

Oct. 28, 1930.

F. G. BAUM

1,779,797

DYNAMO COOLING SYSTEM

Filed May 18, 1927

2 Sheets-Sheet 1

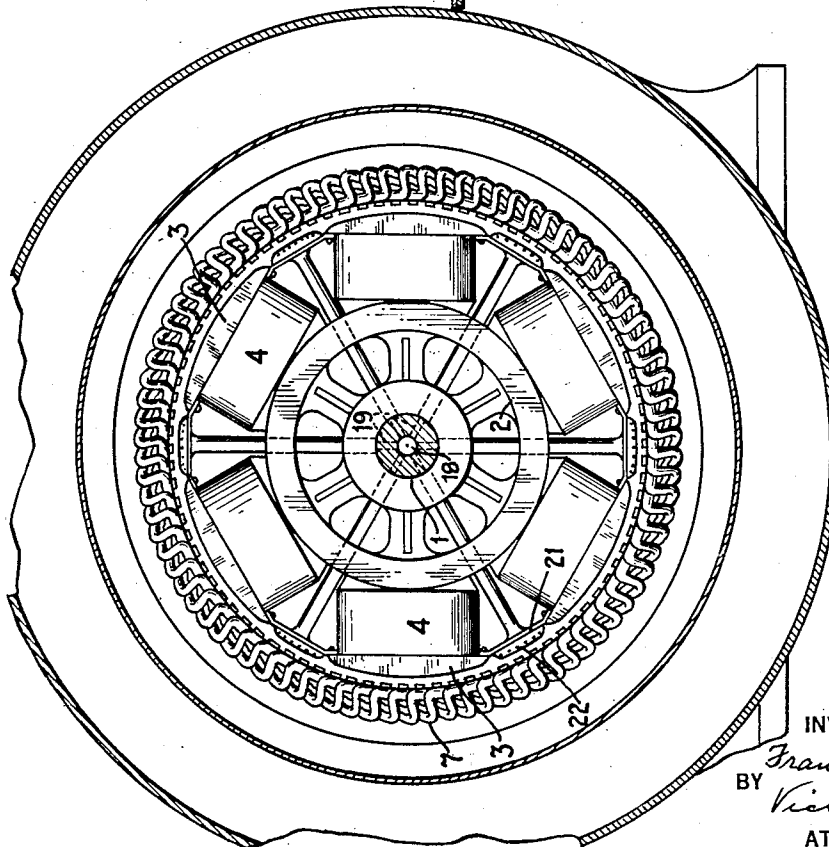
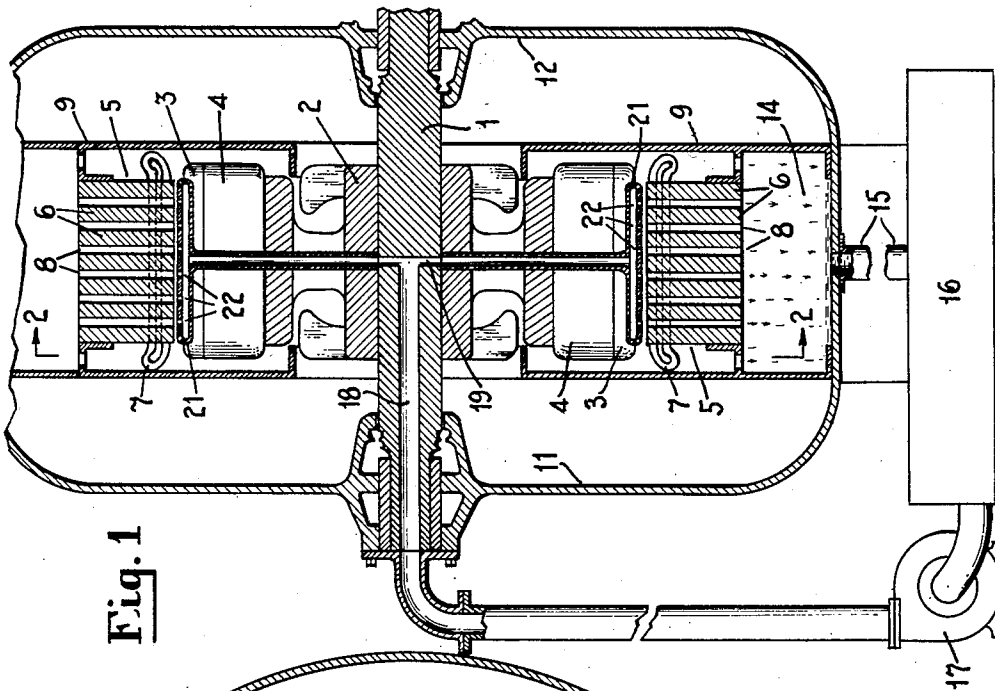


Fig. 2

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Fig. 3

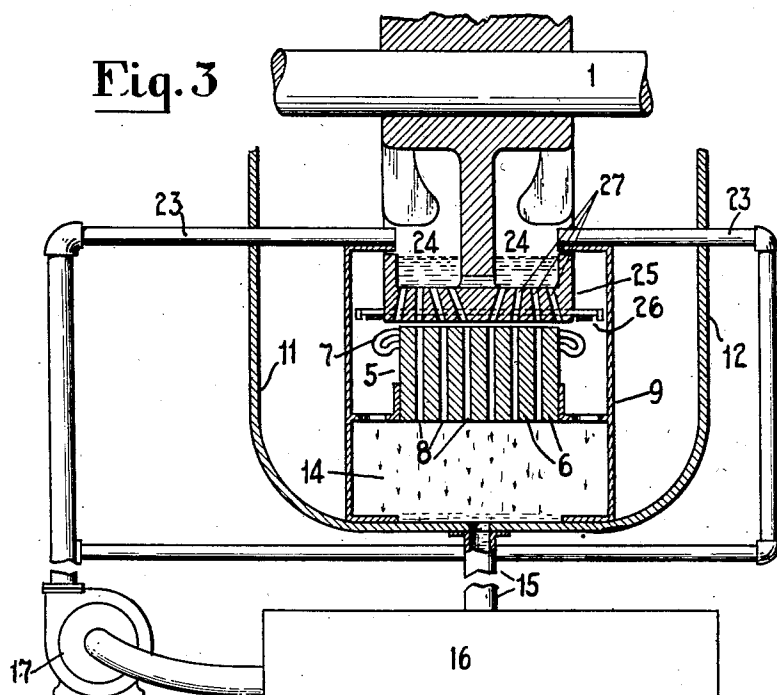


Fig. 4

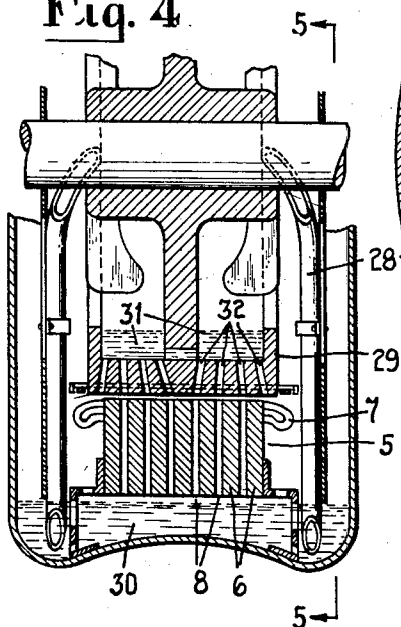
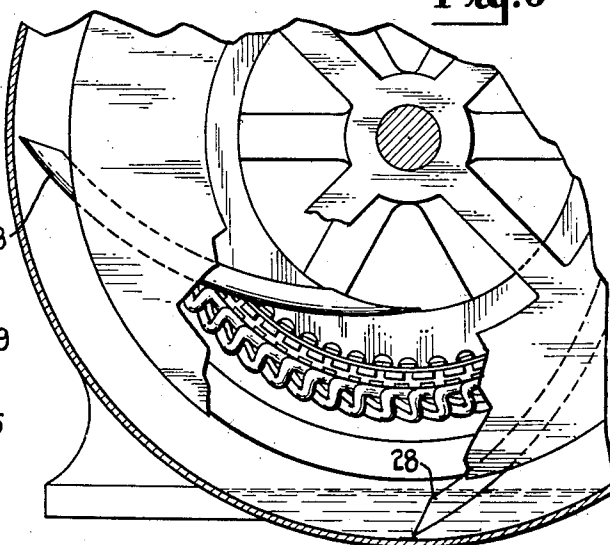


Fig.5



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DYNAMO-COOLING SYSTEM

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My invention relates to dynamo-electric machinery of the rotating pattern and particularly to means for the more effective cooling thereof.

5 The translation of electrical energy from form to form and from point to point is never accomplished without some loss, and the lost energy appears at the site of translation as heat. The limitation upon the capacity of
10 any dynamo-electric machine accordingly is found to be the rate at which the heat produced by the energy loss can be removed from the machine. Transformer devices are customarily cooled for the removal of such heat
15 by the use of oil as a heat absorbing and circulating medium, and they are very effectively cooled thereby. It has not, however, previously been found practicable to cool rotating machinery by the use of oil,
20 since submergence in oil produces prohibitive losses of energy through the churning of oil by the rotating parts, and the use of oil circulated through enclosed pipes has not been
25 successful because of the complicated and bulky tubes and conduits required. Although some attempt has been made to prevent or minimize the loss of energy due to churning of oil, (which loss not only detracts from mechanical efficiency but represents a conversion
30 of such energy into heat) by enclosing the rotor in a cylinder of non-magnetic material, the circulation of oil is thereby so interfered with as to make the cooling system ineffective. Accordingly, in actual practice,
35 as far as I am aware, only the gaseous fluids have been used for the cooling of rotating dynamo-electric machinery, air being the preferred fluid because of the common occurrence thereof and ease with which it is obtained.

My invention provides means for the utilization of oil or other suitable fluid, having a high thermal storage capacity for the cooling
45 of rotating machinery. This result I obtain by the use of a spray of oil, suitably discharged from the rotating member over the stationary member, to absorb the heat, and thereafter allowed to collect in a suitable receptacle. The heated oil is then cooled and
50 resprayed by appropriate means over an ap-

propriate portion of the machine. By the device of my invention I am enabled to utilize the desirably high cooling capacity of oil for the cooling of rotating machinery without the introduction of bulky conduits, and without
55 the production of large energy losses from churning of the fluid. I am thus enabled to obtain a substantial and important increase in continuous rating of a dynamo-electric machine, and accordingly a greatly improved
60 performance and a lower cost of production, from which follows a reduction in the cost of operation in the handling of electric energy.

Other objects and structural details of my invention will be apparent from the following description when read in connection with the accompanying drawings, wherein:

Fig. 1 is a sectional view in vertical elevation of an embodiment of the device of my invention;

Fig. 2 is a side view in vertical elevation of the same embodiment;

Fig. 3 is a sectional view in vertical elevation of an alternative embodiment;

Fig. 4 is a sectional view in vertical elevation of a second alternative embodiment, and

Fig. 5 is a side view in vertical elevation, partly in section, of the embodiment of Fig. 4.

It is well known that oil has a very much higher specific heat than air, and that accordingly the cooling effect which can be obtained from it is much greater. For instance, oil has a weight of about 55 pounds per cubic foot, while air has a weight of about 0.08
80 pounds per cubic foot. The specific heat of oil is about 0.5, where that of air is about 0.237. The ratio of heat absorbing capacity of equal volumes of air and of oil is then given by the following equation:

$$\frac{55 \times 0.5}{.08 \times 0.237} \text{ or about 1450 times.}$$

Accordingly, for a given amount of cooling effect, a very much less volume of oil need be used than of air alone. Accordingly, if a
85 mixture of oil and air be used for cooling purposes, the volume of the mixture necessary for a given cooling effect is very much less than the volume of air alone, depending upon the ratio of oil to air in the mixture
100

used. The oil is preferably applied in the form of a spray, or mist, or in relatively small drops, so that a minimum of churning effect is produced in the mixture by the movement of the rotor, and so that no single particle is sufficiently large to produce unduly large impact forces when it is thrown from the moving rotor to the stator. The spray is formed at the outer face of the rotor. The cooling liquid is conducted to a receptacle at or near the periphery of the rotor where it collects in the form of a liquid in substantial quantities and thus develops the maximum centrifugal force, escaping therefrom through small openings as a spray against the opposing face of the stator. The rotation of the rotor itself within the spray is thereby avoided. Another advantage of this arrangement is the fact that the centrifugal force developed in the liquid can be utilized to induce the circulation of the cooling liquid through a closed system.

To prevent loss of oil, the circulating medium should be enclosed. The dynamo-electric machine may be provided with closed end plates and frame with a receiver portion, and drain, at the bottom, so that as the oil spray strikes the stator, it may drain down over the hot surfaces of the machine to the receiver, after which it may be cooled and recirculated. The mixture of liquid and gas may consist of a fluid, such as oil, and air, or it may preferably consist of a less flammable mixture. For this purpose, it may consist of a mixture of oil spray and carbon dioxide, with or without the inclusion of a small proportion of air, or it may consist of a mixture of oil and nitrogen, also with or without the inclusion of small quantities of air, insufficient to produce a combustible mixture with the oil.

A preferred embodiment of the device of my invention is shown in Figs. 1 and 2. These figures show the essential parts of a typical dynamo-electric machine to which the improvement of my invention may be advantageously applied. The machine may consist of a shaft, 1, supported in bearings, to which is attached a rotor 2. The rotor may be a rotating field or a rotating armature, as desired. In the embodiment shown, it is indicated as a rotating field having salient poles 3, with appropriate field windings 4 thereon. The rotor is surrounded by a stator 5, which may consist of laminations 6, having windings 7 positioned in appropriate slots therein. Passages 8, for cooling fluid, are provided through the body of the stator laminations. A suitable frame member 9 is provided for the support of the laminations forming the stator, and appropriate end-bell closure members 11 and 12 are likewise provided, making a close fit about the shaft 1 and against the machine frame 9. The rotor also has fan blades, as shown, for causing a

circulation of the air or other gas contained in the housing 11, 12, of the machine. A closure member 14 is provided at the bottom of the frame 9 to form a receptacle for the cooling fluid collecting there. A drain pipe 15 is provided, connected thereto, and led to a storage reservoir 16.

A circulating pump 17 is provided with the suction inlet connected to the reservoir 16. The shaft 1 is desirably provided with a passageway or duct 18 extending from one end to a point within the hub of the rotor 2, and connection is made at that point by a plurality of radial ducts 19 extending toward the surface of the rotor. At the rotor surface and between the salient poles of a plurality of liquid receptacles forming spray heads 21 are provided and connected to the radial channels 19, the channel 18, and the pump 17. The spray heads 21 may be of any convenient pattern, but are preferably such as to provide a plurality of fine sprays of oil in the air-gap between the rotor and stator. Provision may likewise be made for the passage of small currents of gas through the rim of the rotor by any convenient means. These may be provided by passages through the body of the salient poles 3 or may preferably be provided by passages between the poles. Either construction provides a current of fluid consisting partly of gas and partly of sprayed oil. The spray heads 21 may desirably be of a pattern to provide a plurality of sprays of oil separated axially by a distance equal to the axial separation of the ventilating ducts 8 in the stator.

The current of fluid from the spray heads 21 on the rotor is directed towards the inner surface of the stator in the bore thereof, and towards the inner openings of the ventilating passages therethrough. The greatly increased thermal capacity of this fluid, as compared to air alone, is thus available for the cooling both of the rotor member and the stator member. A portion of the oil may be conveyed through the ventilating channels 8 in the stator body in the form of a spray and collect a substantial amount of heat therefrom, either by radiation or by conduction. It is desirable that the spray heads 21 be so positioned that the openings 22 through which the oil is discharged and sprayed are located in the planes of the ventilating ducts 8, in order to discharge as large a portion of the oil through the ventilating ducts as possible, and to minimize the accumulation of fluid oil within the air gap between the rotor and stator. Accordingly while some of the oil spray is carried freely through the ducts 8, other portions may strike the surfaces of the ventilating ducts, and coalesce thereon into a layer of liquid. This layer may be carried radially outward along the surfaces of the ventilating ducts by the current of mixed air and oil spray. In its passage over

these surfaces, the oil layer is advantageously related thereto for the desired cooling effect, and it is enabled to absorb a substantial amount of heat in the course of the flow.

5 The oil is thus carried to the outer surface of the stator, through the ventilating ducts, and it then flows downward to the receptacle 14 at the bottom of the frame, from which location it is conveyed by the pipe 15 to the cooler and reservoir 16 where the absorbed heat is removed and dissipated. The oil is then recirculated by the pump 17 to pass through the cycle again for the collection of further quantities of heat. By this means a very thorough and effective cooling of the dynamo machine is obtained with the handling of a minimum bulk of cooling fluid.

10 It is not essential that the cooling liquid be conveyed to the rotor through an opening in the shaft. It may equally well be conveyed by other means, such as that shown in Fig. 3, where the oil leaves the pump 17 and is conveyed to conductors 23, which discharge the cooling oil into troughs 24 forming liquid receptacles and located at points near the periphery of the rotor. It is collected from the stationary conductors 23 which lead to the troughs 24, and is held against the frame of the rotor by centrifugal force. This construction is particularly advantageous in the case of the well known "squirrel cage" type of motor, in which the rotor consists of laminations 25 having peripheral slots in which are positioned the inductor bars 26 characteristic of this type of machine. The oil may be conducted through suitable channels 27 in the rotor body from the troughs 24 to the rotor surface, at which point it may be sprayed by any appropriate means, which may consist of jet plugs or other spray devices positioned within and near the outer ends of the channels 27. The stator construction may desirably be similar to that indicated in Fig. 1, and may consist of laminations 6 having ventilating ducts 8 there-through, supported by a frame member 9 with end-bell members 11 and 12, a bottom receptacle or reservoir 14, a drain pipe 15, and cooler and storage tank or reservoir 16. The oil is then discharged by the pump 17 through the pipes 23 into the troughs 24 from which it passes through the ducts 27 and is sprayed thereby. The ends of the ducts 27 are desirably positioned in the plane of the ventilating ducts 8, as previously described, and the oil spray, together with a portion of gas as previously described, is discharged into them for the production of a similar cooling effect upon the structures. The cooling oil flows over the warm surfaces collecting heat and is caught in a receptacle or reservoir 14 at the bottom of the frame member, from which it is conveyed to a cooler, and storage tank, and thereafter is recirculated as before.

By this construction usually effective and efficient cooling means are provided for the induction type of motor, whereby much superior cooling effects, and therefore much higher load capacity, are obtainable from a given construction.

70 For certain types of machines it is not, however, necessary that a circulating pump be provided for the handling of the oil fluid. Instead, suitable scoops and channels may be provided upon the rotor, dipping into a supply of oil fluid at the bottom of the case and frame, to convey the cooling oil to the rotor. These may consist of curved scoops, or pipes 28, as shown in Figs. 4 and 5, fastened to the rotor 29, and revolving with it. As each scoop revolves, it strikes the pool of oil 30 at the bottom and some of the oil passes into the scoop, to be delivered to the annular trough 31 upon the rotor 29 from which it is delivered by suitable ducts 32 to spray heads as before. It is then sprayed therefrom into and against the stator 5 and the ventilating ducts 8 therein, where it acts, as previously described, for the removal of heat therefrom. The oil may be cooled by any appropriate cooling means, such as water coils at the bottom of the frame.

By the device of my invention it is possible to obtain very much more effective cooling of dynamo machinery, because of the much higher thermal capacity of the fluid employed for cooling. Because of the high thermal capacity of a given volume of the cooling fluid, it is thus possible to obtain equally effective cooling as that obtained by air, by the use of very much smaller ventilating ducts, or if the maximum size of ventilating ducts are employed it is possible to produce much more effective cooling. The device of my construction thus makes it possible to increase the duty on dynamo-electric machinery, thereby considerably reducing the cost of machinery for a given power output, since the additional parts required for the application of the device of my invention are very small items in the cost of the machinery. Thus a direct reduction of the cost of electric power is provided.

Further advantages of the device of my invention are found in the fact that the cooling system may be made completely closed, recirculating a given fluid as it is needed. Thus no external air need be supplied, and the conveyors and ducts which would be necessary for such supply, are saved. Likewise the elimination of the need for cooling air reduces the amount of dirt and moisture which would otherwise be carried into the machine by such circulating air. In consequence, the insulation condition of the machine is much improved, and the necessity for frequent cleaning to remove dirt and other obnoxious material is avoided. The presence of the oil directly adds to the insula-

tion resistance, because of its own high insulation value and because of the elimination of moisture. Likewise the system makes it possible to enclose the machine in a non-combustible atmosphere, thereby greatly reducing the hazard of fires which may occur in the insulation due to overload, excess voltage, and other factors which tend to injure the insulation. Likewise in the event that fire occurs in the insulation, it is smothered at once upon the removal of load from the machine, by the cooling effect of the large quantities of oil thrown in, and by the lack of oxygen to support combustion.

The device of my invention is particularly applicable to relatively large dynamo machines, such as generators, rotary converters, and large motors. It is, however, equally well adapted to application to the smaller types of industrial motors, and is also applicable to railway and other transportation motors. In such service it is particularly advantageous because when so equipped, the motors are operating in a medium having a very high insulation resistance, as compared to operation under ordinary conditions where they are in a medium charged with moisture and other matter, tending towards a low insulation resistance.

While I have shown but three embodiments of my invention in the preceding description, they are capable of various modifications therefrom without departing from the spirit thereof, and it is desired, therefore, that only such limitations shall be placed thereon as are required by the prior art or indicated by the appended claims.

I claim as my invention:

1. In a dynamo electric machine, comprising rotor and stator, means for spraying the interior surface of the stator at a series of points along the length of its air gap with oil and simultaneously directing gas currents against said surface, and means for recovering and recirculating said oil.

2. In a dynamo-electric machine, a rotor member and a stator member, the rotor having an internal circumferential trough within and near its periphery, openings extending through the trough in an outward direction and means for circulating a cooling liquid in a closed path including said trough, and a stationary liquid feeding pipe extending over the open inner periphery of said trough.

3. In a dynamo-electric machine, a rotor member and a stator member, the rotor having an internal circumferential trough within and near its periphery, openings extending through the trough in an outward direction and means for circulating a cooling liquid in a closed path including said trough, said means comprising a collecting reservoir below the axis of the rotor and a scoop rigid with the rotor and extending into the reservoir.

4. In a dynamo-electric machine, a stator, an internal rotor facing the stator and having a radially perforated liquid receptacle disposed at its outer periphery, facing the air gap of the machine, whereby liquid will be sprayed from said receptacle upon the stator, a reservoir for holding a quantity of cooling liquid, a conduit leading to said receptacle and adapted to supply liquid from the reservoir to the receptacle upon rotation of the rotor, and means for circulating a current of gas upon the stator in conjunction with said liquid spray.

5. In a dynamo-electric machine, a cooling system comprising a stator, an internal rotor facing the stator, a housing enclosing the same, a reservoir for holding a cooling liquid within the housing, means carried by the rotor for continuously removing liquid from the reservoir and supplying it to the interior of the rotor, and spray means on the outer periphery of the rotor for discharging liquid in spray form into the air gap of the machine.

6. In a dynamo-electric machine, a cooling system comprising a stator having radial passages therethrough, an internal rotor facing the stator and having a liquid receptacle at its outer face, a housing enclosing the rotor and stator and providing a reservoir for holding a cooling liquid below the stator, means carried by the rotor and dipping into the reservoir for continuously removing liquid from the reservoir and supplying it to the said receptacle, and spray means on the outer periphery of the rotor for discharging liquid in spray form into the air gap of the machine.

7. In a dynamo-electric machine, a cooling system comprising a stator having radial passages therethrough, an internal rotor facing the stator and having a liquid receptacle at its outer face, a housing enclosing the rotor and stator and providing a reservoir for holding a cooling liquid below the stator, means carried by the rotor for continuously removing liquid from the reservoir and supplying it to the said receptacle, spray means on the outer periphery of the rotor for discharging liquid in spray form into the air gap of the machine, and means for circulating a current of gas within the housing coincident with the rotation of the rotor.

8. The method of cooling an electric translating device comprising rotor and stator cores and windings which consists in continuously subjecting the exterior of the rotor and interior of the stator in the air gap of the machine to the cooling effect of a liquid spray, mixing gas with said spray and causing said mixture to pass through the core of said stator in an outward direction at a multiplicity of points, and circulating said liquid in a closed path.

In witness whereof, I hereunto subscribe my signature.

FRANK G. BAUM. 130