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H. D. ELSE ET AL

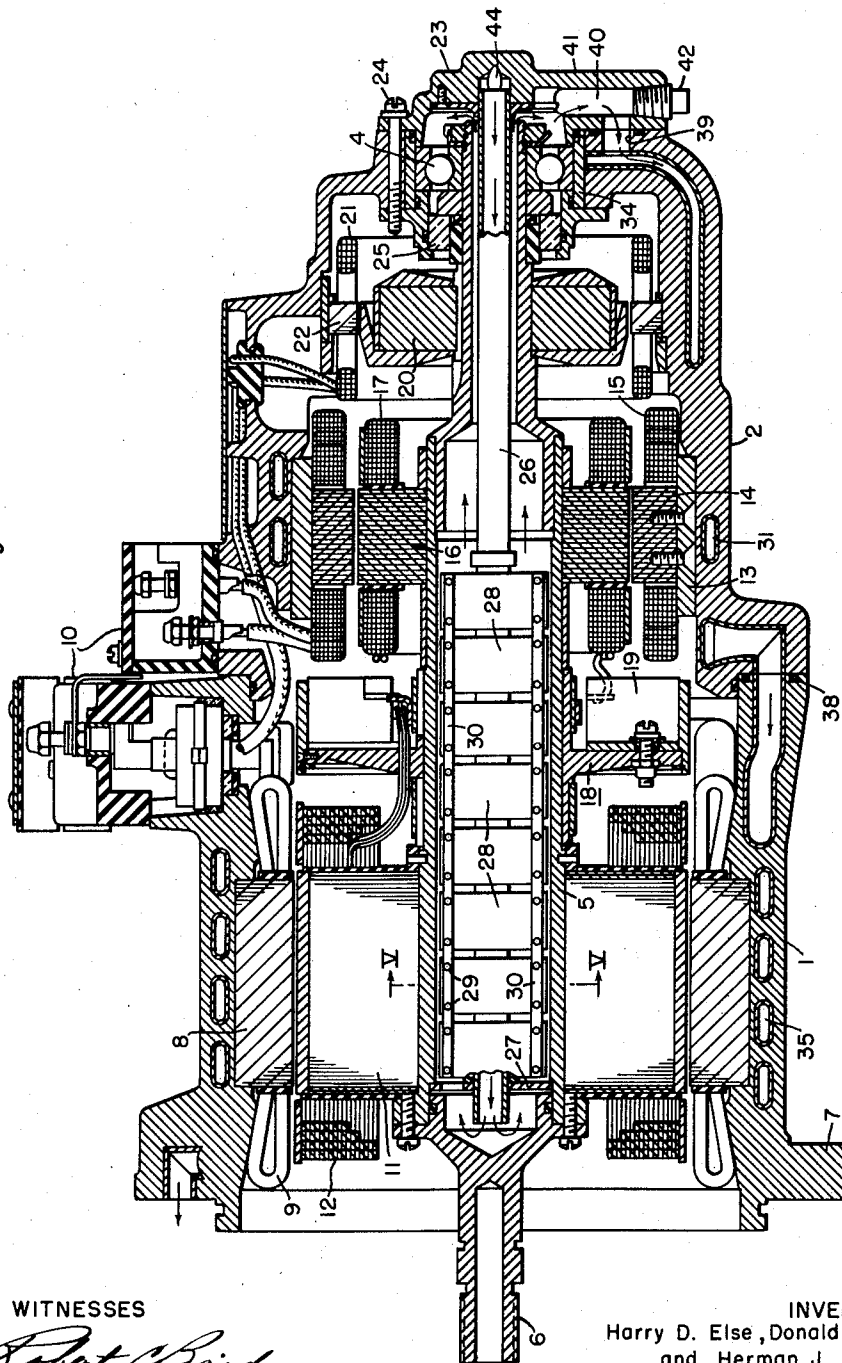
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LIQUID-COOLED DYNAMOELECTRIC MACHINE

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3 Sheets-Sheet 1

Fig. 1.



WITNESSES

Robert C. Baird
Wm. B. Sellers.

INVENTORS

Harry D. Else, Donald R. Basel
and Herman J. Braun.

BY

F. P. Lytle
ATTORNEY

Nov. 25, 1958

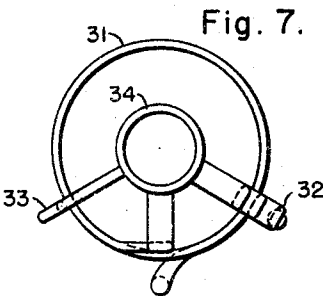
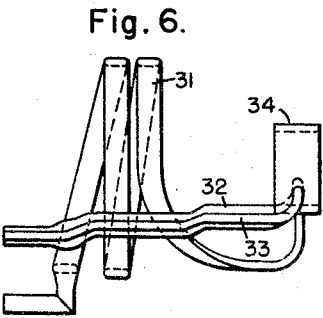
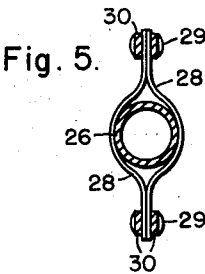
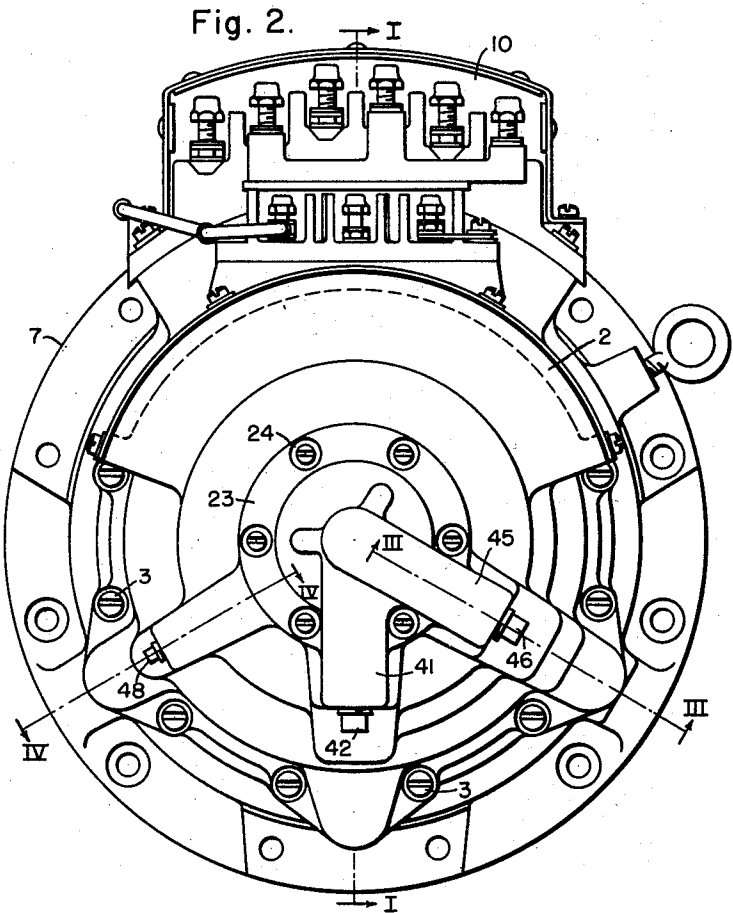
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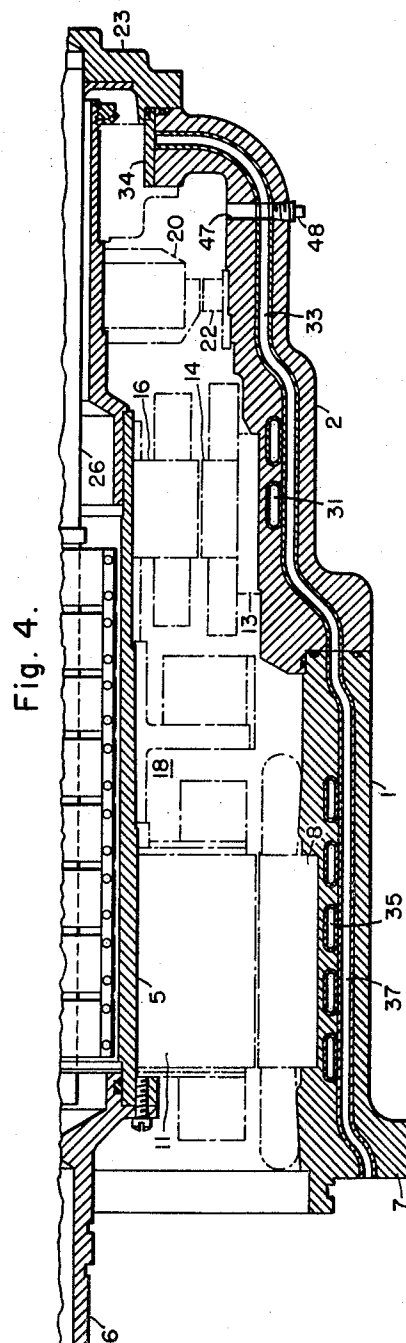
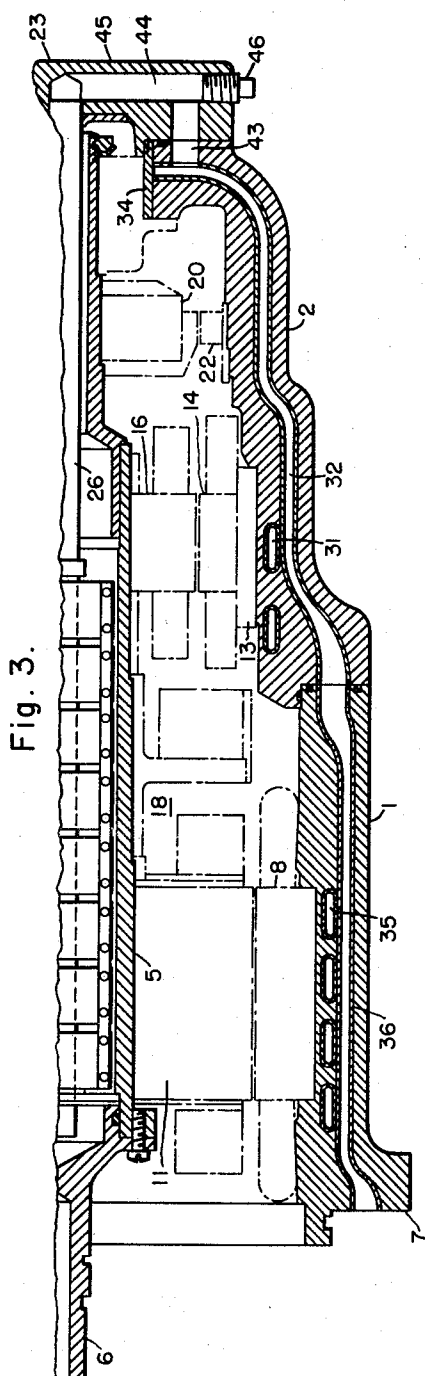
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LIQUID-COOLED DYNAMOELECTRIC MACHINE

Harry D. Else and Donald R. Basel, Lima, and Herman J. Braun, Shawnee Township, Allen County, Ohio, assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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6 Claims. (Cl. 310—54)

The present invention relates to dynamoelectric machines and, more particularly, to a machine which is cooled solely by circulation of a liquid cooling medium without any substantial reliance on air cooling.

The invention is especially applicable to aircraft generators, which are used for supplying the electrical loads on airplanes, although it will be obvious that its usefulness is not necessarily restricted to this specific application and it may be applied to any type of dynamoelectric machine.

Heretofore, aircraft generators have usually been cooled by a blast of air obtained by means of an air scoop on the plane which provided a continuous high-velocity blast of air during flight to effectively cool the generator. This type of cooling has been satisfactory in the past, and has been widely used, but in modern airplanes designed for extremely high speed operation at very high altitudes, this type of cooling is no longer practical, both because of the excessive drag caused by the air scoop and because the compressive effect at high speeds heats the air to such high temperatures that it is not usable as a cooling medium. The present invention provides a machine which is cooled by circulation of liquid in good thermal relation to the heat-producing parts of the machine, so that effective cooling is obtained without the use of an air blast, and without relying on any circulation of air in the machine at all, since at high altitudes the ambient air has such low density that it is practically useless for cooling purposes.

The principal object of the invention, therefore, is to provide a dynamoelectric machine which is effectively cooled by circulation of a liquid cooling medium in good thermal relation to the heat-producing elements of the machine.

Another object of the invention is to provide a liquid-cooled dynamoelectric machine in which the cooling liquid flows through a hollow shaft to cool the rotor, and flows through conduit means embedded in the frame structure to cool the stator, so that all parts of the machine are effectively cooled.

A further object of the invention is to provide a liquid-cooled dynamoelectric machine in which liquid flows through a hollow shaft to cool the rotor, and in which means are provided to produce turbulent flow of the liquid in the shaft to obtain the best possible heat transfer from the rotor to the liquid.

Other objects and advantages of the invention will be apparent from the following detailed description, taken in connection with the accompanying drawing, in which:

Figure 1 is a longitudinal sectional view of a dynamoelectric machine embodying the invention, the section being taken substantially on the line I—I of Fig. 2;

Fig. 2 is an end view of the machine;

Fig. 3 is a partial longitudinal sectional view, taken substantially on the line III—III of Fig. 2;

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Fig. 4 is a similar view taken substantially on the line IV—IV of Fig. 2;

Fig. 5 is a fragmentary transverse sectional view, substantially on the line V—V of Fig. 1; and

Figs. 6 and 7 are a side view and an end view, respectively, of a cooling coil assembly prior to incorporation in the machine.

As previously indicated, the invention is generally applicable to dynamoelectric machines of any type or size, but is particularly suitable for aircraft generators. The invention is shown in the drawing embodied in an alternating-current aircraft generator of the so-called brushless type, in which field excitation for the generator is supplied from an alternating-current exciter through a rotating rectifier, thus eliminating brushes, commutators and slip rings.

The particular machine shown for the purpose of illustration includes a frame structure which may consist of two sections, a generator frame section 1 and an exciter frame section 2, secured together in any suitable manner as by bolts 3 passing through mating flanges. The exciter frame section 2 includes a bracket portion at one end in which an anti-friction bearing 4 is mounted, and a hollow rotor shaft 5 is supported in the bearing 4. The particular machine shown has only one bearing, the shaft 5 having a splined portion 6 at the opposite end for engagement with a suitable driving means (not shown), and in use the machine is intended to be mounted on its prime mover by means of a flange 7, with the splined end of the shaft 5 supported in a driving member in the prime mover which has its own bearing. It will be understood, however, that, if desired, a conventional end bracket and bearing of any suitable type could be provided at the drive end of the machine.

As previously indicated, this machine is of the brushless type. The generator stator core 8 is of the usual laminated construction and is supported in the frame section 1 in any suitable manner, preferably in direct contact with the frame structure so that heat can flow readily from the core to the frame. The core 8 carries alternating-current armature windings 9 of any suitable type connected to a suitable terminal assembly 10. The generator also has a laminated field structure 11 mounted on the shaft 5 and carrying field windings 12. The excitation for the generator is provided by an alternating-current exciter carried in the frame section 2. The exciter has a stationary field member 13 mounted in any suitable manner in the frame section 2, in good thermal relation with the frame, and having salient poles 14 which carry field windings 15. The field windings 15 may be excited with direct current from any suitable external source, or from the output of the generator, through a rectifier and voltage regulator. The exciter has a laminated rotor member 16 mounted on the shaft 5 and carrying alternating-current armature windings 17. The alternating-current output of the exciter armature winding 17 is connected to a rotating rectifier assembly 18. The rectifier assembly may be of any suitable type and in the particular construction illustrated comprises a rotating support clamped on the shaft 5 and carrying a plurality of rectifier cells 19, which are preferably silicon rectifiers because of their high current capacity and ability to operate at relatively high temperatures. The direct-current output of the rectifier assembly 18 is connected to the field windings 12 of the generator to supply the necessary field excitation. Since the exciter armature 16, the rectifier 18, and the generator rotor are all carried on the shaft 5 and directly connected together, no brushes or slip rings are required.

The particular machine shown in the drawing, for

the purpose of illustration, also includes an electrically separate auxiliary generator having a permanent magnet rotor 20 on the shaft 5 and armature windings 21 carried on a laminated core 22 in the frame section 2. The auxiliary generator is also connected to the terminal assembly 10 and is intended to be used with a rectifier to supply direct-current power for control purposes.

The right-hand end of the machine is closed by a cap member 23 attached to the frame section 2 by screws 24. The cap member 23 and the bracket portion of the frame section 2 form an enclosed space at the end of the frame structure, in which the bearing 4 is located, the end of the hollow shaft 5 also being within this enclosed space, as clearly shown in Fig. 1. An oil seal 25, of any suitable type, is provided on the inner side of the bearing 4 to prevent substantial leakage from the bearing to the interior of the machine. A stationary tube 26 is mounted in the cap member 23 and extends longitudinally through the hollow shaft 5 to the opposite end, the other end of the tube 26 being supported in the shaft 5 in any suitable manner, as by a spider 27 within the shaft 5, the spider 27 preferably being mounted to permit relative rotation between the spider and both the tube and the shaft. The tube 26 is open at both ends and is utilized to introduce cooling liquid into the hollow shaft 5 to flow through the shaft 5 to the enclosed space formed by the cap member 23, as explained below.

In order to obtain the best possible heat transfer from the rotor elements of the machine to the cooling liquid, it is desirable to obtain turbulent flow of the liquid along the inner surface of the hollow shaft 5. Any suitable means may be provided for this purpose, and in the construction shown in the drawing, a plurality of normally stationary vanes 28 are mounted on the tube 26. As shown in Figs. 1 and 5, these vanes are clamped on the tube 26 by means of rivets 29 and longitudinal strips 30 which extend for the length of the vane assembly. The vanes 28 are clamped on the tube 26 with sufficient tightness so that in normal operation they are non-rotating and cause turbulent flow of the liquid in the shaft, the amount of turbulence being determined by the clearance between the vanes and the inner surfaces of the shaft. As explained later, a preferred cooling liquid is oil, which may have relatively high viscosity, or be substantially congealed under low temperature conditions if the machine has been idle for a period of time, so that if the vanes 28 were rigidly fixed, it would be difficult to start the machine under these conditions. If the cooling liquid in the shaft is relatively stiff, however, the vanes 28 will yield and rotate on the shaft 26 until the liquid has warmed up and become less viscous. Thus, the presence of the vanes 28 produces the desired turbulent flow under normal conditions, but does not materially increase the difficulty of starting under low temperature conditions. It will be understood that any other suitable means might be used in the shaft 5 to produce turbulence, instead of the vanes 28.

The stator elements of the machine are cooled by circulation of the cooling liquid through passages formed by conduit means embedded in the frame structure. In the preferred construction of the machine, these passages, together with supply and drain passages, are cast in the frame structure, thus positioning them close to the heat producing elements of the machine. The cooling passages, and the supply and drain passages, are preferably made of stainless steel tubing, or of other suitable material which is resistant to corrosion by the hot cooling liquid.

The cooling passage is preferably helical, and in the construction of the machine, the cooling passage is pre-formed from stainless steel tubing, in a configuration such as shown in Figs. 6 and 7, in which a helical cooling coil 31 is made of flattened tubing formed into a helix of the desired diameter and number of turns. A supply passage is provided by a generally straight tube

32, and a drain passage by a similar straight tube 33, both of which, for convenience in assembly, may be attached to the helical cooling coil 31. The ends of all three sections of tubing are attached to a stainless steel ring 34 for convenience in handling and assembly. The tubing assembly shown in Figs. 6 and 7 is intended for the frame section 2, and a similar assembly, including a helical cooling coil 35, with relatively straight supply and drain passages 36 and 37, respectively, is provided for the frame section 1. After the pre-formed tubing assemblies have been prepared, the frame sections 1 and 2 are cast around the tubing to produce finished frame sections substantially as shown in the drawing, the frame sections 1 and 2 preferably being made of a light metal such as magnesium or aluminum alloy. The tubing sections are arranged so that their ends in the adjoining surfaces of the frame sections 1 and 2 register accurately, and the joints are sealed by means of resilient O-rings 38, or other suitable sealing means, to prevent substantial leakage. The other ends of the cooling coil 35 and of the supply and drain passages 36 and 37 in the frame section 1 are suitably located in the flange 7 for connection with the circulating system which supplies the cooling liquid as described hereinafter.

The cooling coil 31 in the frame section 2 communicates with the enclosed space at the end of the frame structure by means of a hole 39 drilled through the end of the frame structure into the tubing 31. The hole 39 communicates with a passage 40 in a radial boss 41 on the cap member 23, the passage 40 being closed by a threaded plug 42. The passage 40 communicates with the enclosed space formed by the cap member 23, as clearly shown in Fig. 1.

Cooling liquid enters the machine through the supply passage formed by the tubing sections 32 and 36. As shown in Fig. 3, the passage 32 communicates through a hole 43 drilled in the frame structure with a radial passage 44 in a radial boss 45 on the cap member 23, which is closed by a threaded plug 46. The passage 44 extends to the axis of the machine and communicates with the end of the hollow tube 26 to supply cooling liquid thereto. The drain passage formed by the tubing sections 33 and 37, as shown in Fig. 4, communicates with the interior of the machine by means of a hole 47 drilled through the frame structure and closed at its outer end by a threaded plug 48.

In operation, cooling liquid is supplied to the machine through the supply passage described above, from which it flows through the radial passage 44 to the stationary tube 26. The liquid flows through the tube 26 to the opposite end of the shaft 5 and then flows back through the shaft, on the outside of the tube 26, as indicated by the arrows in Fig. 1. Since the flow of liquid in the shaft 5 is made turbulent, and since it is in direct contact with the inner surface of the shaft 5, very good heat transfer is obtained from the rotor elements of the machine to the liquid, and very effective cooling results. The liquid flowing through the shaft 5 is discharged into the enclosed space formed by the cap member 23 and substantially fills this space, so that the bearing 4 is immersed in the liquid which thus serves to lubricate the bearing, any substantial leakage of liquid being prevented by the seal 25. The liquid fills the enclosed space and flows from it through the passage 40 into the cooling coil formed by the tubing sections 31 and 35 and flows through the cooling coil to the opposite end of the machine where it is discharged. It will be noted that the cooling coil is positioned close to the heat-producing stator elements of the machine, and since the cooling coil is embedded in the metal frame structure on which the stator elements are mounted, very effective cooling is obtained as the heat generated in the stator elements can easily flow to the cooling liquid.

The cooling liquid is prevented from escaping into the machine by the seal 25 and by the sealed joints between

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the frame sections, but a small amount of leakage may unavoidably occur. It will be understood that the presence of oil or oil vapor within the machine is not particularly harmful in a machine of the type shown, since there are no exposed contact surfaces, but it is undesirable to allow the cooling liquid to accumulate in the machine, and the drain passage formed by the tubing sections 33 and 37 is provided for this purpose. This passage communicates directly with the interior of the machine adjacent the seal 25, and any substantial amount of liquid that may leak into the machine drains off through this passage.

As previously indicated, any suitable cooling liquid may be utilized, oil being preferred as the cooling liquid is also utilized for lubricating the bearing, in the machine shown. The particular machine shown in the drawing is intended for use with a constant-speed drive unit of the hydraulic type, which is widely used in aircraft. Drives of this type are actuated hydraulically, and a supply of oil is thus readily available, the oil supply for the drive usually being a part of the oil system for the main engines of the airplane. The machine shown, therefore, utilizes this oil as a cooling medium. The hydraulic drive unit contains a pump so that adequate oil pressure is maintained to force the oil through the generator, and the generator is intended to be mounted directly on the drive unit by means of the flange 7 in the usual manner. An oil supply line is provided in the drive unit at the proper place to connect to the supply passage 36, and a discharge line is provided at the proper location to connect to the discharge end of the cooling coil. The drain passage may be connected to a sump line to return oil draining from the machine to the oil system. While this particular arrangement is very desirable, since it uses a readily available source of cooling liquid, it will be evident that other cooling liquids may be used. Thus, for example, if the generator is mounted directly on a jet or gas turbine engine, the fuel passing from the fuel tank to the engine may be made to flow through the generator on its way to the engine, and thus serve as a cooling medium. Similarly, any other available liquid which is capable of cooling the generator may be utilized.

It should now be apparent that a liquid-cooled dynamoelectric machine has been provided in which very effective cooling is obtained by circulating the cooling liquid in good thermal relation to the heat-producing elements of the machine. A specific embodiment of the invention has been shown and described for the purpose of illustration, but it will be obvious that the invention is applicable to dynamoelectric machines of any type or size, and that various modifications may be made. Thus, the cooling coil or passage may be arranged in any desired manner and is not necessarily limited to the helical configuration shown. The bearing has been shown as being lubricated by flooding it with the cooling liquid but it will be obvious that other lubricating means may be used if desired. It will also be obvious that the cooling liquid may be introduced into the hollow shaft in any desired manner, as by introducing it directly into the drive end of the shaft through the splined portion 6, for example. The invention is not limited, therefore, to the specific details of construction shown but includes all equivalent embodiments and modifications.

We claim as our invention:

1. A dynamoelectric machine having a stator member and a rotor member, the stator member including a frame structure having conduit means embedded therein to provide a passage for cooling liquid from end to end of the frame structure, said passage communicating with an enclosed space at one end of the frame structure, a bearing for the rotor member in said enclosed space, the rotor member including a hollow shaft supported in said bearing, and means for introducing a cooling liquid into the hollow shaft to flow axially therethrough from end to end, the liquid being discharged from the shaft into

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said enclosed space to lubricate the bearing and flowing from the enclosed space directly into said passage in the frame structure.

2. A dynamoelectric machine having a stator member and a rotor member, the stator member including a frame structure having conduit means embedded therein to provide a passage for cooling liquid from end to end of the frame structure, said passage communicating with an enclosed space at one end of the frame structure, the rotor member including a hollow shaft, a stationary tubular member supported in the frame structure at said one end thereof and extending through the hollow shaft, a passage in the frame structure extending from the other end of the machine for introducing cooling liquid into said tubular member at said one end to flow therethrough to the other end of the shaft and through the shaft to said enclosed space, the liquid flowing from said space into said conduit means in the frame structure to flow therethrough.

3. A dynamoelectric machine having a stator member and a rotor member, the stator member including a frame structure having conduit means embedded therein to provide a passage for cooling liquid from end to end of the frame structure, said passage communicating with an enclosed space at one end of the frame structure, the rotor member including a hollow shaft, a bearing for the shaft in said enclosed space, a stationary tubular member supported in the frame structure at said one end thereof and extending through the hollow shaft, a passage in the frame structure extending from the other end of the machine for introducing cooling liquid into said tubular member at said one end to flow therethrough to the other end of the shaft and through the shaft to said enclosed space, the liquid filling the enclosed space to lubricate the bearing and flowing from the space into said conduit means in the frame to flow therethrough.

4. A dynamoelectric machine having a stator member and a rotor member, the stator member including a frame structure having conduit means embedded therein to provide a passage for cooling liquid from end to end of the frame structure, said passage communicating with an enclosed space at one end of the frame structure, the rotor member including a hollow shaft, a bearing for the shaft in said enclosed space, a stationary tubular member supported in the frame structure at said one end thereof and extending through the hollow shaft, a passage in the frame structure extending from the other end of the machine for introducing cooling liquid into said tubular member at said one end to flow therethrough to the other end of the shaft and through the shaft to said enclosed space, the liquid filling the enclosed space to lubricate the bearing and flowing from the space into said conduit means in the frame to flow therethrough, and a drain passage in the frame structure for draining off liquid escaping into the interior of the frame structure.

5. A dynamoelectric machine having a stator member and a rotor member, the stator member including a frame structure having conduit means embedded therein to provide a passage for cooling liquid from end to end of the frame structure, said passage communicating with an enclosed space at one end of the frame structure, the rotor member including a hollow shaft, a stationary tubular member supported in the frame structure at said one end thereof and extending through the hollow shaft, a passage in the frame structure extending from the other end of the machine for introducing cooling liquid into said tubular member at said one end to flow therethrough to the other end of the shaft and through the shaft to said enclosed space, normally stationary means on the tubular member within the shaft for causing turbulence in the liquid flowing through the shaft, the liquid flowing from said enclosed space into said conduit means in the frame structure to flow therethrough.

6. A dynamoelectric machine having a stator member

and a rotor member, the stator member including a frame structure having conduit means embedded therein to provide a passage for cooling liquid from end to end of the frame structure, said passage communicating with an enclosed space at one end of the frame structure, a bearing for the rotor member in said enclosed space, sealing means between the bearing and the interior of the frame structure for sealing the bearing and the enclosed space from the frame structure, the rotor member including a hollow shaft supported in said bearing, and means for introducing a cooling liquid into the hollow shaft to flow axially therethrough from end to end, the liquid being discharged from the shaft into said enclosed space to lubricate the bearing and flowing from the enclosed space into said passage in the frame structure.

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References Cited in the file of this patent

UNITED STATES PATENTS

242,400	Volker	May 31, 1881
1,135,327	Savage	Apr. 13, 1915
1,448,700	Seidner	Mar. 13, 1923
1,830,457	Apple	Nov. 3, 1931
1,885,546	Rice	Nov. 1, 1932
2,662,195	Fisher	Dec. 8, 1953
2,688,946	Jarsaillon	Sept. 14, 1954
2,706,260	Heintz	Apr. 12, 1955

FOREIGN PATENTS

320,563	Great Britain	Oct. 17, 1929
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