cylindrical surface of the rotor to the facing cylindrical surface of the stator across a very small air gap. This construction makes it possible to build up the armature and field structures out of punched sheets, the number of sheets and the resulting thickness of the stack being at the choice of the designer to vary the capacity of the generator. This punched sheet construction is quite inexpensive. The armature and field windings are conveniently placed in slots in the stacked punchings. For an electromagnet type of generator, this construction combines the advantages of cheapness of construction and assembly, strength, and flexibility in varying capacity.

The same structure has heretofore been used with permanent magnet field generators, using a rotating field in which the flux flows across a cylindrical air gap. In such a structure, particularly when the number of poles is low, such as 2, 4 or 6, it is difficult to produce proper magnet length and protecting structures without disturbing an efficient relation between pole pitch and axial length. Since the magnets, protecting structures, and pole pieces tend to slide out of surrounding structures in an outward radial direction, it is necessary to use fastening devices of sufficient strength to hold them in place against inertial forces. Figs. 1 and 2 show a construction of this type for a 4 pole permanent magnet field generator, in which the

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housing and bearings are not shown. Here, 1 is the stator or armature (winding not shown), 2 the field pole faces, 6 is a square soft steel magnetic circuit for magnets 4, parts 5 are non-magnetic spacers between pole faces 2, and 3 is cast aluminum which fills the remaining spaces to provide a current conducting path to assist in shielding the magnets and also to help support the structure.

In the invention, a special structure adapted to a flat fact or axial air gap is used; this structure being uniquely advantageous for permanent magnet rotating field design.

In Figs. 3, 4, 6 one form of the invention is shown. In this embodiment, it will be seen that the rotor pole faces 8 lie on a flat surface, facing the flat working surface of the stator 7. The constructions available for the stator, and the winding therein, shown in the drawing at 22, will require no further explanation to those skilled in the art. This air gap plan permits a structure of the rotor now to be described which is uniquely suitable in many ways to the special needs of permanent magnet field design.

As is well known in permanent magnet generator design, the magnets 9 must be looped or encircled by a path of very high conductivity, which has a special function in protecting the magnetic state of the magnets from overload and short circuit armature reaction. In this invention, this function is efficiently served by the wrought Duralumin block 10, which has holes to receive the cylindrical magnets 9. The conducting path is indicated at 11. This structure not only supplies this essential function, but also acts as the principal mechanical structure of the rotor. The cross-section outside the magnets at one and the same time functions as a heavy-section low resistance conductor and a heavy-section high strength ring retaining the inertial load of the magnets and of its own mass. The sections directly between magnets also act as conductors and further mechanical supports. It is well known that Alnico V and other high performance magnet materials are very weak mechanically, and can carry no significant mechanical loads except in direct compression. It will be noted that in the construction of the invention the magnet is fully supported, and carries even its own weight entirely in compression. The proper support is enhanced if the magnets have their cylindrical surfaces accurately finished, and are pressed or shrunk into the holes in the main structure.

The pole piece structure may take the form shown in Fig. 5. Here, it comprises a composite disc or plate, containing pole faces 8, damper windings 15, and appropriate non-magnetic metal spacers 16, which may replace or share in the mechanical and electrical function of parts 15. The whole structure provides the action of the pole pieces in relation to the stator, and also has the important function of furnishing a flux path for the magnets when the generator is disassembled and the rotor is removed from proximity to the stator. This structure can be welded or brazed into a self-supporting mechanical whole, centered by the shaft and held in place against the magnets by assembly screws or studs 12, Fig. 3. The load on these studs is a nominal assembly force, not in any part the very great inertial forces developed at high speed. If desired, the pole face structure can alternatively be non-welded or only partially self-supporting, and be wholly or additionally supported by a flange 13 on the main aluminum structure.

To act as a return circuit at the far ends of the magnets, a soft-magnetic steel plate 14 faces against the ends of the magnets. This plate will in some designs not be flat on its outer face, or necessarily round in periphery but of suitable shape and thickness to conduct the flux with a minimum of total weight. The plate is obviously suitable to carry its own inertial load, and is held against the magnets by the assembly studs or screws 12, in a

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manner similar to the pole pieces. The studs are preferably of strong non-magnetic steel, such as 18-8 stainless or high manganese steel.

The dimensions of the air gap area per pole are determined by well known design factors. Since this shape is in no way related to the length of the magnets, it becomes independently possible to choose the magnet length for optimum design performance.

The main aluminum structure may be made up of two or more disc shaped plates, placed end to end, if the material is not available in great thicknesses, or if fabrication in such shapes is more convenient. The use of several parts does not in any way weaken the mechanical strength or reduce the conductivity in the essential circling current path.

Although wrought Duralumin has been shown for this structure, any material combining high strength and high conductivity is also suitable. This comprises other aluminum and magnesium alloys, and beryllium-copper and other copper alloys. Alternatively, a part of the strength of the main structure may lie in a wire wound binding 17 around the cylindrical surface as shown in Figs. 7, 8 or in an outer tube or shell 18, Figs. 9, 10, preferably of non-magnetic high strength steel. In this case, the inner material can be made smaller in section, or alternatively chosen of high conductivity material of low weight and only moderate strength, such as pure aluminum, high aluminum content alloys, magnesium alloys, etc.

The adaptability of the pole piece structure to form a proper by-pass path for flux when the rotor is removed from the assembly is obvious from the fact that the available radial depth is much greater than the thickness of the magnet, that the axial length of the magnet and hence its M. M. F. is at the choice of the designer without interfering with other design factors, and that projection of the pole piece along the cylindrical surface of the main structure is also possible, as shown in Fig. 11. Such by-pass paths have another vital function. As is well known, when the generator is running and a short circuit takes place, it is necessary for an amount of flux that usually exceeds the normal working flux to escape from the pole pieces. Some of this flux originates in the stator and is forced into the pole pieces across the air gap, and in general the stator is not under these conditions any path for the field flux. Also, the magnet structure must be affected as little as possible, and hence should continue its normal flux output. Thus, the pole pieces must serve as an escape path for large amounts of flux without entry into the stator or magnets. To do this, very great magneto forces are called into play, since the available path is always limited.

It is the main function of the electrical conductivity built into paths 11, Fig. 6 of the main structure to supply this very great magneto-motive force. Obviously, this force is reduced when the escape path is more permeable, and this permits a reduction in conducting section, with resulting saving in size and weight, or alternatively, a higher state of magnetization of the magnet.

A study of Fig. 11 will reveal that 180 degrees in the plane of the paper and the full cylindrical surface outside the pole pieces is available space for permitting this flux 20 to go into the air. Also available are the by-pass paths across the non-magnetic inserts between adjacent pole pieces, and flux inward in the shaft section. The previously mentioned extension 19 of the pole piece back over the cylindrical surface of the main structure as shown in Fig. 11 serves further to increase the surface and space available to dissipate this flux. It will be appreciated that the essential geometry of the structure of the invention supplies a roomier and hence more permeable path than that available in the old cylindrical air gap design. The importance of this escape path cannot be exaggerated in the theory of protection

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of the magnets on which modern permanent magnet built generators operate.

The magnet cross-section shown in previous embodiments is round. This is convenient in permitting drilling of the main structure, and easy grinding of the magnets. However, when maximum magnet section with minimum diameter is desired, a shape making better use of the space available, such as the sector shown in Fig. 12 is obviously advantageous. Each magnet 9 can be built up of triangular, square, or other compactly fitted rods in cases where this is advantageous.

In the figures, a four pole generator has been shown. The structure, however, is adapted to any number of poles. Figs. 13, 14 show the rotor of an 18 pole generator, using magnets 9 of square cross section. Here, openings 21 in structure 10 serve to lighten the weight of the unit. Other parts have functions obviously similar to those before described.

Fig. 15 shows a 2 pole rotor according to the principles of the invention. Here magnets 9 are made up of a number of sectors, since too large a mass of magnet material cannot be properly heat treated throughout to develop its full potential characteristics.

I claim:

1. In an axial air gap generator having a rotating field comprising permanent magnets, said permanent magnets requiring a flux conducting path when said rotating field is removed from said generator, means supporting said magnets against centrifugal forces produced by rotation of said field, pole pieces in contact with said magnets, said pole pieces having their flux producing faces lying substantially in a single plane and having outer cylindrical appendages extending exteriorly of said magnet supporting means, whereby a maximum volume of free space is available for air conduction of said flux, and a supporting structure bearing against the outer edge portion of said pole pieces to restrain the same against centrifugal forces produced by rotation of said field.

2. In a generator having a rotating field comprising permanent magnets, a stator, and an axial air gap therebetween, said permanent magnets requiring a flux conducting path independent of said stator when an overload or short circuit is applied to said generator, a block of material of high conductivity and high strength encircling said magnets, whereby to support said magnets against centrifugal forces produced by rotation of said field and simultaneously provide a highly conductive path encircling said magnets for protecting the magnetic state thereof, pole pieces at one end of said block of material in contact with said magnets, and means supporting said pole pieces against centrifugal forces produced by rotation of said field, said pole pieces having their flux producing faces lying substantially in a single plane and having outer cylindrical appendages extending along the outer surface of said block of material, whereby a maximum volume of free space outside of said stator and rotor is available for air conduction of said flux.

3. In an axial air gap generator having a rotating permanent magnet field structure and a stator, a field structure comprising, a rotor body formed of a material characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body being formed with a series of magnet receiving apertures extending therethrough in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body surrounding and enclosing said magnets for substantially the full length thereof whereby said rotor body provides a strong mechanical support for said magnets along substantially the complete length thereof to permit high speeds of rotation of said field structure and simultaneously provides a highly electrically conductive path independent of said stator encircling said magnets for substantially the complete length

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thereof to protect the magnetic state thereof from overload and short circuit armature reaction, pole piece means arranged in contact with the end faces of said magnets adjacent said stator, said pole piece means having flux producing faces lying substantially in a single plane whereby a maximum volume of free space outside of said stator and said rotor body is available for air conduction of flux, and flux conducting means in contact with the opposite end faces of said magnets.

4. In an axial air gap generator, a rotating permanent magnet field structure comprising, a rotor body formed of a material characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body having a series of magnet receiving apertures extending therethrough in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body extending substantially the full length of said magnets to substantially completely enclose the same, said rotor body thereby providing a strong mechanical support for said magnets along substantially the full length thereof to permit high speeds of rotation of said field structure and simultaneously providing a highly electrically conductive path substantially completely enclosing said magnets for protecting the magnetic state thereof from overload and short circuit armature reaction, pole piece means carried by said rotor body on the air gap end face thereof in contact with the corresponding end faces of said magnets, means including a flange formed integrally with said rotor body and encircling said pole piece means to restrain the same against centrifugal force produced by rotation of said field structure, and flux conducting structures arranged in contact with the opposite end faces of said magnets.

5. In an axial air gap generator, a rotating permanent magnet field structure, a stator, said field structure comprising, a rotor body formed of a material characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body having a series of magnet receiving apertures extending therethrough in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body completely surrounding said magnets for substantially the full length thereof, said rotor body thereby providing a strong mechanical support completely supporting said magnets along the length thereof against centrifugal force to permit high speeds of rotation of said field structure and simultaneously encircling said magnets with a highly electrically conductive path for protecting the magnetic state thereof from overload and short circuit armature reaction, pole piece means arranged in contact with the end faces of said magnets adjacent said stator, and flux conducting means in contact with the opposite end force of said magnets.

6. In an axial air gap generator, a rotating permanent magnet field structure comprising, a rotor body formed of a material characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body having a series of magnet-receiving apertures extending therethrough in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body extending substantially the full length of said magnets to substantially completely encase the same, said rotor body thereby providing a strong mechanical support for said magnets along substantially the full length thereof to permit high speeds of rotation of said field structure and simultaneously providing a highly electrically conductive path substantially completely enclosing said magnets for protecting the magnetic state thereof from overload and short circuit arma-

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ture reaction, and a pole piece structure arranged on the air gap end face of said rotor body, said pole piece structure including pole pieces in contact with the air gap end faces of said magnets and plate means secured to said rotor body end face and having cut out portions accommodating said pole pieces therein, said plate means including non-magnetic spacing material between said pole pieces.

7. In an axial air gap generator, a rotating permanent magnet field structure, a stator, said field structure comprising, a rotor body formed of a wrought material characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body having a series of magnet receiving apertures extending therethrough in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body completely surrounding said magnets for substantially the full length thereof, said rotor body thereby providing a strong mechanical support completely supporting said magnets along the length thereof against centrifugal force to permit high speeds of rotation of said field structure and simultaneously encircling said magnets with a highly electrically conductive path for protecting the magnetic state thereof from overload and short circuit armature reaction, pole piece means arranged in contact with the end faces of said magnets adjacent said stator, and flux conducting means in contact with the opposite end faces of said magnets.

8. In an axial air gap generator, a rotating permanent magnet field structure, a stator, said field structure comprising, a rotor body formed of Duralumin characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body having a series of magnet receiving apertures extending therethrough in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body completely surrounding said magnets for substantially the full length thereof, said rotor body thereby providing a strong mechanical support completely supporting said magnets along the length thereof against centrifugal force to permit high speeds of rotation of said field structure and simultaneously encircling said magnets with a highly electrically conductive path for protecting the magnetic state thereof from overload and short circuit armature reaction, pole piece means arranged in contact with the end faces of said magnets adjacent said stator, and flux conducting means in contact with the opposite end faces of said magnets.

9. In an axial air gap generator, a rotating permanent magnet field structure, a stator, said field structure comprising, a rotor body formed of an alloy of a material selected from the group consisting of aluminum, magnesium and copper characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body having a series of magnet receiving apertures extending therethrough in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body completely surrounding said magnets for substantially the full length thereof, said rotor body thereby providing a strong mechanical support completely supporting said magnets along the length thereof against centrifugal force to permit high speeds of rotation of said field structure and simultaneously encircling said magnets with a highly electrically conductive path for protecting the magnetic state thereof from overload and short circuit armature reaction, pole piece means arranged in contact with the end faces of said magnets adjacent said stator, and flux con-

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ducting means in contact with the opposite end faces of said magnets.

10. In an axial air gap generator, a rotating permanent magnet field structure, a stator, said field structure comprising, a rotor body formed of a material characterized by a high degree of electrical conductivity and a high degree of mechanical strength, said rotor body having a series of magnet receiving apertures extending there-through in substantial parallelism with the axis of rotation of said field structure, permanent magnets fitted in said apertures with the ends of said magnets being free in said apertures for the entrance and exit of magnetic flux, said rotor body completely surrounding said magnets for substantially the full length thereof, said rotor body thereby providing a strong mechanical support completely supporting said magnets along the length thereof against centrifugal force to permit high speeds of rotation of said field structure and simultaneously encircling said magnets with a highly electrically conductive path for protecting the magnetic state thereof from overload and short circuit armature reaction, pole piece means ar-

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ranged in contact with the end faces of said magnets adjacent said stator, flux conducting means in contact with the opposite end faces of said magnets, and reinforcing means surrounding said rotor body.

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