

Jan. 15, 1946.

M. P. WINTHER

2,393,211

EDDY-CURRENT ELECTRIC APPARATUS

Filed Dec. 10, 1943

3 Sheets-Sheet 1

FIG. 1.

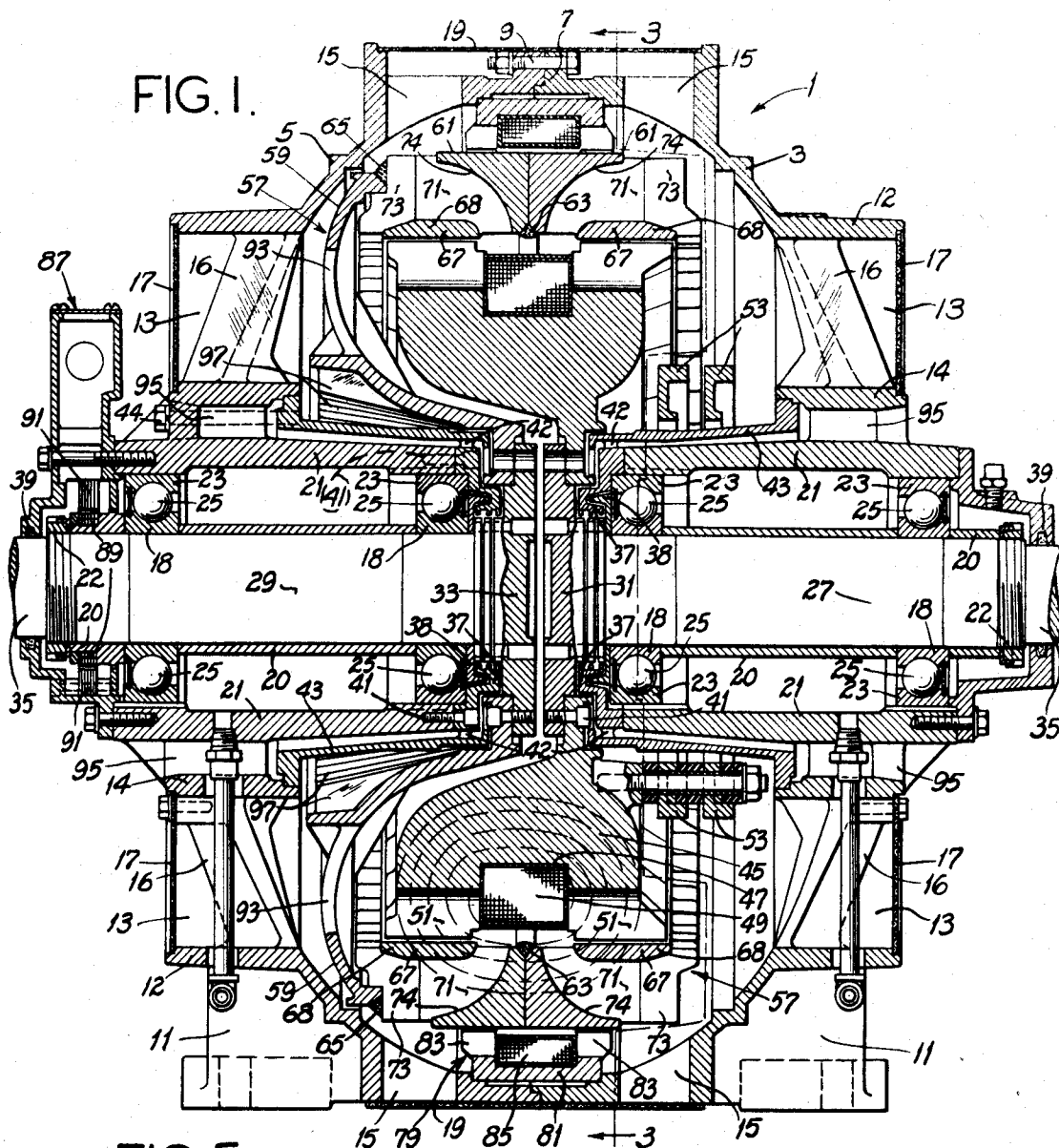
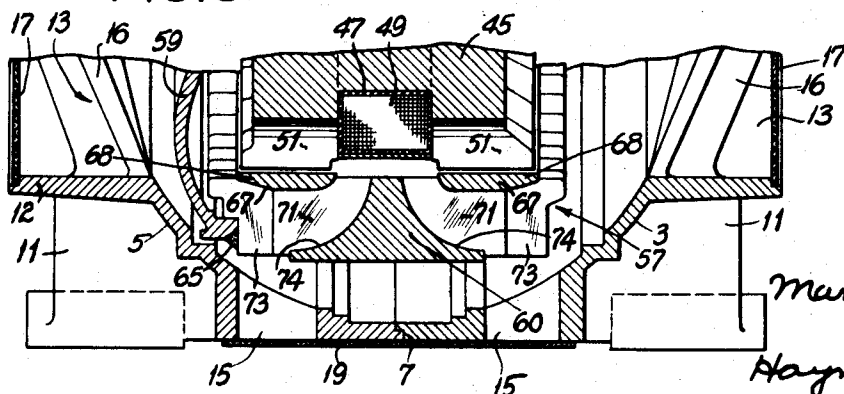


FIG. 5.



Martin P. Winther,
Inventor.
Haynes and Henig
Attorneys.

FIG. 2.

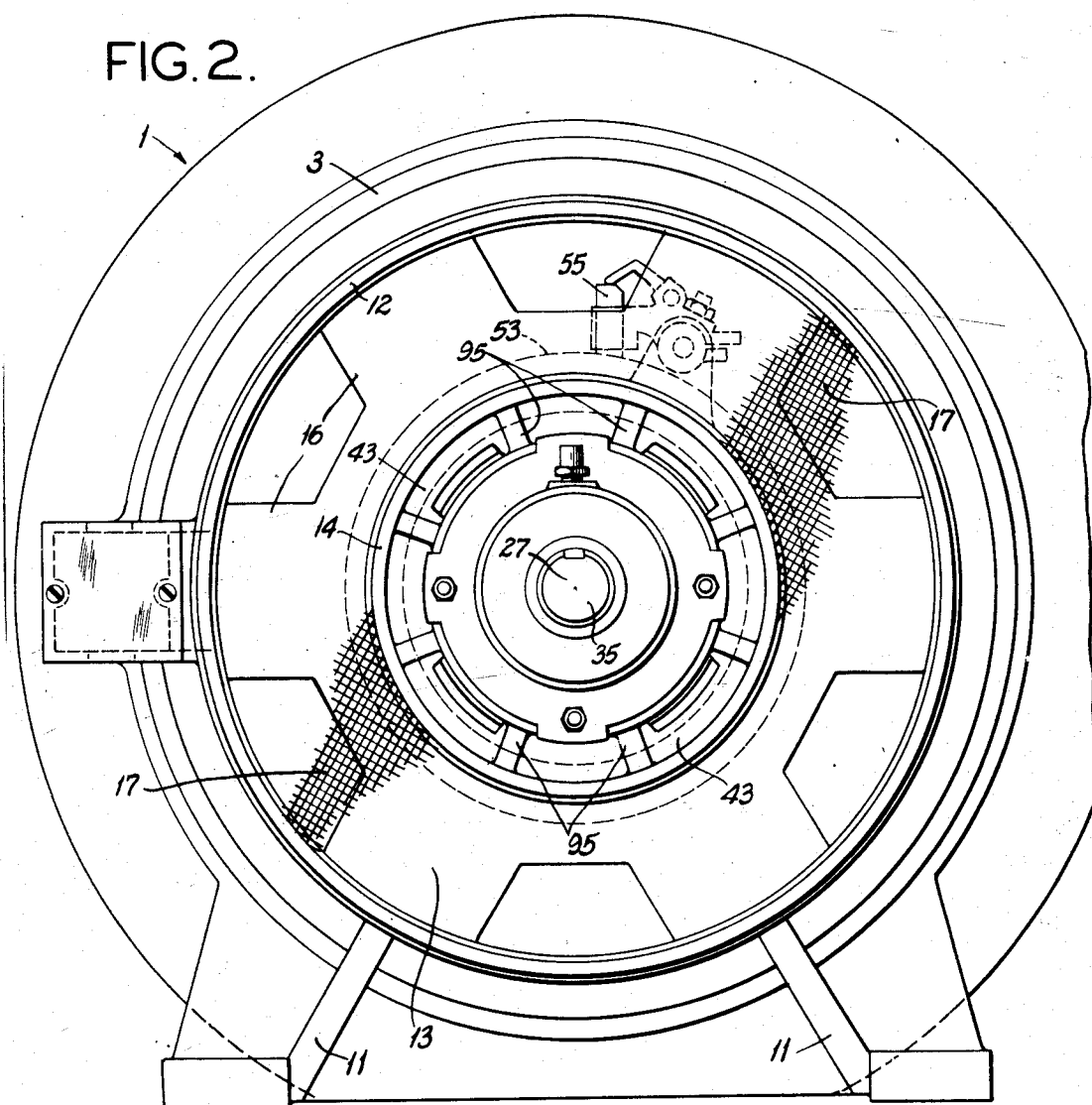
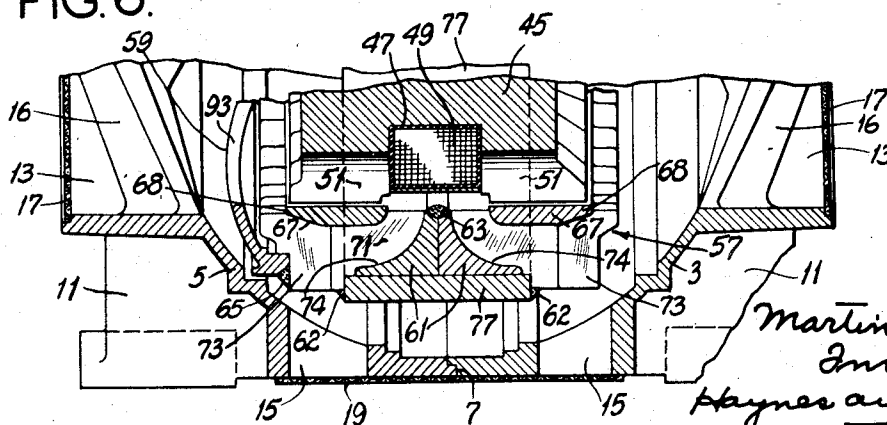


FIG. 6.



Martin P. Winther,
Inventor.
Haynes and Koenig
Attorneys.

FIG. 3.

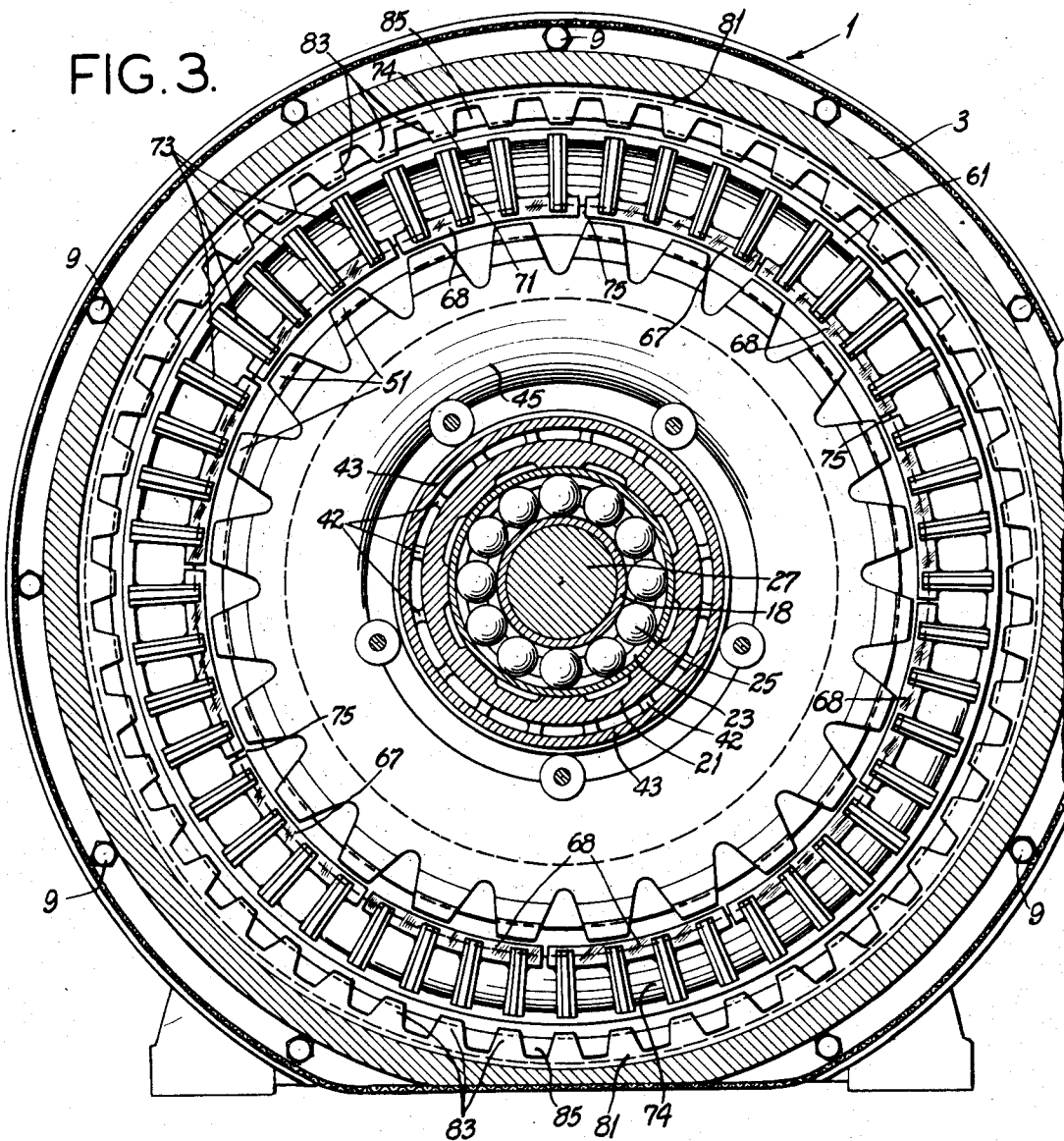
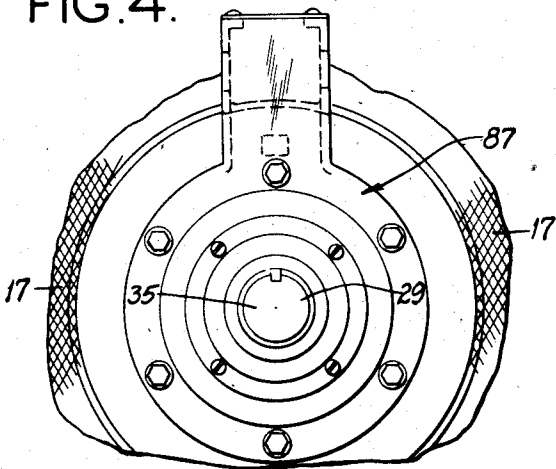


FIG. 4.



Martin P. Winther,
Inventor.
Haynes and Koenig,
Attorneys.

UNITED STATES PATENT OFFICE

2,393,211

EDDY-CURRENT ELECTRIC APPARATUS

Martin P. Winther, Waukegan, Ill., assignor to
Martin P. Winther, Waukegan, Ill., trustee

Application December 10, 1943, Serial No. 513,801

12 Claims. (Cl. 172-284)

This invention relates to eddy-current electric apparatus, and more specifically to eddy-current couplings, clutches, brakes, dynamometers and the like.

Among the several objects of the invention may be noted the provision of an electric eddy-current slip coupling, clutch, brake, dynamometer or the like having a more constant flux gap over a wide temperature range; the provision of a clutch of the class described having a low manufacturing cost because the use of pilot bearings may be avoided in view of said improved gap condition; the provision of a clutch of the class described which, by eliminating said pilot bearings, also eliminates the usual critical lubricating requirements encountered therewith; and the provision of a clutch of this class which may be made with and which retains a vibration tolerance which is less than that which could be maintained with said pilot bearings. 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 of one form of the invention;

Fig. 2 is a right-end elevation of Fig. 1;

Fig. 3 is a vertical section taken on line 3-3 of Fig. 1;

Fig. 4 is a fragmentary left-end view of Fig. 1;

Fig. 5 is a fragmentary longitudinal section corresponding to the lower regions of Fig. 1 but showing an alternative form of the invention; and,

Fig. 6 is a view similar to Fig. 5 and showing another alternative form.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

The terms slip clutch and slip coupling as used herein are to be taken as synonymous.

In the past, in certain apparatus of the general class described herein, it has been common practice to use a pilot or quill bearing between the driving and driven members. This was made necessary because of the fact that a small, cold, air gap was imperative between the rotors in order that the clutches or couplings could be made in sizes that were commercially practicable. The

air gap, under cold starting conditions, was made as small as possible without actually having mechanical interference. Becoming warm under operating condition, the outer rotary member, which usually was the eddy-current member, would expand away from the rotating field member or spider, thus considerably increasing the air gap. As the torque ratings had to be established under maximum gap conditions, that is, under maximum operating temperatures, such ratings were based on the characteristics prevailing when the air gap was at a maximum, which, in itself, was satisfactory enough.

However, as the coupling cooled to normal room temperature, the air gap would again shrink to the minimum value, and when the coupling was again started for a succeeding cycle of operation, it would, for a time, operate with a small air gap. Then, if perchance, an operator would fully excite the field under such conditions of minimum air gap, the eccentric or off-center force generated between the magnetic surfaces would be tremendous, even with only slight variation in the air gap due to misalignment or looseness in the bearings.

Off-center pull varies approximately with the inverse square of the air gap. Thus $\frac{1}{4}$ -inch air gap will have four times the off-center pull of a $\frac{1}{2}$ -inch air gap.

The above made necessary a pilot bearing directly between the driving and driven members.

One of the remedies was found to be obtained through the use of a copper lining inside of the eddy-current drum of the order of a $\frac{1}{8}$ -inch in thickness. This separated the magnetic members sufficiently to reduce the off-center pull to a value that did not become dangerous to the operation of the machine when starting. While this was a substantial improvement, the manufacturing costs of the liner was relatively high. The present invention eliminates both the need for the liner and the pilot bearing and maintains a close air gap when needed, and automatically prevents formation of too small a gap under starting conditions when not needed, thus minimizing said eccentric loading condition.

In order that the objection to a pilot bearing may be fully understood, it may be explained that the method of lubricating anti-friction bearings of this class is by means of grease. It is not very often possible to use oil, unless special precautions are taken and these precautions are also costly. Where grease is used, which is by far in most of the cases, centrifugal force will cause the grease to form a circular sheet clinging to

the outer surface of the bearing member, which in the case of a pilot bearing rotates. If the grease content of the bearing is exactly right, the thickness of this layer in the bearing will be such as to feed a small volume of the grease to the bearing constantly. If, however, the grease content is too low, the layer will be so thin that no grease will enter the bearing. If, on the other hand, the grease content is too high, it will form a layer with a considerably smaller inside diameter than the inside diameter of the ball bearing outer race. The result is that a copious flow of grease to the bearing is constantly had with a resultant extreme agitation of the grease with accompanying generation of heat. This heat soon destroys the grease, volatilizing the lighter ends and before long the bearing is destroyed. Thus it will be seen how critical lubrication of pilot bearings is and how desirable it is to eliminate it, or take other suitable precautions.

There are other mechanical reasons for avoiding the use of a pilot bearing. For example, the normal tolerances of the eccentricity in such bearings are not close enough to make the coupling always operate smoothly. Machines of this type are balanced to a vibration tolerance of one mil, or .001 inch. The normal eccentric tolerance of a ball bearing is from one and one-half to three times one mil. Thus a clutch may be balanced with the bearing running out as low as one mil and be perfectly smooth until but not after this bearing wears down. Also, a newly installed bearing may run out three mils. Furthermore, if a newly fitted bearing has a run-out 180° from that of the original bearing, the machine will be very badly out of balance. The difficulty is accentuated in pilot bearings because these have rotating inner and outer races which must fit tightly in the housing and on the shaft without physical play between the housing and the outer race of the bearing. Thus the eccentricity of the outer race and the inner race are both elements in producing eccentric rotation of the two members, which would not be a condition met with when using a bearing with a stationary outer race in a stationary housing. In the latter case only the eccentricity of the inner race becomes a factor in the trueness of rotation of the unit. According to the construction herein described only bearings having stationary outer races are used.

Referring now more particularly to Fig. 1, there is shown at numeral 1 a stationary case made in two cup-shaped halves 3 and 5 which are substantially enough identical so that they may be cast from a single main pattern. Then, by slight differences in auxiliary loose pattern pieces, or in machining as, for example, as the tongue-and-grooved joint 7, they may be adapted to one another or other parts. Parts 3 and 5 are thus organized at 7 by means of bolts 9 to form a complete hollow frame.

Each frame member 3 and 5 has similar legs 11 and also a series of axially located ports 13 for air inlet purposes, and a series of radial ports 15 for air outlet purposes. Suitable annular screens 17 cover the ports 13 and a cylindric screen 19 covers the outlet ports 15. The ports 13 are within annular rings 12 and 14 connected by arms 16. Connected to the inner rings 14 by means of webs 95 are cylindric bearing sleeves shown at 21. These carry the outer stationary races 23 of ball bearings 25. One set of bearings 25 (the righthand set in Fig. 1) support a rotary

drive shaft 27 and the other set of bearings 25 (left-hand set) support a rotary driven shaft 29.

The shafts 27 and 29 are flanged at their ends as indicated at 31 and 33 respectively. The shafts 27 and 29, including the flanges 31 and 33 respectively, are preferably made identical. Their end portions 35 are broken away in Fig. 1, but it is to be understood that these are identical stubs to which the desired driving and driven members are keyed. The inner races 18 of the bearings 25, as well as other appurtenances, are held in position by suitable spacing sleeves 20 clamped by nuts 22. The identicalness of shafts 27 and 29, along with the substantial identity between the frame members 3 and 5 is very desirable from a manufacturing viewpoint.

Suitable inner lubricant-retaining, stationary labyrinths 37 are bolted to the inner ends of the cylinders 21. These cooperate with rotary labyrinth members 38 on the rotary shafts respectively. At the outer stub ends 35 suitable oil retainers 39 are used. The labyrinth members 37 are held in place by means of studs such as exemplified at numeral 41. The labyrinth members 37 are the ends of spaced cylindric sleeve members 43 surrounding the cylinders 21, being spaced by webs 42 and bolted at the outer ends as indicated at 44. Thus air may flow in between rings 14 and sleeves 43 on the one hand and the respective cylinders 21 on the other hand.

On the flange 31 of the driving shaft 27 is bolted a magnetic field member 45 recessed at 47 to provide for an annularly wound field coil 49 located between two peripheral rows of tapered, flux concentrating teeth 51. These teeth 51 concentrate the toric flux field generated around the annular coil 49 when the latter is electrically energized. They are also extended and tapered endwise to act as air fans. Exciting current is circulated through the coil 49 through suitable slip rings 53 and brushes 55 (see Figs. 1 and 2). Wiring between the slip rings and the coil is not shown, the necessary character of which is obvious.

The armature of the coupling comprises a rotary composite ring indicated generally at numeral 57. This armature is made up in either two or more pieces, depending upon the speed at which it is to be rotated. For nominal, or slow speed operation such as 1200 R. P. M., the three piece form illustrated in Fig. 1 is suitable. In all forms there is used a main cone-shaped supporting member 59 having openings 93, which is bolted to the flange 33 of the driven shaft 29. In the case of the Fig. 1, the remainder of the composite ring 57 is made in two identical cast steel halves 61, welded at the center as exemplified at 63 and elsewhere if necessary, the assembly of the two being welded to the ring 59 as at 65. The reason for having two halves 61 is to meet foundry conditions; otherwise steel castings constituted by rings 61 may be made up in one piece as indicated at 60 in Fig. 5.

The shapes of the confining rings 61 (Fig. 1), and their integral counter-part 60 (Fig. 5), are of substantial importance to the invention. They comprise continuous inner rings 67 having smooth cylindric eddy-current surfaces next to the ends of the teeth 51 of the field member 45. Each ring 67 is initially cast in a continuous form, being connected to its respective outer ring 61 or 60, as the case may be, by forty-eight (according to the present example) fins 71 approximately 75 one-half inch thick. The fins 71 at their axial

ends are extended and tapered as shown at 73 to act as air fans.

After the eddy-current drum 57 as a whole has been made up by welding parts 59 and 61 (Fig. 1) or parts 59 and 60 (Fig. 5), and has been rough-machined, the spaced inner eddy-current rings 67 are sawed completely through, for example, at twelve places in each ring as indicated at 75, the saw being of approximately $\frac{1}{8}$ inch gauge. Thus each circular eddy-current ring adjacent to the teeth 51 consists of twelve segments 68 indicated in Fig. 3. These are supported by the fins 71 and are held in circular positions by the respective outer solid ring portion 61.

It will be seen that when the field coil 49 is energized its toric flux field, which is indicated by dotted lines at the bottom of Fig. 1 interlinks the field member 45 (including its flux-concentrating teeth 51), and the members 61 (including the fins 71 and segments 68). Upon rotation of the driving shaft 27, shaft 29 will be driven with some slip by reason of the magnetic reaction set up due to eddy-current generation primarily in the segments 68. Most of the eddy-current generation is in the segments 68 of the rings 67 because such generation takes place quite close to the point where lines of magnetic flux enter an eddy-current member. The segmental rings 67 may therefore be referred to as eddy-current heating rings.

When the clutch is operated, the segments 68 will become much hotter than the outer ring portion 61, because of the temperature drop through the fins 71 brought about by air circulation between rings 61 and 67. There may be as much as 100° F. to 125° F. difference in mean temperature between the outer portions 61 and the inner ring segments 68. However, since the temperature of the outer ring members 61 will determine the normal diameter of the clutch, increase in this diameter is small. In other words, the spaced segments 68 are more or less held in fixed radial positions by reason of the fact that their supporting fins 71 are anchored on the outside to relatively cool metal in the rings 61. Stated otherwise, the hottest ring portions of the armature have been both structurally isolated and slitted so as to allow peripheral expansion to take place in the slots 75 without commensurate radial expansion. A continuous steel ring will increase in diameter approximately $\frac{1}{8}$ of 1% for every 150° F. rise in temperature. By cutting up the rings 67 into the segments 68 by slits 75 any increase in diameter of the inside of the segments is only a fraction as much as if the inner eddy-current surface were continuous. Thus the flux gap is more nearly constant, at whatever value is set for it.

The above remarks all apply to the construction shown in Fig. 5 wherein it is to be understood that the rings 67 are also cut up into segments as above described. The only difference is that the two welded outer rings 61 of Fig. 1 are in Fig. 5, cast into a single outer ring 60.

In Fig. 6 is shown a modification of the invention for high-speed operation, say 1800 R. P. M. or so. In this case, like numerals designate like parts as in Fig. 1. A rolled or forged steel band ring 77 is shrunk to the outside of the cast steel rings 61, and welded thereto as indicated at 62. It is to be understood that this banded structure can be made also to apply to the Fig. 5 structure by suitable modification. The band provides a structure which will, with

more safety, withstand the added centrifugal forces due to increased speed.

Tapers 73 of the webs 71 act as air paddles which centrifugally induce a flow of air through the inlets 13 and to the outlets 15. Some flow of air is also induced by and between the teeth 51 to flow up around and in between the segmental rings 67 and around the cooling webs 71. The outwardly flared shapes of the passages 74 between the rings 61 and 67 facilitate centrifugal blowing action. Thus not only is cooling of ring 67 accomplished, but a large temperature gradient is maintained between the outer continuous rings 61 and the segmental rings 67. Also, the supporting member 59 of the composite armature 57 has the openings 93 therein for accommodating flow of air. Another feature to be noted in this connection is that the sleeves 43 are spaced from the cylinders 21 and openings are provided at 95 so that air may be drawn in axially between said sleeve 43 and said cylinders 21 for bearing cooling purposes. Fins 97 on the inside of the inner cone formed by the supporting member 59 of the armature 57 help to induce a radial flow of air from the center out.

Fig. 1 shows an auxiliary which may be used if desired. This is an induction brake 79 composed of a magnetic ring 81 having inwardly directed radial teeth 83. An annular coil 85 is carried between the rows of teeth 83 and when energized sends a toric flux field through the member 81, including the teeth, and interlinking the outer rings 61 of the driven rotary member. This induction brake will fit any standard unit and is designed to be used in the kind of service requiring frequent starting and stopping, but very little speed reduction for constant operation. The brake of course operates to decelerate the output shaft, since it is effective upon the driven drum 57.

In Fig. 4 is shown an end view of an auxiliary generator unit 87, the internal operating portions of which are not shown with the exception of a rotor unit 89 and a stator unit 91. This item is used in connection with associated control apparatus and forms no part of the present invention but is shown for completeness of the device as it exists.

It is clear that the principles of the invention may be carried out by making the field member the outer member with teeth 51 extending inward and the armature member inside with the rings of pads 68 extending outward. In this event the segmental eddy-current members would be outside of their cooler supporting rings and attached thereto by fins. The same advantages would accrue, namely, that the cool continuous ring would maintain a mean armature diameter which is more constant than if the eddy-current surfaces per se were continuous.

It will also be understood that under the principles of the invention the shaft 29 may be the driver and shaft 27 the driven member, making the armature 57 the driver and the field member the driven member. Also, coil 49 may be mounted in member 57, instead of in 49.

In view of the above it will be seen that the eddy-current armature of this machine consists of interrupted rings forming separate segments or pads in which the eddy currents are generated and in which the majority of the heating occurs. The other continuous ring or rings, as the case may be, provide the entire support for the interrupted rings by means of connecting cooling fins. The cooling between the inner interrupted

rings and the outer continuous rings is sufficient to obtain a substantial working temperature difference or gradient between the interrupted eddy-current rings and the outer supporting rings.

The fact that the coaxial cylindric extensions 21 reach farther inward into the bodies 3 and 5 than outward therefrom provides long steady bearings without occupying much space outside of the device. At the same time, no pilot bearing is required because of the reduction of off-center pull during starting.

It is preferable that the rings 67 forming the segments 68 be of low carbon steel because this is best for eddy-current production. Of course all of the material in the rings 67 and 61 should be magnetic and likewise the material of the field member 45.

While the slip coupling herein is shown between two rotating members, it may be between two members one of which is held stationary, as in the case of an eddy-current dynamometer or a brake and the claims are intended to cover such application of the invention.

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 eddy-current electric apparatus, an inner field-concentrating member having outwardly directed flux concentrating teeth, an outer armature, said member and armature being relatively rotary, means providing a flux field interlinking the field member and said armature, the armature comprising an outer continuous ring, at least one inner discontinuous ring closely adjacent to the periphery of the field member and spaced radial cooling and supporting members joining the outer continuous ring and the inner discontinuous ring, the discontinuous ring carrying most of the eddy currents and heating while the relatively cool continuous ring maintains the discontinuous ring at a substantially constant flux gap distance with respect to the field-concentrating member.

2. In eddy-current electric apparatus, an inner rotary field member, at least two peripheral rows of flux-concentrating teeth thereon, an annular coil in a plane between said rows, a cooperating armature, said armature and field member being relatively rotary, the armature comprising inner segmental eddy-current rings respectively adjacent to said rows of teeth on the field member, a continuous outer supporting ring forming part of said armature and supporting said segmental rings, spaced supporting and heat dissipating webs connecting between said continuous supporting ring and the segmental rings, the planes of said webs being substantially axial, and the axial section between the outer and inner armature rings flaring outward from points between the rows of field member teeth, said coil generating a toric flux field interlinking said rows of teeth, said segmental rings, the webs and the outer supporting ring.

3. In eddy-current electric apparatus, an inner rotary field member comprising an annular coil, outwardly directed radial rows of teeth on opposite sides of said coil, a relatively rotary armature

outside of said field member and comprising an outer continuous confining ring means opposite said coil, inner discontinuous eddy-current heating rings respectively closely adjacent and opposite to said rows of teeth on the field member, spaced fins joining said continuous outer ring means with the discontinuous inner rings of the armature, and a peripheral strengthening band around said outer ring means and attached thereto.

4. In eddy-current electric apparatus, a rotary field member an annular field coil, radial teeth on the field member and in the field of said coil, a relatively rotary armature and comprising an outer continuous confining ring, an inner discontinuous eddy-current heating ring closely adjacent and opposite to said teeth on the field member and spaced supports joining said continuous outer ring with the discontinuous ring, said continuous outer ring being joined to a rotary supporting member located at one axial end of the field member, separate rotary shafts respectively carrying the field member and the armature, and a frame surrounding said rotary members and separate bearings independently supporting the shafts in the frame.

5. In eddy-current electric apparatus, an inner rotary field member, an annular field coil, outwardly directed radial rows of teeth in planes on opposite sides of said coil, a relatively rotary armature outside of said field member and comprising an outer continuous confining ring opposite said coil, inner discontinuous eddy-current heating rings closely adjacent and opposite respectively to said rows of teeth on the field member, and spaced fins joining said continuous outer ring with the discontinuous ring, said continuous outer ring being formed in two parts joined in a median plane, the assembly of said two parts being joined to a third supporting member, and an outer band around said outer ring.

6. In eddy-current electric apparatus, an inner rotary field member, an annular field coil, outwardly directed radial teeth on said coil and in the field of said coil, a relatively rotary armature outside of said field member and comprising an outer continuous confining ring, an inner discontinuous eddy-current heating ring adjacent and opposite to said teeth on the field member, spaced webs joining said continuous outer ring with the discontinuous ring, and axial extensions from said webs adapted to induce a flow of air around the discontinuous inner ring and past the continuous outer ring.

7. In eddy-current electric apparatus, an inner rotary field member, an annular field coil, outwardly directed radial rows of teeth on opposite sides of said coil and in the field of said coil, a relatively rotary armature outside of said field member and comprising an outer continuous confining ring opposite said coil, inner discontinuous eddy-current heating rings respectively closely adjacent and opposite to said teeth on the field member, spaced groups of webs joining said continuous outer ring with the discontinuous rings, and opposite axial extensions from the respective groups of webs adapted to induce separate flows of air through said teeth around the discontinuous inner rings and past the continuous outer ring.

8. In an electric clutch, a drive shaft, a driven shaft, a rotary field member on one of the shafts, a rotary armature on the other shaft, a housing comprising two joined cup-shaped bodies, spaced coaxial inward extensions forming parts of said bodies and extending farther inward than out-

ward, flanges on said shafts located between said extensions, said rotary members being attached to said flanges between said extensions, bearings supporting said shafts independently in said extensions, sleeves spaced from and located around said extensions and axial openings in said cup-shaped members and within said sleeves and adapted to direct air between said extensions and sleeves.

9. In an electric clutch, a drive shaft, a driven shaft, a rotary field member on one of the shafts, a rotary armature on the other shaft, a housing comprising two cup-shaped bodies joined at a median line, spaced coaxial cylindric extensions forming parts of said bodies, flanges on said shafts located between said coaxial extensions, said rotary members being attached to said flanges between said extensions, independent bearing means for said shafts respectively in said extensions, sleeves spaced from said extensions and reaching from a region adjacent to the spacing between said extensions to points of attachment with the cup-shaped members, radial openings in said cup-shaped members, axial openings therein communicating both outside and inside of said sleeves and adapted to direct air to inside points in the housing, and said sleeves supporting labyrinth means for retaining lubricant within said bearings.

10. In eddy-current electric apparatus, an inner rotary field member, an annular field coil, outwardly directed radial teeth on said field member and in the field of said coil, a relatively rotary armature outside of said field member and comprising an outer continuous confining ring, an inner discontinuous eddy-current heating ring adjacent and opposite to said teeth on the field member, spaced webs joining said continuous outer ring with the discontinuous ring, axial extensions from said webs adapted to induce a flow of air around the discontinuous inner ring and past the continuous outer ring, and axial extensions from said radial teeth cooperating to produce said flow of air.

11. In eddy-current electric apparatus, an eddy-current member, a field member having spaced flux-concentrating means directed toward the eddy-current member, said members being relatively rotary, means providing a flux field interlinking said members, said eddy-current member comprising a confining ring substantially spaced from the field member, spaced eddy-current segments forming a sectional ring close to the points of flux concentration from said field member, and spaced supporting connections between said confining ring and said eddy-current segments, whereby the confining ring may be maintained substantially cooler than the segments and whereby at various higher segment temperatures caused by eddy currents therein the flux gap between the segments and the adjacent flux-concentrating portions of the field member tends to be maintained substantially constant.

12. In eddy-current electric apparatus, a magnetic eddy-current member, a magnetic field member having axial flux-concentrating teeth directed toward the eddy-current member, said members being relatively rotary, a circular field coil generating a toric flux field interlinking said members and carried by one of them, said eddy-current member comprising a continuous magnetic ring portion substantially spaced from the field member, spaced eddy-current magnetic pads forming a sectional ring close to the points of flux concentration in said field member, and spaced magnetic supporting connections between said solid ring and said eddy-current pads, said pads, connections and continuous ring accommodating substantially all of said flux field, circulation of a cooling medium being accommodated between the pads and the ring to maintain the ring cooler than the pads, whereby a substantially constant flux gap tends to be maintained between the pads and the toothed portions of the field member regardless of temperature variations in said pads.

MARTIN P. WINTHER.