Jan. 25, 1938. A. WINTHER 2,106,542

ELECTROMAGNETIC APPARATUS

Filed July 29, 1936 5 Sheets-Sheet 1

FIG. 1.

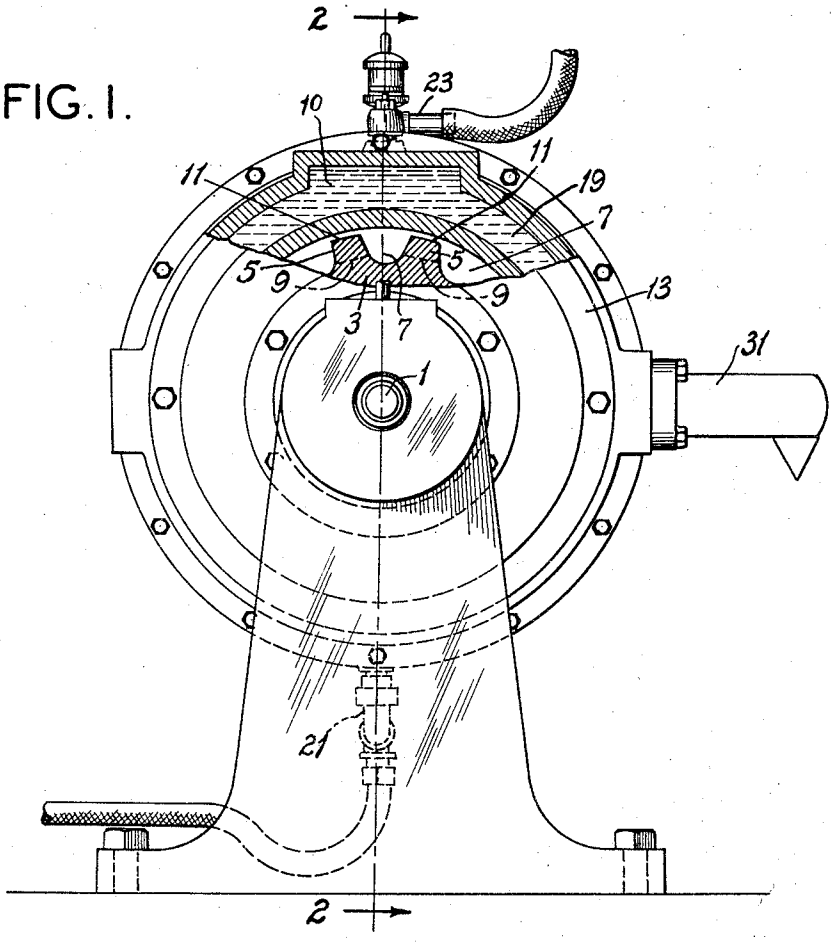
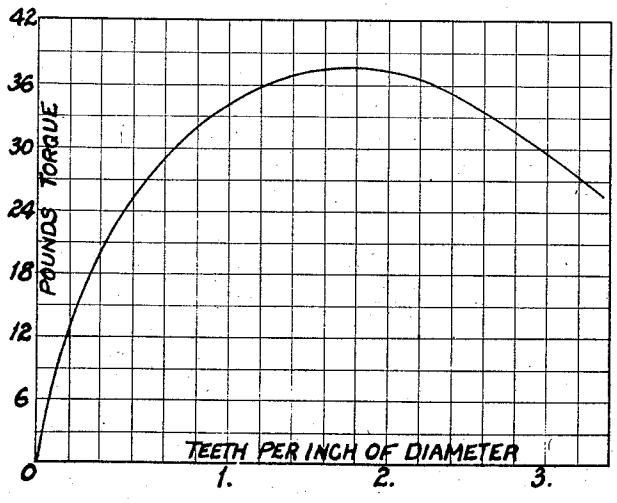


FIG. 9.



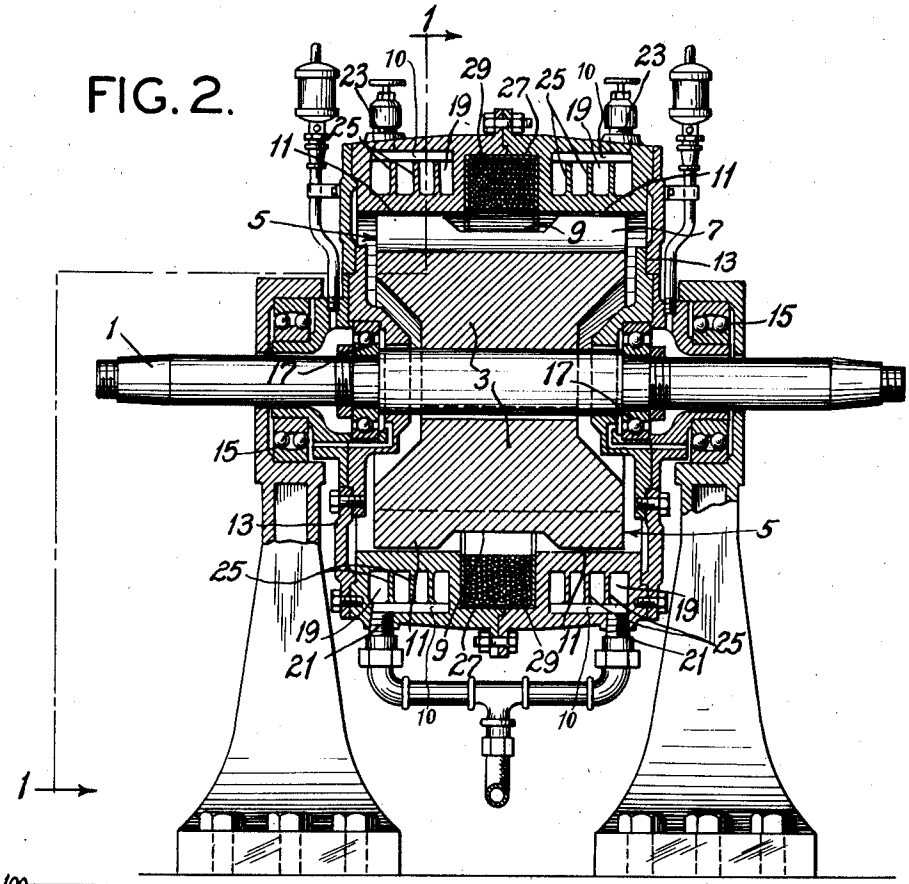
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Jan. 25, 1938. A. WINTHER 2,106,542

ELECTROMAGNETIC APPARATUS

Filed July 29, 1936 5 Sheets-Sheet 2

FIG. 2.



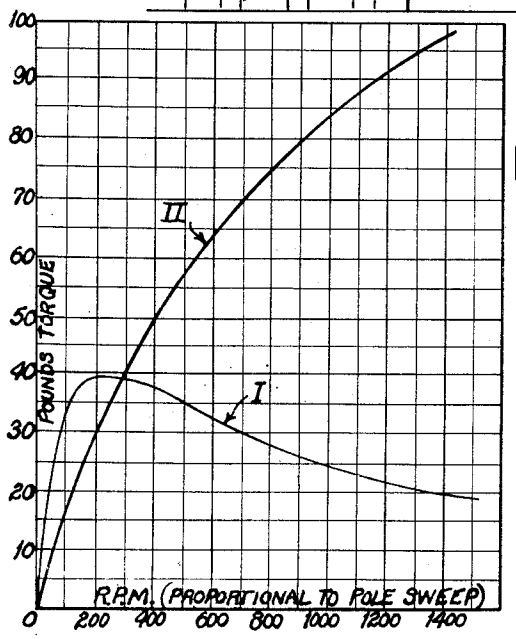


FIG. 8.

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Jan. 25, 1938. A. WINTHER 2,106,542

ELECTROMAGNETIC APPARATUS

Filed July 29, 1936 5 Sheets-Sheet 3

FIG.3.

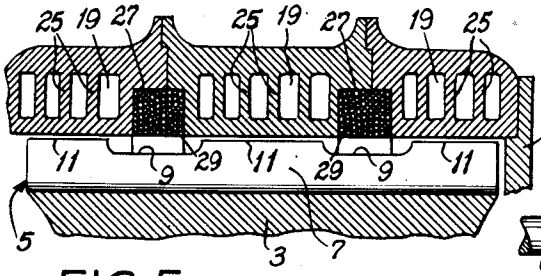


FIG.4.

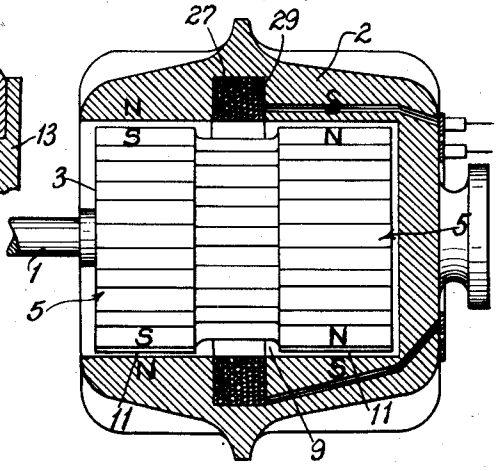


FIG.5.

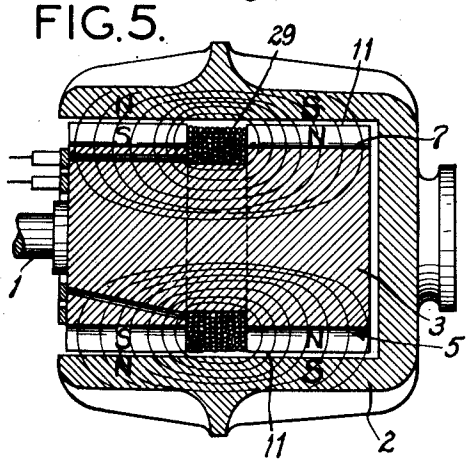


FIG.6.

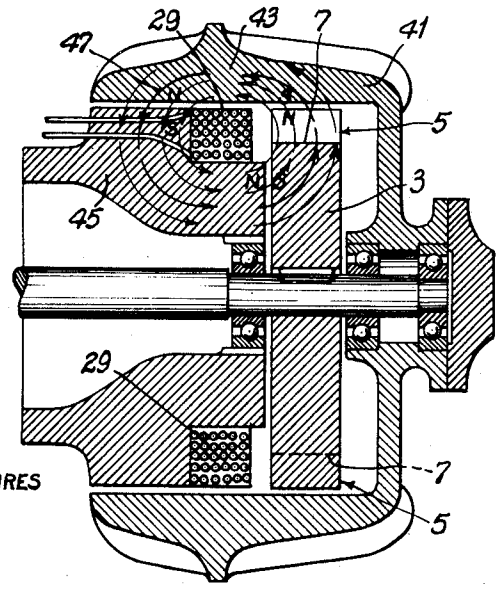


FIG.7.

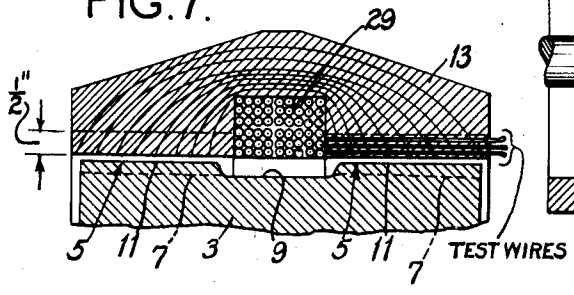
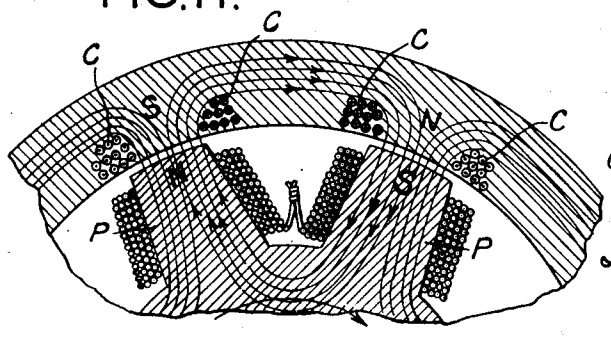


FIG.11.



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Jan. 25, 1938. A. WINTHER 2,106,542

ELECTROMAGNETIC APPARATUS

Filed July 29, 1936 5 Sheets-Sheet 4

FIG. 10.

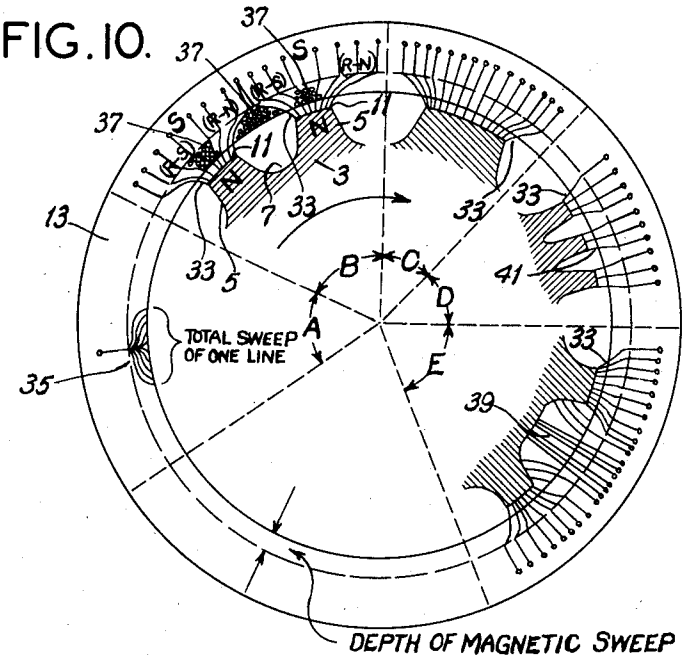


FIG. 12.

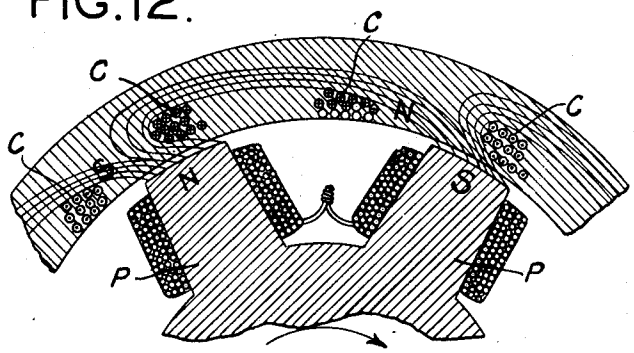
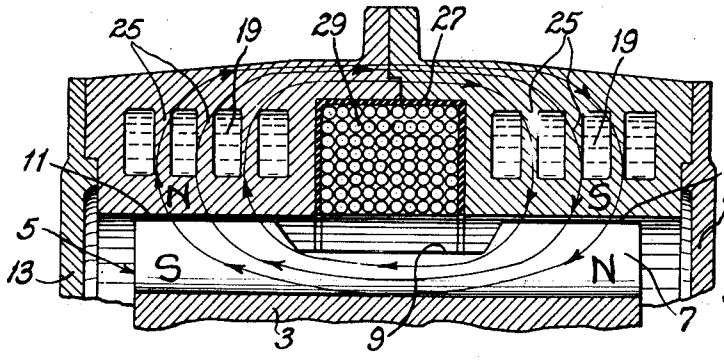


FIG. 13.



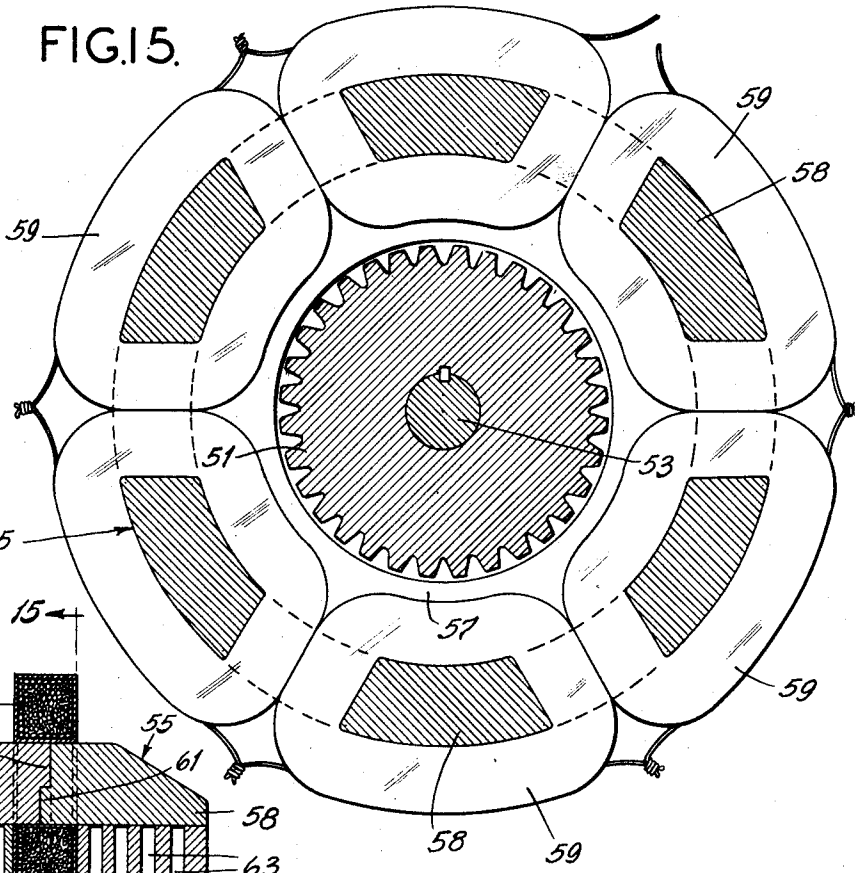
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ELECTROMAGNETIC APPARATUS

Filed July 29, 1936 5 Sheets-Sheet 5

FIG.15.



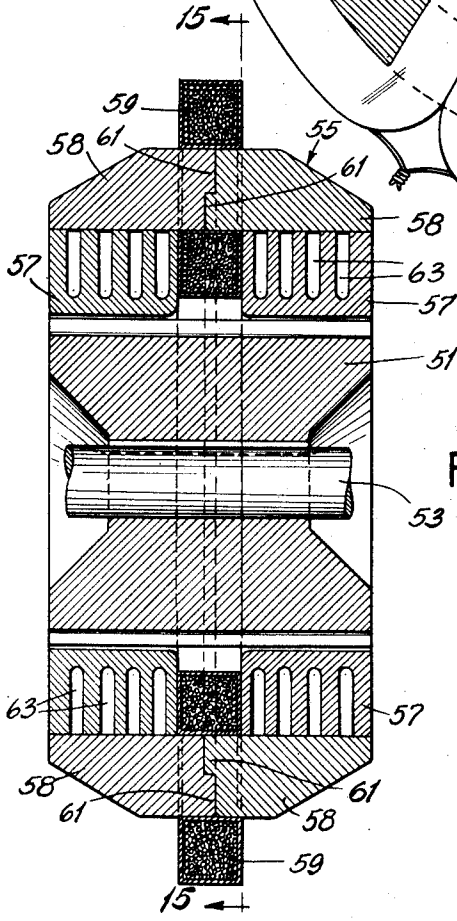


FIG.14.

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Patented Jan. 25, 1938 2,106,542

UNITED STATES PATENT OFFICE

2,106,542

ELECTROMAGNETIC APPARATUS

Anthony Winther, Kenosha, Wis.

Application July 29, 1936, Serial No. 93,176

15 Claims. (Cl. 171—252)

This invention relates to improvements upon electromagnetic apparatus of the general class shown in my United States Patent 1,977,600, dated October 16, 1934, reissued December 29, 1936, as No. 20,225.

Among the several objects of the invention may be noted the provision of an improved arrangement of magnetic circuits and the provision of certain flux concentrating or distorting means, and method of moving the latter, whereby a steadily rising torque may be delivered from an output member as the velocity of an input member increases; the provision of apparatus of the class described which will avoid the heretofore undesirable drooping of the torque curve after a predetermined speed is reached; the provision of apparatus of the class described in which the exciting current for operation is materially reduced; and the provision of apparatus of this class which may be more expeditiously mechanically embodied as energy transmission apparatus, energy absorption apparatus such as dynamometers and the like, and analogous apparatus, all of which apparatus is lighter and simpler than prior corresponding apparatus. 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 an end view on line 1—1 of Fig. 2, showing one form of energy absorption apparatus to which the invention applies, parts being broken away to show a section;

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

Fig. 3 is a fragmentary section, similar to parts of Fig. 2, showing an alternative form to that shown in Fig. 2;

Fig. 4 is a diagrammatic, longitudinal section illustrating another form of the invention for energy transmission purposes;

Fig. 5 is a view similar to Fig. 4 showing another form;

Fig. 6 is a view similar to Fig. 4 showing another form;

Fig. 7 is a fragmentary diagrammatic section illustrating certain test apparatus;

Fig. 8 shows comparative torque curves of prior apparatus and of the present invention;

Fig. 9 is a curve of torque plotted against number of teeth per inch of diameter;

Fig. 10 is a diagram illustrating various statements made hereinafter in the specification;

Fig. 11 is a diagram illustrating certain old difficulties;

Fig. 12 is a view similar to Fig. 11 showing an alternative relationship;

Fig. 13 is an enlarged detail section of a part of Fig. 2;

Fig. 14 is a detail section of another form of the invention; and,

Fig. 15 is a section taken on line 15—15 of Fig. 14.

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

The electromagnetic apparatus shown in my said United States Patent 1,977,600, and its reissue 20,225, while it sets forth improvements in pole shapes, has in common with other old apparatus, the method of inducing eddy-currents by sweeping successive electromagnetic poles of opposite polarities past given points on the member in which the eddy-currents are induced. Such apparatus, efficient as it may be at low relative sweep rates of the electromagnetic poles, has the disadvantage that above the relatively low sweep rates, the torque delivered from driving to driven member drops off. This point is illustrated in the curve I shown in Fig. 8 herein. This curve I has been plotted from a six-pole apparatus of the old type having an armature of ten inches diameter and a total of 11,400 ampere turns. This curve I shows that as the driver increases in speed up to about 250 R. P. M., (pole sweep speed being proportional) the torque increases steadily, but that thereafter the torque drops off, until at 1400 R. P. M. it is only slightly more than fifty per cent of its maximum. In other words, as the sweep rate of the poles increases above a predetermined rate, the torque drops off. This is an undesirable condition both in transmission and absorption apparatus, which if corrected, greatly enhances the use of this class of machines.

By means of the present invention, the conditions of curve II in Fig. 8 are obtained, in which there is continuous rise in the torque transmitted with increase in speed of the pole sweep. The apparatus for curve II also has only a ten inch diameter of armature, the same being of the new

axial pole class to be described, with twelve flux distorting or concentrating teeth.

Referring now more particularly to Figures 1 and 2, these show the invention as applied to an absorption dynamometer. Numeral 1 shows the drive shaft, driven from a suitable source of power. Fastened to the drive shaft 1 is a rotor 3 which is simply made of solid magnetic material, such as iron or steel and which carries peripheral teeth 5 with spaces 7 therebetween. Each tooth 5, by means of a central depression 9 is formed with two working faces 11 which, as will be seen later, form magnetic concentrators or distorters.

Swingably mounted around the shaft 1 is a case 13 supported in bearings 15. The shaft 1 is supported within the case on bearings 17. This case 13 constitutes the energy absorption member which is to receive energy from the shaft 1 and rotor 3, convert it into heat, and apply the resulting torque to a suitable measuring device. For the purpose of carrying away generated heat, the periphery of the case 13 has four peripheral water circulating channels 19 leading from inlets 21 to outlets 23 respectively. Between the channels 19 are peripheral walls 25 serving purposes to be described. Adjacent the inlets 21 and outlets 23 are cross passages 10 joining the respective sets of four passages 19 with said inlets or outlets, as the case may be. Thus water may flow from the inlets 23, through the upper cross passages 10, around passages 19, through the lower passages 10 and to the respective outlets 21. At all peripheral points, except at said cross passages 10, the peripheral walls 25 completely separate the channels 19.

Between the pair of members which form the channels 19 is provided a peripheral recess 27 in which is peripherally wound a coil 29 which is connected into a suitable electric circuit. A torque arm 31 on the case serves to impress force on a scale balance or the like. It is to be understood that the water inlets 21 and outlets 23 have suitable flexible hose connections, so that the case 13 may freely swing to the degree required by the measuring apparatus with which the torque arm 31 contacts.

In view of the above, it will be seen that if the circuit is closed through the coil 29 that the resulting excitation will result in a magnetic field being established of generally toric form around the coil 29 and along the general lines indicated by the arrows in Fig. 13. This induces two north and south magnetic poles axially arranged in the periphery of the case, as indicated. These north and south poles in the case will induce opposite polarities in the adjacent faces 11 of the teeth 5, the magnetic circuit passing through the case, and the various teeth 5. The teeth function as distorters of the magnetic field. All teeth at one end of the rotor 3 are of one polarity. Thus all adjacent teeth peripherally considered are of one polarity.

If the shaft 1 be rotated, it will be seen that the effect of the teeth 5, as their faces 11 pass a given point on the inner face of the case 13, is to concentrate the lines of flux from the adjacent areas into areas approximating the areas of the faces 11 of the teeth. This is illustrated in the diagrammatic Fig. 10, section B. Numeral 33 has been applied to the concentrating lines of flux to illustrate the point in Fig. 10. Therefore, as a tooth 5 moves, its end face 11 causes each line of flux emanating from, or entering the inner face of the case 13 to sweep, as shown at numeral 35 in Fig. 10, section A. Assuming a clockwise tooth rotation, the magnetic line sweep is first left as the tooth approaches from the left, and then right as the tooth leaves toward the right. Now, although in said Patent 1,977,600 and its reissue 20,225, a similar effect occurs, the advantages of it were overcome at high sweep speeds by reason of the following: In said patent the successive poles which swept a given point on the inductor were of different polarities. In the present improvement the successive concentrator poles are of the same polarity. Where the successive poles are of different polarities, and themselves cause in the inductor the magnetic field, said field must necessarily be reversed throughout as the successive reverse poles pass the given point. With the present apparatus, the lines of the magnetic circuit are never reversed in the inductor. Furthermore, the magnetic field in the inductor is due as a whole to the coil in the inductor or in a stationary member as in Fig. 6 and is not induced therein as a whole by adjacent and moving poles in the toothed member as heretofore and the effect of the adjacent and moving poles is merely to distort, without inducing the movement of this field completely or reversing it. Only portions of each line are swept from back and forth as illustrated at 35 in Fig. 10, section A. This sweeping of portions of the magnetic circuit in the inductor is what induces the eddy-currents which set up the magnetic reaction for slip driving between the driver and driven members 3 and 13 respectively.

I have also found out that the total sweep of the ends of the magnetic lines in the inductor are quite near its surface. This is illustrated in Figures 7 and 10. In Fig. 7 is shown a group of test wires inserted into the inductor near its surface. These were connected to an oscillograph and it was found that the wire near the surface, as the pole swept by had the highest current, that the wire that was a little deeper had less current, and the one that was deepest had substantially none. The deepest wire was only one-half inch below the surface of the inductor as shown in Fig. 10. This shows that it is not necessary to sweep the magnetic lines of force otherwise than at the skin of the inductor for maximum effect. The total reversal of the magnetic field heretofore carried out has been unnecessary, as well as the use of a flux emanating pole of any kind to sweep the entire flux through the inductor.

Said reversal and/or sweeping polar flux has not only been unnecessary, but has been deleterious as shown by the curve I in Fig. 8. To explain this, I have inserted Figures 11 and 12 which diagrammatically illustrate the old method.

Referring to Fig. 11, it is apparent that, as the poles P progress in the direction of the arrow, the field which originated in the poles themselves must be moved bodily through the iron of the armature, and the eddy-currents are generated in the iron of the armature about as shown at C. I find that the position of the eddy-currents and the shape of the field set up in the armature varies with the speed at which these poles sweep the armature. At low pole sweep the flux has little difficulty in entering the armature and setting up eddy-currents which are practically opposite the poles. The eddy-currents so set up cause opposite magnetic poles to be set up in the armature, thus insuring a strong torque between the two members (Fig. 11).

However, at higher sweep rates the reluctance

of the iron in the armature to field entry and reversal causes the induced poles to lag behind the field poles as shown in Fig. 12, with the result that, as the rate of sweep goes higher, the induced pole with its generating eddy-currents is more and more out of phase with the field pole. If the lag is great enough at very high sweep rates, a condition can occur where this induced pole may move to a point causing enough lag in eddy-currents to cancel nearly all driving effect between the two members.

It should be noted in Fig. 12 that, as the poles sweep under the armature inductor iron, the iron must be continually changed in magnetic polarity, calling for relatively high magneto-motive force to maintain such a field.

In view of the above it will be seen why the old type of magnetic apparatus is found to produce very high torque at low sweep rates, and why the torque drops off at high sweep rates. It also shows why more exciting current is necessary than with the present invention.

With my apparatus there is no reversal of direction of any portion of any magnetic circuit in any inductor member, nor is there bodily rotary movement through the inductor of a complete flux field caused by the toothed member. Short segments of the lines of magnetic flux of fixed polar direction in the inductor are merely swept back and forth laterally by the toothed member (Fig. 10, section A).

Referring to section B of Fig. 10, the lines of flux are shown descending toward the armature face at right angles. Throughout Fig. 10 is lined off an active region or shell to show the fact that the lines or their ends move only within that region (see the single line in section A of Fig. 10). If the rotor **3** moves in the direction of the arrow, the ends of the flux lines are picked up, or bent toward an advancing tooth in a direction opposite that of movement of the tooth. Directly above the tooth the lines straighten out again in the opposite direction, now agreeing with the movement of the tooth, and are finally dropped by the receding edge of the tooth to start their bending toward the next tooth behind the first one. Eddy-currents are generated probably as shown at **37**. It is apparent that such eddy-currents cannot lag behind the teeth as in the case of the old magnets of different polarities.

In the new form, the eddy-currents are generated by the lateral bending of the ends of flux lines, and not by the movement of the entire field of flux. Thus a very small percentage of the length of a line of flux is moved, while the major portion of the field stands still. In the new form the flux is homogeneously disposed and is of a fixed value (with fixed excitation) throughout the rotor and stator, except at the ends of the teeth, and in a thin shell of the armature.

Since the eddy-currents are generated by virtue of the distortion of the ends of the flux lines, and since this distortion can occur only at given distances from an approaching or receding pole tooth edge, it follows that eddy-currents must be nearly always in phase regardless of sweep rate. Furthermore, regardless of the sweep rate there is ahead of each tooth edge a uniform and constant supply of flux to be distorted, so that the eddy-currents must be in phase, as contrasted with the older form of magnet in which the moving pole was compelled to induce flux in the armature.

Tests show that the curve of torque with the new type seeems to rise indefinitely. Very small rotors (of 10 inches diameter and 7 inches long) are thus able to cause the absorption of very high amounts of power. A ten-inch machine is able to absorb 300 H. P. at a speed of 4000 R. P. M., and 75 H. P. at 1000 R. P. M. The value of torque for the salient pole magnet would with the same diameter drop quite low at such speeds as 4000 R. P. M. In order to produce torque at high sweep rates, the old type requires high excitation, (or increasing excitation) which is finally cut off by saturation, but in the case of the new type, the torque rises with the speed to high values and with fixed excitation. In fact, these values are so high for normal excitation that not even small machines have been fully tested for their maximum capacity.

It is known that ordinary electric motors have a tangential force per square inch of iron pole face of about one and one-half pounds. In the case of the present field distorting type, values as high as 28 pounds per square inch of pole end have been reached, and it is believed that higher values may be produced. Thus it can be seen that the new form of magnet lends itself to new applications, such as magnetic slip clutches where high torques are required at high slip, and for use in absorption dynamometers of the class above described for the measurement of the power of prime movers.

An advantage of electric dynamometers of the class shown in Figures 1 and 2 is that they are infinitely adjustable to various values of power. This is in contrast with the great difficulty encountered in adjusting the regulation of a load on such dynamometers as water brakes, rope brakes, and the like. Furthermore, the present type of dynamometer has a much lower cost than the old generator type. For example, electric dynamometers required to be operated at very high speeds must have very expensive armatures, while in the case of the present invention, the rotor is nothing more than a small, solid toothed steel member.

It will at this time be seen that the walls **25** are flatwise peripherally and are thus best adapted to accommodate therethrough the magnetic lines of force, and therebetween the circulating water. Thus the cooling water jacket is formed to carry the flux. However, the flux path thus formed is only imperfect at best, and the advantage gained by the present scheme is that the flux is unchanging through said imperfect path. Obviously, it would be difficult to pass rapidly changing flux through such an imperfect magnetic path, improved as it is.

I have carefully investigated the proper form of tooth to use to obtain the highest efficiency out of the new type of machine. To do this I have built a large number of rotors of varying tooth form, as to width, depth, spacing, tapering, etc., and in general can say that it is advantageous to taper the teeth from their bases to their faces, and to make their width such that the pole tooth end width will be between 25 and 50 percent (say 35 percent as an average) of the total peripheral distance from the edge of one tooth to the corresponding edge of the next one. This can be stated in another way by saying that the width of an open space should be (for highest torque) about twice that of the width of a tooth.

The tooth depth may vary from one-fourth to twice the tooth width; it being best to make it about the latter for the reason that as little leakage as possible is desired between teeth. As disclosed in Patent 1,977,600, (Reissue 20,225) it is

important to taper the tooth edges so as to effect flux saturation at the tooth faces or ends.

In the case of Patent 1,977,600 (Reissue 20,225) it was shown that if the pole end areas were about thirty percent less than the sectional area of the pole which needed to carry all the flux including leakage flux which did not go through the end area, then highest efficiency of transmission was obtained. The same rule applies in the present circumstances, except that the areas to be considered are the superficial or end areas of the teeth at either end of the rotor (exclusive of those at the other end), as compared to the cross-sectional area of the rotor through the waist within the loop of the coil **29**. Thus the total of the superficial end areas of the teeth at one end of the rotor should be about thirty percent less than the central cross-sectional area of the rotor. This is for the same reason given in said patent, namely, that the cross-sectional area of the rotor needs to carry all of the flux which is to pass out through the ends of the teeth, plus leakage flux. In order to cause a maximum concentration at the tooth ends, the metal of the tooth ends should be worked at flux saturation. Since there is about thirty percent leakage of flux aside from that which goes through the tooth end areas, it follows that to saturate said tooth end areas with seventy percent of the flux, said areas must be thirty percent or so less than the rotor waist area. The rotor is in effect an axial pole, the waist of which must carry all flux, and the superficial end areas of the flux-distorting teeth of which carry only working flux, the remainder of the flux being leakage flux. If the pole areas are greater than the waist area, the torque will drop and, of course, if solid rings are used for the pole ends the torque will drop to zero.

To show what happens when the teeth are not properly proportioned I can state:

(1) If the teeth are too wide, too much flux is inactive or stands still above the tooth as it passes, and action occurs only at the edges (Fig. 10, section C).

(2) If the teeth are too narrow and far apart, too much flux **39** leaks over to the rotor between teeth, and is thus inactive (Fig. 10, section E).

(3) If the teeth are too close together, too little sweep of the line ends **41** occurs as the flux adjusts itself from tooth to tooth (Fig. 10, section D). This later condition finally approaches that of a solid ring, if carried too far, with which no torque is transmitted.

Fig. 9 shows the change in a torque with the change in teeth per inch of diameter, the curve being based upon a uniform 30 percent ratio of tooth width or area, to width or area of open space, and preservation of the proper ratio between tooth end areas and waist area of the rotor.

Another peculiar reason for the extremely high torque between driver and driven element or between rotor and stator is as follows: Referring to Fig. 10, section B, I have marked the bending flux above the pole to show that at the leading edge of the pole the eddy-currents cause the fixed flux of the armature to become relatively north, although the armature is magnetized south. I have indicated this by R—N. The N pole of the rotor just below it then, has a tendency to push this pole ahead, thus exerting torque upon the armature. On the other hand, the eddy-currents generated at the trailing edge of the tooth have a tendency to intensify the south flux of the armature, so the area enclosed in this part of the eddy-current is opposite in polarity to the tooth. Hence the tooth exerts a strong pull upon this area of the armature. This pull and the push of the leading edge combine to make a strong torque between the two members.

Now even if the sweep rate goes high, it is clear that the phase displacement cannot be as great as in the case of the old type. This is because the eddy-currents are generated out of substantially homogeneously disposed flux, said flux being permanently maintained and not reversed in one member, and said eddy-currents being possible only at the leading and trailing edge of a tooth.

One unit of about 12 H. P. which is now in use requires excitation of about 5 amperes at 32 volts, or 160 watts applied to the terminals of the coils in order to carry the load at 1400 R. P. M. when using the old type of magnet. The same load at the same speed when driven or carried by the new form of magnet requires only 1.5 amperes at 32 volts, or 48 watts applied to the terminals of the coils, thus saving considerably on the excitation current.

Another point is the matter of cost. It is clear that a simple, annular coil is less costly to construct than 6 or 8 separate coils with their many connections. The rotor also is cheaper to make.

In Fig. 3 is shown how in a single unit, the elements of the invention may be compounded. This figure is inserted to show that the new principle can be carried out by the use of more than two poles per tooth.

It will of course be understood that the adaptation of the invention to power transmission, instead of absorption, is readily made. This is done, in effect, by releasing the case **13** for rotation. This condition is illustrated in Fig. 4 wherein like numerals designate like parts. The driven member is indexed **2** instead of **13** and it may be the driver. In the case of power transmission, it is of course not necessary to have the water circulating means for absorbing heat of energy conversion, the energy remaining primarily in mechanical form.

In Fig. 5 is shown an alternative to the structure shown in Fig. 4. In this case, the electromagnetic coil **29** is wound around the driving member instead of around the driven member. This driving member may be the driven member. The theory is in general the same, there being no reversal of flux field in any member but merely a distortion of uni-directional field.

In Fig. 6, is shown another form of the invention for use as a magnetic slip clutch. In Fig. 6 the driver is designated by the numeral **41**, or it may be the driven member, and it composes a homogeneous, magnetic drum **41** surrounding the member **3**, the latter having teeth **5** with spaces **7** therebetween and spaced portions which are adjacent the inner surface of said driving drum **41**. The portion **43** of the drum **41** forms part of a flux carrying path. The member **3** and teeth **5** form another part. A third part is formed by a stationary member **45** which carries the exciting coil **29**. The flux path is shown at **47**. By driving the drum **41**, the ends of the teeth **11** by their relative movement cause flux concentrations to change at given points on the inside face of the drum. The spaces between the drum **43** and the stationary member **45**, as well as the space between member **45** and the rotor **3** are made smooth so that no torque effect is created at these gaps.

It is clear that in Fig. 6, I make use of only half of the available gaps to create torque, but because of the exceedingly large torque available

in this type of clutch, I can still obtain ample torque from relatively low excitation. With one gap, and at low sweep rates I have been able to obtain from 40 to 65 percent of the torque available if two gaps had been used, while at higher sweep rates (of the order of 2000 feet per minute) I get the same torque with the single-gap form as with the two-gap form.

The form of the invention as shown in Fig. 6 has many advantages. For example, since the coil is stationary, no slip rings or brushes are needed, and thus the wires supplying current to the coil may be continuous from the source. The elimination of slip rings and brushes, particularly when this device is used for air conditioning apparatus on railway trains is of great advantage, reducing the possibilities of failure, and reducing inspection and maintenance costs.

The form of the invention shown in Fig. 6 also partakes of the advantage of the teeth adjacent a smooth surface having the effect of distorting a part of a field in the smooth member without sweeping or reversing in the smooth member the entire magnetic circuit.

In Figures 14 and 15 is shown a form of the invention applying for example to dynamometers in which the single coil is eliminated and in which the magnetic field is produced by a multiplicity of peripherally arranged coils. In these figures numeral **51** shows the toothed rotor on shaft **53**. The rotor is rotatable within a magnetic stator **55**. The means for swingingly supporting the stator **55** are not shown, (Figures 14 and 15 being intended to be diagrammatic in form) and are amply disclosed hereinbefore.

The stator comprises body **57** having water passages **63** and outside peripheral members **58** having adjoining supporting lugs **61** within coils **59**. A plurality of the coils **59** and lugs **61** are arranged around the periphery of the body **58** thus producing a magnetic field which has the general form hereinbefore specified. The members **58** are continuous peripherally about the openings **63**, so that said openings are sealed off to form passages.

Another advantage of this invention in general is that on some applications of the old type, the absolute maximum excitation must be used to get sufficient torque at high speeds. This high excitation adds to the heat generated in the drum (which is also heated by the eddy-currents), thus making the dissipation of heat a large factor. On the other hand the new form requires such low excitation that the coils remain very cool, and add little if any heat to that of the eddy-currents.

It is to be understood that the terms "pole sweep" and "slip" are used synonymously herein.

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 carrying out 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, a rotor, a stator, said rotor having teeth adjacent the stator, a coil located peripherally of one of said members and forming a toric flux field passing through both of them and engendering opposite polarity at adjacent surfaces between the rotor and stator, at least one peripheral water circulating passage about the stator and at least one heat transmitting wall in said passage adapted to accommodate said flux.

2. In apparatus of the class described, relatively movable members including a rotor, said rotor having a waist of a given cross-sectional area, an electromagnetic coil about said waist forming a flux field passing through the waist and emanating from the rotor at a point outside of the waist, and teeth on the rotor at the point at which said flux emanates, the total of the end areas of the teeth on one side of the waist being substantially thirty percent less than the cross-sectional area of said waist.

3. In apparatus of the class described, a magnetic driving member, a magnetic member which is forced, relatively movable and cooperating spaced faces on said members, one of which faces is smooth and peripherally homogeneous and the other having teeth, the toothed member having a waist, an electromagnet forming a field which passes through the waist of the tooth member and which field passes from one of said members into the other at said spaced faces the total of the end areas of the teeth on one side of the waist being substantially thirty percent less than the cross sectional area of said waist.

4. In apparatus of the class described, a magnetic driving member, a magnetic member which is forced, at least one of said members being adapted to accommodate eddy currents formed therein and being composed of homogeneous material, relatively movable and cooperating spaced faces on said members, one of which is peripherally smooth and homogeneous and the other of which is of a contour to provide teeth, an electromagnet forming a field which passes from one of said members into the other at the spaced faces, the tooth member having a waist, the teeth thereof at the point at which the flux emanates having a total of end areas on one side of the waist substantially thirty percent less than the total of the cross sectional area of said waist.

5. In apparatus of the class described, a magnetic driving member, a magnetic member which is forced, at least one of said members being adapted to accommodate eddy currents and being composed of homogeneous material, relatively movable and cooperating radial spaced faces on said members, one of which is peripherally smooth and the other of which is of a contour to provide peripherally spaced teeth, said teeth being tapered down in an outwardly radial direction, an electromagnet forming a flux field which passes from one of said members into the other at the radial spaced faces, said electromagnet being mounted so that the member with peripherally spaced faces moves independently of it, the energy generated by the slip between said driving member and the forced member being effective to move said forced member in the direction of movement of the driving member, and all of the energy which is not used in forcing said forced member to move being converted into heat.

6. In apparatus of the class described, a magnetic driving member, a magnetic member which is forced, at least one of said members being adapted to accommodate eddy currents and being composed of homogeneous material, relatively movable and cooperating radial spaced faces on said members, one of which is peripherally smooth and the other of which is of a contour to provide peripherally spaced teeth, said

teeth being tapered down in an outwardly radial direction to form intervening spaces which are of the order of twice the width of a tooth, an electromagnet forming a flux field which passes from one of said members into the other at the radial spaced faces, said electromagnet being mounted so that the member with peripherally spaced faces moves independently of it, the energy generated by the slip between said driving member and the forced member being effective to move said forced member in the direction of movement of the driving member, and all of the energy which is not used in forcing said forced member to move being converted into heat.

7. In apparatus of the class described, a magnetic driving member having an axis, a magnetic member which is forced and being co-axial, relatively movable and cooperating spaced faces on said members, one of which faces is smooth and peripherally homogeneous and the other having teeth, the toothed member having a waist in a plane perpendicular to said axis, an electromagnet forming a field all of which passes through the waist of the tooth member and a substantial portion of which passes from one of said members into the other through said teeth, the total of the end areas of the teeth on one side of the waist being so related to the cross-section of the waist that the flux which actually emanates from said teeth effects substantial flux saturation at the ends of said teeth.

8. In electromagnetic apparatus a magnetic rotor comprising a cylindric portion rotatable on its axis, radial teeth on said cylindric portion having ends forming spaced faces for radially directing the magnetic flux which is at least partially substantially axially disposed in the body portion, the ratio of the total of the end areas of said spaced faces to the area of the cross section of said cylindric portion which accommodates said axial flux being such that there is substantial flux saturation at the said spaced faces.

9. In electromagnetic apparatus an exclusively magnetic rotor comprising a cylindric portion rotatable on its axis, a circle of radial teeth on said cylindric portion which are tapered down in an outward direction and having ends forming spaced faces for radially directing the magnetic flux which is at least partially substantially axially disposed in the body portion, said circle of teeth all having like polarities, the ratio of the total of the end areas of said spaced faces to the area of the cross section of said cylindric portion which accommodates said axial flux being such that there is substantial flux saturation at the said spaced faces of the teeth.

10. Apparatus of the class described, according to claim 7 in which the electromagnet is located in the member having the smooth face.

11. Apparatus of the class described, according to claim 7 in which the smooth-faced member is located exteriorly of the toothed member and in which the electromagnet is located in said smooth-faced member.

12. Apparatus of the class described, according to claim 7 in which the smooth-faced member is located exteriorly of the toothed member and in which the electromagnet is located in said smooth-faced member, said electromagnet comprising a single closed coil surrounding the toothed member.

13. Apparatus of the class described, according to claim 7 and including a stationary member through which said flux passes, said electromagnet being carried by said stationary member.

14. Apparatus of the class described, according to claim 7 in which the electromagnet comprises a plurality of coils arranged to effect a toric field.

15. Apparatus of the class described, according to claim 7 in which the electromagnet comprises a plurality of coils arranged to effect a toric field, said coils being located on the smooth-faced member.

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