

June 20, 1944.

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2,351,963

ELECTROMAGNETIC APPARATUS

Filed March 3, 1943

5 Sheets-Sheet 1

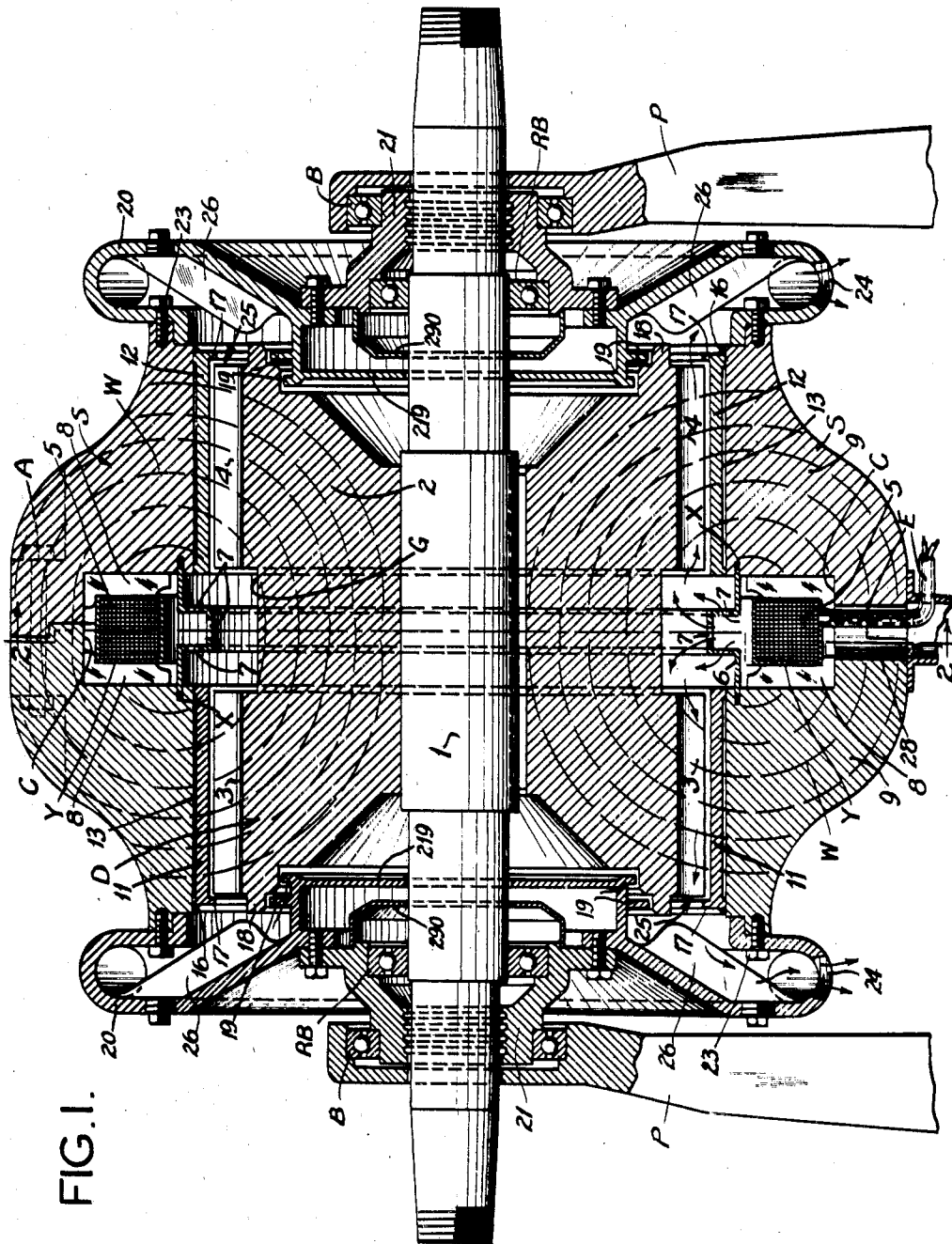


FIG. 1.

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5 Sheets-Sheet 2

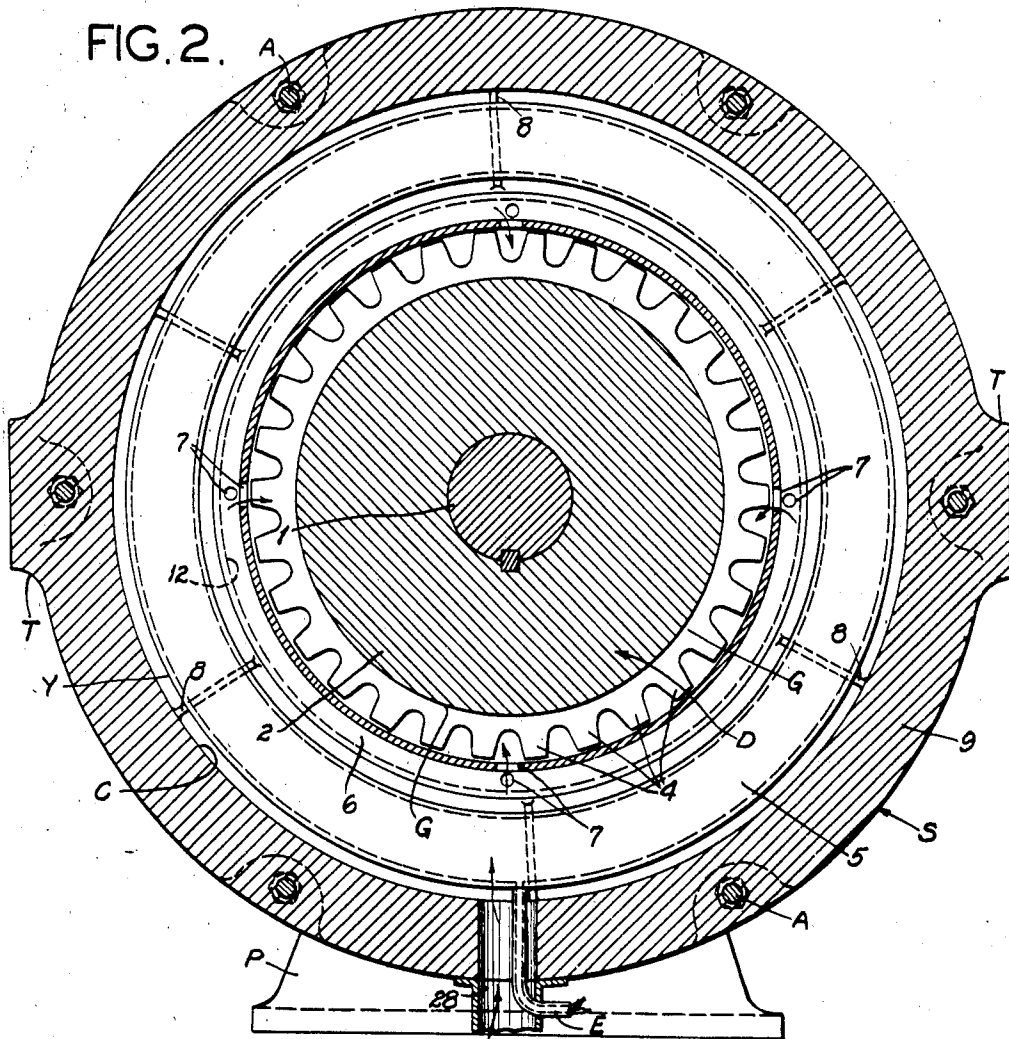
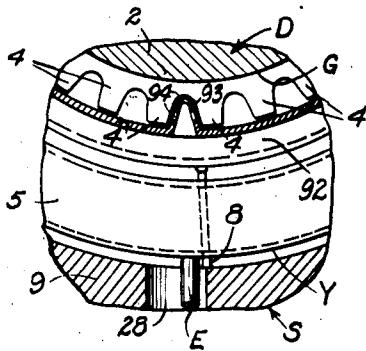


FIG. 8.



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5 Sheets-Sheet 3

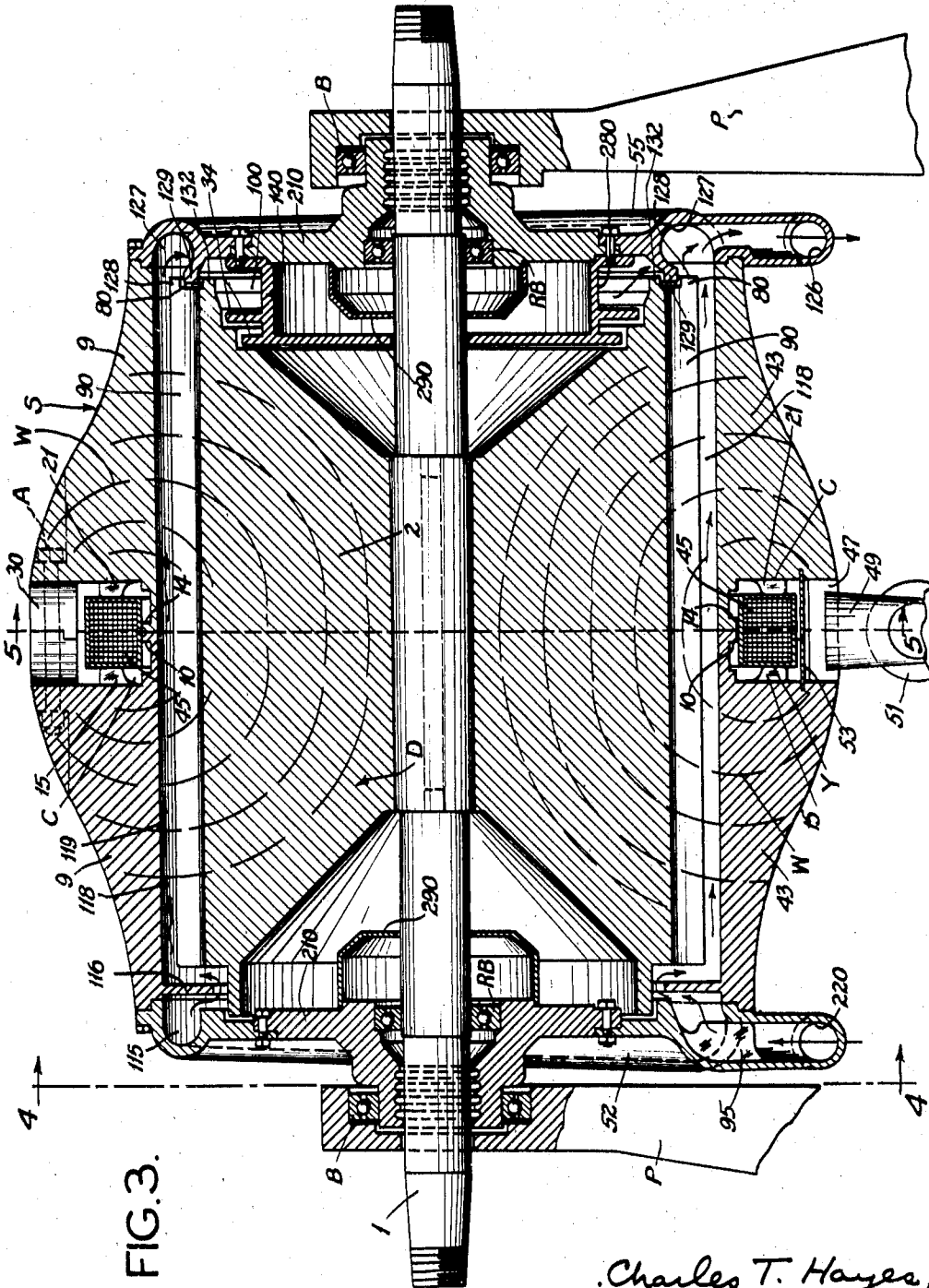


FIG. 3.

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FIG. 4.

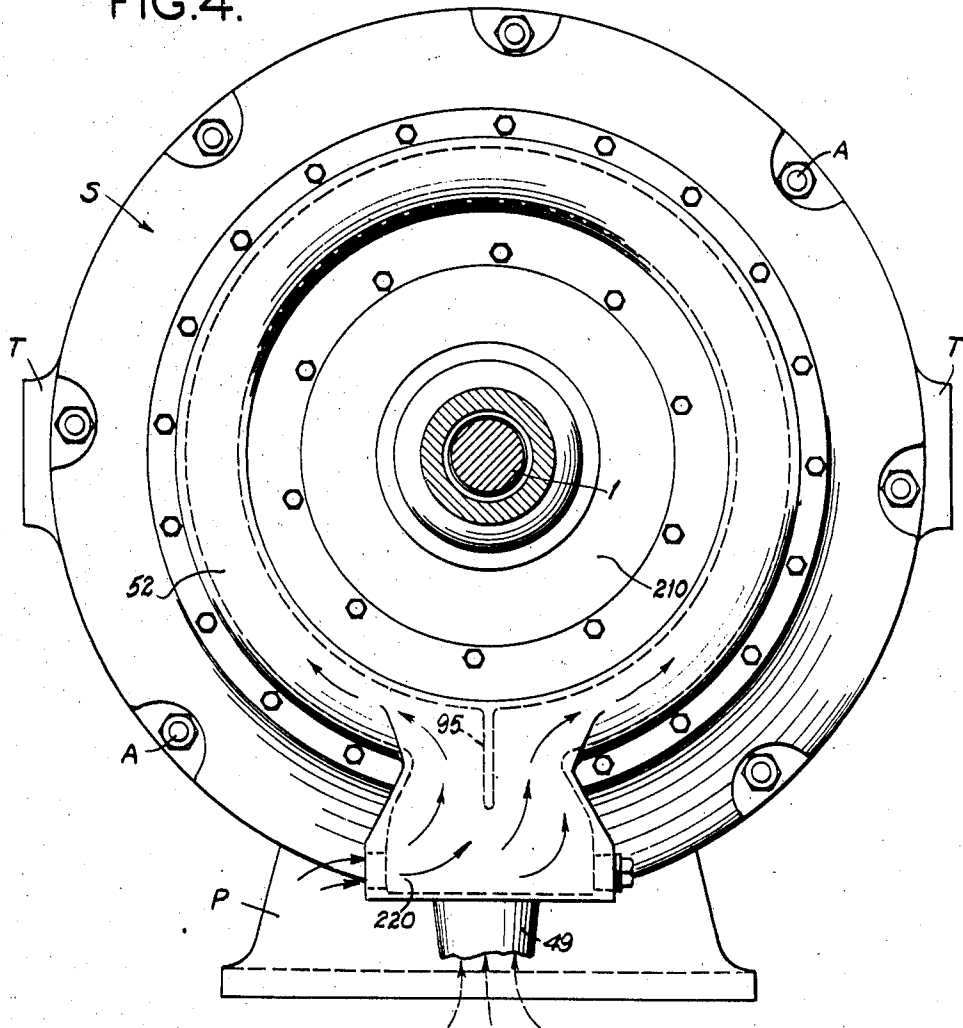
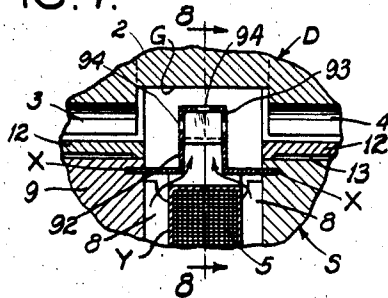


FIG. 7.



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FIG. 5.

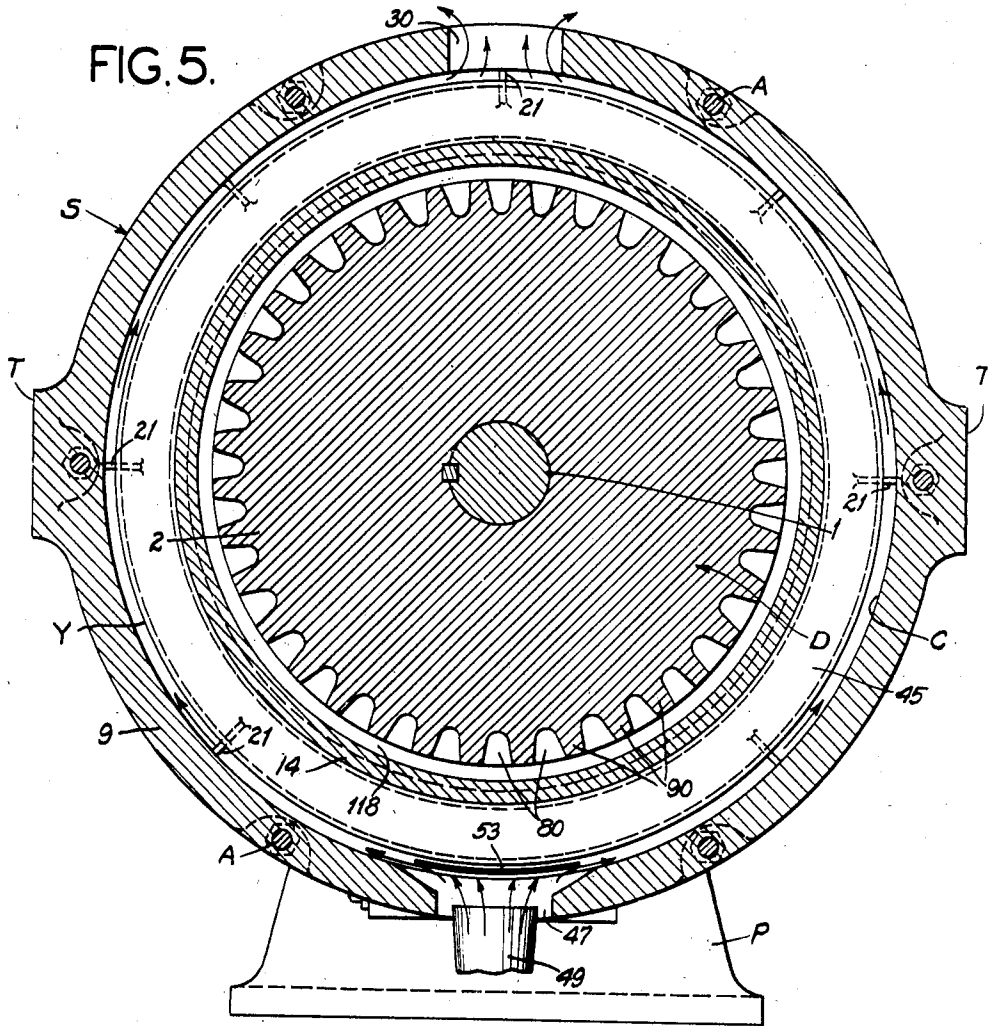
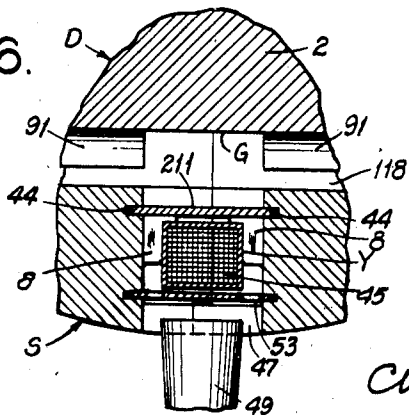


FIG. 6.



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UNITED STATES PATENT OFFICE

2,351,963

ELECTROMAGNETIC APPARATUS

Charles T. Hayes, York House, Worcester, England, assignor to Martin P. Winther, trustee, Waukegan, Ill.

Application March 3, 1943, Serial No. 477,817
In Great Britain September 18, 1942

17 Claims. (Cl. 188—104)

This invention relates to electromagnetic apparatus, and with regard to certain more specific features, to electrical dynamometers of the eddy-current, induction type.

The invention is an improvement upon the eddy-current dynamometers shown in United States Patents 2,106,542 and 2,220,032, dated January 25, 1938, and October 29, 1940, respectively.

Among the several objects of the invention may be noted the provision of means for increasing the cooling capacities of eddy-current dynamometers, so that they will be enabled successfully to convert a substantially greater amount of mechanical energy into heat energy than was heretofore possible in machines of given electrical capacities; the provision of dynamometers of the class described in which heat energy is more efficiently abstracted from the machines with less deleterious effects thereto than heretofore; and the provision of machines of the class described which may be made in smaller sizes for higher energy absorption ratings, and the mechanical constructions of which are relatively simple so that they are economical to build, operate and maintain. Other objects will be in part obvious and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which are illustrated several of various possible embodiments of the invention,

Fig. 1 is a longitudinal section illustrating one form of the invention;

Fig. 2 is a cross-section taken on line 2—2 of Fig. 1;

Fig. 3 is a longitudinal section illustrating another form of the invention;

Fig. 4 is a vertical section taken on line 4—4 of said Fig. 3;

Fig. 5 is a cross-section taken on line 5—5 of Fig. 3, showing certain air flow characteristics;

Fig. 6 is a view similar to Fig. 3, but fragmentary and enlarged, and showing a modified form of coil enclosure;

Fig. 7 is a fragmentary view similar to the lower part of Fig. 1, showing an alternative water-feeding construction; and,

Fig. 8 is a vertical section taken on line 8—8 of Fig. 7.

Similar reference characters indicate corre-

sponding parts throughout the several views of the drawings.

While the invention herein is disclosed as being applied to eddy-current dynamometers, it is to be noted that the improvements can also be applied to eddy-current brakes, clutches, and the like of the type in which power is transmitted from a driving to a driven member by means of an electromagnetic coupling. Such coupling is derived from a magnetic flux circuit which emanates from one of said members and enters the other at relatively high concentration, the relative motion between the driving and driven members causing the concentrated flux to function inductively through eddy-currents to bring about a reactive magnetic condition for driving purposes.

In such apparatus, as is well known, the driven member may be prevented from rotating by suitable means while the driving member continues to rotate, overcoming the resistance to rotation which is set up by the electromagnetic coupling. The power which is developed in overcoming the resistance to rotation generates eddy currents in the surface of the armature ring forming one member of the machine, the heating in the armature ring surface which is consequent upon the generation of these eddy currents being dissipated by the circulation of air, water or other liquid around the armature ring.

Usually the cooling systems hitherto employed for this general class of machines have supplied the air or cooling liquid to the surface of the armature ring relatively remote from the surface in which the eddy currents are generated. However, in some cases cooling has been provided directly on the eddy-current surface; see United States Patent No. 2,334,976 of Martin P. Winther, issued November 23, 1943, for Eddy-current coupling; also United States Patents 854,996 and 2,188,398.

Usually, but not necessarily, the eddy-current generation takes place on the inner circumferential surface of the armature ring, and the cooling liquid circulates around the outer circumferential surface of the armature ring. As a result of this construction there is a thickness of iron or steel between the eddy-current surface and the surface exposed to the cooling liquid. This thickness of metal is determined by consideration of (a) the annular area required for the passage of the magnetic flux and (b) mechanical strength, so that as a general rule the actual thickness is substantial. Now inasmuch as the eddy currents generated have a frequency which

is a function of the number of poles on the one rotating member and its speed of rotation relatively to the other member, it will be seen that this frequency is of a high order and it has been found that the eddy current (and heat) generation takes place in a thin section of the armature nearest to the rotating member carrying the poles. For example, it has been found in some machines, that substantially 95% of the heat generated is created within a thin layer of metal where flux enters and is of the order of only $\frac{1}{16}$ inch or so in depth. The cooling liquid or the greater portion of it is thus spaced from the region in which the eddy currents (and consequently the heat) are generated, and the latter region therefore reaches a temperature considerably in excess of that prevailing on the surface in contact with the cooling liquid. The temperature gradient or difference between the two surfaces is considerable because the iron or steel, from which the ring must necessarily be made, is relatively a poor conductor of heat.

A high temperature on one (usually the inner) surface of the ring and a much lower temperature on the other surface is disadvantageous because (a) the material of the ring is subject to large and undesirable temperature stresses; (b) the electrical resistance of the ring increases with temperature and reduces the eddy-current generation thus limiting the capacity of the machine; and (c) the air gap between the driving and driven members increases with increasing temperature and reduces the flux concentration, thus again limiting the capacity of the machine. In order to reduce these disadvantages to reasonable proportions it has hitherto been necessary to provide in the design sufficient area on the eddy-current surface of the armature ring to ensure a moderate temperature gradient between hot and cool surfaces, and in consequence the whole machine becomes larger than would otherwise be necessary. Any increase in size is undesirable on grounds of cost and of the increased moment of inertia of rotating parts.

By means of the present invention there is obtained a construction enabling faster abstraction of heat and enabling the eddy-current surface of the armature ring to be maintained at a much lower temperature than hitherto; also practically eliminating temperature stresses and at the same time improving the eddy-current generation. The construction also enables the ring surface to be substantially reduced for any given capacity, thus reducing size and cost.

As an illustrative example, in a machine using the older type of remote cooling, a rating of 1500 H. P. is based on the useful rate of heat transmission, but in the same machine the possible electrical rating is actually 6000 H. P. Thus 4500 H. P. of the electrical rating are rendered useless.

Referring now more particularly to Figs. 1 and 2, the pedestals of the machine are shown at P. These carry bearings B providing a rocking mount for the driven stator member shown generally at S. Member S according to the present example is prevented from doing more than rocking by a suitable torque arm connected thereon at one of the pads T. This arm (not shown) is coupled with the ordinary weighing machine for obtaining the force for computing torque, as is known.

The driving member is shown generally at D and constitutes a shaft 1 rotary in bearings RB within the driven member S. Keyed to the shaft 1 is a magnetic rotor 2 having located on its outer

peripheral surface flux-concentrating teeth 3 and 4. These teeth are parallel to the axis of the shaft 1. Between peripheral sets of teeth 3 and 4 is a peripheral groove G. The flux-concentrating purpose of the teeth is clear from said patents above-mentioned.

The stator S is preferably made in two halves 9 bolted together as indicated at A, and formed between them is a peripheral channel C in which are spacing lands 8 for nesting a peripherally wound exciting coil 5. The toric flux field generated by this coil is shown at W. This coil 5 is waterproofed by an enclosing copper container sheath Y. The sheath allows cooling water to flow around the coil without damaging it. The leads of the coil 5 are taken out through suitable water-protective copper tubing E soldered or otherwise fastened to the sheath D. A water-cooling inlet is shown at 28 and it will be understood that similar inlets may be employed around the periphery of the coil 5 if increased water inlet capacity is desired. As is usual with fluid connections on rocking stators, inlet 28 has a flexible lead to it from the main water supply. This is not shown, being common.

Between the two stator halves 9, there is inserted a continuous circular bronze (non-magnetic) belt member 6 which causes the water to be guided around the coil space. Packing is shown at X. The water is allowed to flow out either through a single opening or a number of openings, such as 7, either at one position on the periphery or at several positions. Several positions are shown.

At numerals 11 and 12 are shown soft steel inserts forming eddy-current cylinders. These are locally attached at welded end flanges 16. It is to be understood that the cylinders may be inserted without flanges and attached, but that the flanges provide for easy removal of the cylinders should they become damaged by erosion, corrosion or the like. To remove them it is only necessary to cut away the welded flange sections in a lathe or boring mill to make the cylindrical inserts removable. It is also to be understood that inserts may be dispensed with entirely (as shown on the second form of the invention to be described; Fig. 3) and the inner surfaces of the stator halves used directly for inductive eddy-current purposes. The small air gaps at 13 (Fig. 1) have a low reluctance and they do not substantially reduce the magnetic efficiency of the machine. Small dams 17 are used on the stator beyond the ends of the teeth 3 and 4 of the rotor for purposes to be described.

Attached to the ends of the stator halves 9 by means of studs 23 are hollow circular headers 20. These in turn are attached to central trunnions 21 which are carried by said bearings B. Water outlets are indicated at 24, and baffles at 26. Labyrinth packless seals are constituted by axial flanges 18 on the opposite ends of the rotor 2, and by radial flanges 19 on the headers 20. These, along with diaphragm partitions 219, keep water out of the bearings B and RB.

When water flows radially from the openings 7 into the recess G, the water has a tendency to be distributed around the rotor. If the rotor is moving, which is usually the case when water is being introduced, the teeth 3, 4 pick up the water and throw it vigorously against the inner surfaces of the two eddy-current insert members 11 and 12, and since the water is being forced in at inlet 28 it progresses axially toward the discharge headers 20 at the ends, as shown by the

arrows. The teeth 3 and 4 act as fans causing the water to be slung out radially and maintained on the inner eddy-current surfaces of the stator. The dams such as 17 mentioned as being at the outer ends of the eddy-current rings 11 and 12 assure a substantially continuous depth of water film on the inner surfaces of 11 and 12, which is of a more or less uniform depth. Since the dams are low the water is spread out as a thin film. The ends of the teeth 3, 4 dip into this film and drag the water around the periphery of 11 and 12, and at the same time the water is forced out at the ends as shown at 25. Here it strikes the baffles 26 which tend to absorb from the water any tangential forces which are imparted to the stator. Thus the energy imparted to the water in a tangential direction will be absorbed and indicated as torque in the machine. The water flows very rapidly through the flux gap shown, and cooling is extremely efficient, since heat is abstracted from the points at which the temperature is highest.

The headers 20 carry water from the top of the machine periphery around the machine to the bottom where the water outlets 24 take care of all of the discharge. The flanges 18 have a tendency to throw the water outward and to prevent the water from accumulating to a great depth at flanges 19. This prevents any water from reaching the shaft of the machine. Diaphragms 290 act principally as vacuum guards for bearings R and RB.

Figs. 7 and 8 show a construction of the belt member 6 which delivers water closer into the center of the machine. It will be seen from Fig. 1 that the innermost diameter of the member 6 is necessarily larger than the outermost diameter on the teeth 3 and 4 of the rotor 2. This is for assembly purposes. In Figs. 7 and 8, a belt member 92 is used, having inwardly reaching nozzles 93 which are small enough to be introduced between spaces between adjacent teeth on the rotor, as is clear from Fig. 8. The holes in the nozzles are shown at 94. The advantage of this modification is that water is introduced inside of the centrifugal influence of the rotor and in a low pressure zone within the recess G. Thus the pressure for driving water into the apparatus needs not overcome any pressure due to centrifugal force and in fact may be aided thereby, the rotor providing the primary pumping action.

In Fig. 3 is shown another form of the invention in which like numerals designate like parts. In this form, water is introduced at one end and carried through the entire gap of the machine. The stator S is composed of two circular sections 43 including lands 10, 14, 15 and 21 for the flux-exciting coil 45. These lands may be integral with halves 43 or welded on, if desired. The coil in this case is air cooled, an air inlet being shown at 47. This inlet is somewhat larger than the nozzle 49 of an air blower 51. Air is directed into the opening 47 from the nozzle 49. The freedom between 47 and 59 allows for the required swinging or rocking movement of the stator S. A baffle 53 is inserted beneath the coil 45 and over nozzle 49 so that the air immediately divides and flows through the passages around the coil 45 around opposite sides of the machine. It then passes to the outlet 30. Fig. 5 shows this passage.

In this form of the invention, the water is caused to flow in at an inlet 220 of one circular stator header 52. The flow divides at baffle 95

and follows the circular header channel 115 and then over a circular dam 116, then through an air gap 118 and across the entire machine to the opposite end where the water is discharged into channel 127 of a circular stator header 55. It flows then to the lower portion of the machine to be discharged from an outlet 126.

The circular dam 116 is important because the water is brought into contact with the rotor 2 at a short radius and hence the water is positively forced outwardly toward the inner stator surface 119 and across the machine toward the outlet chamber 127. When the velocity of the rotor 2 reaches any substantial rate, the water entering at 220 is more or less uniformly distributed throughout the circular inlet chamber 115, so that the water has a tendency to overflow the dam 116 substantially throughout the entire periphery of the machine, and there is no special tendency for the water to enter gap 118 only at the bottom of the machine. In short, the rotor 2 compels the water to form a cylindrical ring around the entire machine. It is to be understood that the circular dams, although providing a difference in head, can be dispensed with by supplying adequate water pressure at inlet 220.

Water seals shown at 34 on a guard 140 prevents the water from flowing down into the inside of the machine and resulting circular chamber 130 conducts any water into the circular chamber 127. Excess is led down to the bottom 280 of chamber 100 where centrifugal force carries it into the lower part of the ring 127 for final discharge at outlet 126.

It is to be noted that the rotor teeth 90 in Fig. 3 are continuous throughout the length of drum 2, and that they are extended as at 80 at the outlet end to form endwise extension blades 128 which serve to direct water into the chamber 127 over an edge 129 of header 55. Inside the edge 129 the rotor is provided with a sealing rim extension 132.

Diaphragms 290 on opposite ends are principally vacuum guards for the lubricating chambers around the rotor bearings RB. It is to be understood that the guard 140 and water seals 34 may, if necessary, also be duplicated at the left-hand side of the machine to take care in some designs of any spill in the water entering from the chamber 115.

The headers 52 and 55 of Fig. 3, or 20 of Fig. 1, which contain the water channels, may be made of non-magnetic material, such as brass or bronze, or non-magnetic iron, if desired. This use of non-magnetic material increases the magnetic efficiency of the machine.

It is clear from Fig. 3 that trunnions 210 borne in the bearings B form the support for the entire stator S, and the driving shaft 1 the support (in bearings RB) for the rotor 2. Pedestals P again carry the bearings B. A choice of pads T is again provided for the torque transmission apparatus (not shown) to the weighing scales (also not shown).

As stated, the coil 45 is isolated from the water by means of the special lands 10 and 14 which, as shown, are integrally cast with the steel stator halves 43, but which may be welded in place. Although the introduction of these elements in the form of steel will cause some magnetic inefficiency, they are made thin enough so that they become magnetically saturated. However, in case higher magnetic efficiency is desired, the non-magnetic band such as the bronze shown

in 211 (Fig. 6) may be inserted between the two stator halves in slots in the bottom of which packing 44 is inserted so as to produce a seal against entrance of water to the coil. While the recess thus formed in the periphery of the stator S does not substantially interfere with water flow, it is desirable to reduce centrifugal spinning of water therewith. This is accomplished by cutting away opposite portions of the rotor teeth, to make two sets as indicated at 91 (Fig. 6). If desired, this feature may also be used opposite the lands 10 and 14 in the form of the invention shown in Fig. 3, if these be welded in a recess.

It is intended that the rate of water flow be such that the ends of the teeth on the rotor barely dip into the centrifugally formed cylinder of water on the interior eddy-current surfaces of the rotor. To this end the water outlets such as 24 (Fig. 1) and 126 (Fig. 3), as indicated in the drawings are disposed below the level of the substantially lowermost portions of the smooth flux receiving surface of the stator, which prevents building up of any substantial bulk of water in the stator beyond the film determined by the flow rate and the sweep of the rotor teeth. This avoids filling the spaces between rotor teeth and avoids the consequent unmeasured energy losses. It is of course clear that in both forms of the invention water is brought to the space between the rotor and the stator by means of a circular header which ensures proper peripheral distribution as the cooling space is entered. In this connection the space around coil 5 in Fig. 1 may be considered to be an inlet header. Also the heated water is taken off by a circular header which relieves the space at all peripheral points.

The torque effect of the water on the machine is very small because only the very tips of the rotor teeth are allowed to dip into the film of water which covers the stator eddy-current surface. When high peripheral velocities are arrived at, the water torque effect becomes fairly constant, that is, does not change with more increase in speed. Hence, although the water contributes to the torque of the machine, it is a relatively stable and constant part of its performance. In this respect the form of the invention shown in Figs. 1 and 7 is preferable to that of Fig. 3, because the axial length of a given pass of water through the machine is shorter than a given pass in Fig. 3. This is due to the split passages in Fig. 1, resulting in the length of each cylindric film of water being less than its diameter. The advantage of this will appear from the following:

Any given cylindric film of water which is positioned on the inside of the outer cylindric member should be equal in depth throughout its axial length as it is possible to obtain, so that the rotor teeth will dip into it equally throughout the lengths of the teeth.

However, it requires some difference in depth of a given cylindric film between its inlet region and the outlet region in order to obtain a hydraulic head which will produce the hydraulic gradient necessary to force it to flow axially. The longer the axial distance that the water must travel the greater will be the hydraulic head required, and hence the greater will be the difference between the liquid depth near the inlet region compared to its depth near the outlet region. Thus a shorter axial passage of a given cylindric film minimizes the required difference in film depth between its ends, and hence minimizes inequalities of the dipping depth of each rotor tooth from one end of the tooth to the other. It

is very desirable that a tooth at no point be dipped too deeply into the water film, otherwise hydraulic churning and surging action increases.

As indicated in Fig. 1 the axial length of each water passage between the rotor and stator, respectively to the left and right of the central inlet belt, are each less than the diameter of the machine.

It is desirable that surfaces of the machine which may become corroded by water be chromium- or cadmium-plated for protection.

While most of the advantages of the invention are clear from the above, the following are also important.

In the operation of prior eddy-current machinery one serious difficulty caused by cooling through the relatively thick iron is the violent changes in torque due to the slowness with which heat is transferred through the iron. This is due to the fact that the eddy-current resistance of the iron changes with the temperature. When the resistance to the passage of eddy currents rises, the currents drop in value, and since the torque is proportional to the strength of the eddy currents, the torque will drop off when the iron becomes hot and will increase when the iron becomes cold. The seriousness of this type of performance can be realized from the following example.

If an aircraft engine is running at a moderately low speed, the horsepower being absorbed by the dynamometer is relatively low, and if a rapid increase in speed and power is desired, as is common in the aircraft engine industry for testing purposes and particularly to simulate the so-called "take-off" tests, it is apparent that the heating in the iron suddenly rises very rapidly. If temperature responsive valves are used for increasing the water supply, there is some lag in spite of everything that can be done in the opening of the valves to supply more water. Meantime, the iron becomes hot and the torque absorbed drops off. When the inrush of colder water finally reaches the iron, an additional time is required for the heat to be transferred to the colder water, and after a considerable time period has elapsed the torque suddenly increases.

Furthermore, in tests at constant speeds, the same difficulty is met with due to an oscillating effect of torque results with the opening and closing of water control valves. The difficulty has caused added expense for extra equipment required to counteract it.

With the new type of cooling herein described, the dynamometer rotor literally acts as a circulating pump supplying water directly to the heated surfaces. Furthermore, the rotor of the dynamometer imparts a high velocity to the water so that ideal cooling conditions are obtained. Also, some of the energy of the engine is used in circulating the water, and at the same time the torque required to do this is registered on the scales.

The total volume of water moving peripherally around the machine at any one instant is less than the total of volume spread around through the channels of the older type cooling rings. Since the total volume of water to be heated at any instant is much less than in the older style, and it is spread out in a flatter sheet or film, the temperature transfer is substantially faster (in fact almost instantaneous) and therefore the temperature of the iron does not vary so much as it does in the older types of machines.

Thus, high velocity and quick transfer of the water across the surface of the dynamometer is

obtained, and since the water is in direct contact with the heated surface in which eddy-currents are generated, the old oscillations in torque are eliminated or at least reduced. This is an advantage from the standpoint of accuracy of testing, as well as from the standpoint of economy.

It has also been found that with the new system the iron is kept cooler on the average of the order of 50° to 200° F. than on the older systems, due to the intimate contact of water with the hot surface. The average torque of the machine is increased over the average torque available from the older type by as much as from 10% to 30%. Therefore, this raises the capacity of the machine for any given weight and contributes to economy, since smaller sizes of machine can be used for higher powers than are now possible. In fact the horsepower capacity of a dynamometer of given dimensions and weight can substantially be doubled over the older sizes.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. In apparatus of the class described, outer and inner relatively rotary coaxial cylindric magnetic members, the outer one of which is hollow and the inner one solid, means for generating a magnetic field and linking said members, the hollow member having a smooth flux-receiving surface and the solid member a flux-concentrating toothed surface, whereby heat is generated at the smooth surface, and means for circulating liquid between said members and in contact with the flux-receiving surface comprising at least one inlet for the circulating liquid and at least one outlet therefor disposed below the level of the substantially lowermost portions of said smooth flux receiving surface, said liquid being supplied at such a rate as to maintain on the smooth surface a cylindric film by rotary centrifugal action thereon of the toothed surface, said film having a discrete surface adjacent to the ends of the teeth on the toothed surface.

2. In apparatus of the class described, relatively rotary interior and exterior magnetic members, a field coil mounted on one of said members and providing a magnetic field interlinking said members, one of the members having flux-concentrating means adjacent the other, said members where adjacent providing a magnetic gap therebetween, and channel means around the coil and communicating with the gap for circulating water around said field coil and through said gap.

3. In apparatus of the class described, relatively rotary interior and exterior magnetic members, a field coil mounted on one of said members and providing a magnetic field interlinking said members, one of the members having flux concentrating means adjacent the other, said members where adjacent providing a magnetic gap therebetween, and channel means around the coil and communicating with the gap intermediate its ends for circulating water serially first around said field coil and then through said gap in two directions.

4. A dynamometer comprising a hollow cylindric magnetic stator, a rotor within the stator having flux-concentrating teeth spaced from the

cylindric interior of the stator to provide a gap for concentrated flux, a peripheral field coil carried by the stator providing a flux field interlinking the rotor and stator, and means for circulating a cooling liquid around said coil and thence through the flux gap between the rotor and the stator.

5. In a dynamometer, a hollow stator having an interior eddy-current surface in cylindric form, a solid rotor therein having exterior flux-concentrating teeth spaced from said interior surface whereby a flux gap is formed for flux concentrations from said teeth, said teeth being formed in two belts with non-toothed space therebetween in the rotor, a peripheral field coil mounted in said stator opposite said non-toothed space, means providing a water channel around said coil and including connections with the space between the rotor and stator, outlet headers on the ends of the stator and cooperating with the rotor to form outlet passages, and means for forcing water around said coil, through said connections and between the rotor and the stator to said outlet headers.

6. In a dynamometer, a magnetic stator having an interior cylindric eddy-current surface, a magnetic rotor within the stator having flux-concentrating teeth spaced from said surface, a peripheral field coil mounted in the stator and providing a flux field interlinking the rotor and the stator through said teeth and said eddy-current surface, opposite liquid headers on the rotor and cooperating with the ends of the stator, means for introducing liquid between the rotor and the stator through one header and extracting said liquid through the other header, means providing circulating space around said coil in the stator, and air blower means for forcing air through said space for cooling the coil independently of liquid flow.

7. In a dynamometer, a stator having an interior cylindric eddy-current surface, a rotor within the stator and having exterior flux-concentrating teeth the ends of which are spaced from said surface to provide a gap for concentrated flux, means engendering a flux field linking said rotor and said stator through said teeth, means for introducing cooling liquid between the rotor and the stator at one axial point and abstracting it at another axial point comprising at least one inlet for the cooling liquid and at least one outlet therefor disposed below the level of the substantially lowermost portions of said eddy current surface, said teeth acting upon the liquid to maintain a substantially cylindric film on said eddy-current surface, the rate of flow of said liquid being such that the film reaches little more than to the ends of said teeth and forming a hollow cylinder of water having a discrete inner surface just within the teeth ends.

8. A dynamometer comprising paired members annularly abutted to form a composite annular stator, a rotary shaft passing axially through said annular members, a rotor on said shaft, end closure members on the stator forming with said paired annular members a water compartment between the rotor and the stator, said annular members being recessed at their abutments, an annular coil in the recess providing a toric flux field interlinking the rotor and the stator and passing through the water in the compartment, and an annular coil segregating means located between said annular members within the recess to form an annular compartment for the coil segregated from said water compartment.

9. A dynamometer comprising individual paired members annularly abutted to form a composite annular stator, a rotary shaft passing axially through said annular members, a rotor on said shaft, end closure members on the stator forming with said paired annular members a water compartment between the rotor and the stator, said annular members being recessed at their abutments, an annular coil in the recess providing a toric flux field interlinking the rotor and the stator and passing through the water in the compartment, a one-piece annular sealing means within said recess and forming a one-piece water-tight connection between said pair of annular members within the recess to provide an annular substantially water-protected coil compartment between said annular members.

10. A dynamometer comprising paired members annularly abutted to form a composite annular stator, a rotary shaft passing axially through said annular stator, a rotor on said shaft, end closure members on the stator forming with the annular members a water compartment between the rotor and the stator, said annular members being recessed at their abutments, an annular coil in the recess providing a toric flux field interlinking the rotor and the stator and passing through the water in the compartment, a separate annular member within said recess and having water-tight connections with the adjacent annular stator members thus providing an annular substantially water-protected coil compartment between said annular members and the outside of the water compartment.

11. A dynamometer comprising paired members annularly abutted to form a composite annular stator, a rotary shaft passing axially through said annular members, a rotor on said shaft, end closure members on the stator forming with said paired annular members a water compartment between the rotor and the stator, said annular members being recessed at their abutments, an annular coil in the recess providing a toric flux field interlinking the rotor and the stator and passing through the water in the compartment, and an annular coil segregating means located between said annular members within the recess to form an annular compartment for the coil segregated from said water compartment, said coil segregating means being non-magnetic.

12. A dynamometer comprising a cylindric stator, a rotor located within the stator, one of said members having a smooth cylindric surface and the other a polar surface, means providing a flux field linking said members, end members attached to the stator, water seals between said end members and the rotary parts providing an enclosed cylindric water space between the rotor and the stator, the rotor and stator being shaped to provide an axially flowing mere cylindric sheet of water adjacent to the periphery of said stator, water inlet means guiding water directly to said peripheral sheet at such a rate as to maintain the sheet form of said cylindric sheet of water, and water outlet means disposed below the level of the substantially lowermost portions of said smooth cylindric surface.

13. A dynamometer comprising a cylindric stator member, a rotary shaft passing axially through the stator, a rotor member attached to the shaft and located within the stator, one of said members having a smooth cylindric eddy-current surface and the other a polar surface, means providing a flux field linking said members, end members attached to the stator, water

seals between said end members and peripheral portions of the stator ends spaced outwardly from the shaft, thus providing an enclosed water space between the rotor and the stator, inlet means for bringing water directly to said water space, the water remaining in said space until removed from the machine, the rate of flow of the water being controlled and the rotor being shaped to provide in view of its rotation a mere cylinder of water adjacent its periphery in flowing from said inlet, and outlet means for carrying away the water disposed below the level of the substantially lowermost portions of said cylindric eddy current surface.

14. A dynamometer comprising a cylindric magnetic stator, a magnetic rotor within the stator, one of said members having flux-concentrating means thereon, an annular field coil carried in the stator and providing a toric flux field interlinking the rotor and the stator, and enclosures on the stator cooperating with the rotor and having water outlets, and means for introducing water into the space between the rotor and the stator at a point between said end members.

15. A dynamometer comprising a cylindric magnetic stator, a magnetic rotor within the stator, one of said members having flux-concentrating means thereon, an annular field coil carried in the stator and providing a toric flux field interlinking the rotor and the stator, and enclosures on the stator cooperating with the rotor and having water outlets, and means for introducing water into the space between the rotor and the stator at a point between said end members for split flow between the rotor and the stator to the end members respectively.

16. Apparatus of the class described, comprising a hollow cylindric inductive member having an inside surface, a polar field member providing flux-concentrating surfaces near the inner surface of the cylindric member, means providing a flux field inter-linking said members through the inside and the flux-concentrating surfaces, said cylindric and polar members being relatively rotary and adapted to be coupled magnetically thereby causing said inside cylindric surface to be heated, inlet means for introducing a cooling liquid at one axial point on said hollow cylindric surface, said relative rotary movement between said cylindric and polar member causing said cooling liquid to be centrifugally forced against said cylindric surface, and means for escape of said liquid from said cylindric surface from a second axial point thereon, outlet means for receiving liquid from said second axial point, said outlet means being disposed below the level of the substantially lowermost portions of said cylindric surface, the rate of introduction of the cooling liquid being such that, in view of said outlet location, only a thin cylinder of liquid is maintained on the cylindric surface of a depth permitting at most only a superficial dipping therein of the polar parts of the polar member, the axial length of the liquid cylinder being less than its diameter.

17. Apparatus of the class described, comprising a hollow cylindric inductive member having an inside surface, a polar field member providing flux-concentrating surfaces near the inner surface of the cylindric member, means providing a flux field inter-linking said members through the inside and the flux-concentrating surfaces, said cylindric and polar members being relatively rotary and adapted to be coupled magnetically thereby causing said inside cylindric surface to be heated, inlet means for introducing a cooling

liquid at one axial point on said hollow cylindric surface, said relative rotary movement between said cylindric and polar members causing said cooling liquid to be centrifugally forced against said cylindric surface, and means for escape of said liquid from said cylindric surface from a second axial point thereon, outlet means for receiving liquid from said second axial point, said outlet means being disposed below the level of the

substantially lowermost portions of said cylindric surface, the rate of introduction of the cooling liquid being such that, in view of said outlet location, only a thin cylinder of liquid is maintained on the cylindric surface of a depth permitting at most only a superficial dipping therein of the polar parts of the polar member.

CHARLES T. HAYES.

CERTIFICATE OF CORRECTION.

Patent No. 2,351,963.

June 20, 1944.

CHARLES T. HAYES.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: In the heading to the printed specification, line 7, for "In Great Britain September 18, 1942" read --In Great Britain September 8, 1942--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 24th day of April, A. D. 1945.

Leslie Frazer

Acting Commissioner of Patents.

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