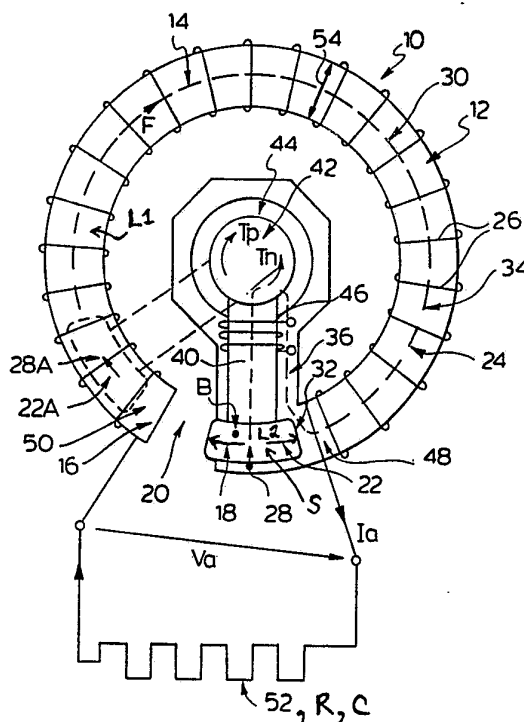




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<p>(21) International Application Number: PCT/CA93/00088 (22) International Filing Date: 3 March 1993 (03.03.93) (30) Priority data: 2,062,383 6 March 1992 (06.03.92) CA (71) Applicant (for all designated States except US): ELECTRO ERG LIMITED [GB/HU]; c/o Omega Techno Ltd., Budapesti Kepviselet, Szabadsag ut 117, H-2040 Budaors (HU). (72) Inventor; and (75) Inventor/Applicant (for US only) : SZABO, Leslie, I. [CA/HU]; Omega Techno Ltd., Budapesti Kepviselet, Szabadsag ut 117, H-2040 Budaors (HU).</p>		<p>(74) Agent: RICHES, McKENZIE &amp; HERBERT; 2 Bloor Street East, Suite 2900, Toronto, Ontario M4W 3J5 (CA). (81) Designated States: AT, AU, BB, BG, BR, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG). <b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>

(54) Title: ASYMMETRICAL ELECTRO-MECHANICAL DEVICE a.k.a. CDCII



## (57) Abstract

An asymmetrical, electro-mechanical device (10) comprises a geometrically-magnetically-asymmetrical stator (12) and a rotor (22) which move with respect to each other. There is a stator air gap (20) which makes the stator (12) asymmetrical. The magnetic flux passing from the rotor (22) to the stator (12) is interrupted when the rotor (22) passes by the stator air gap (20). The invention is able to achieve improvements over the prior art electro-mechanical devices, particularly in respect of efficiency.

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ASYMMETRICAL ELECTRO-MECHANICAL DEVICE a.k.a. CDCIIBACKGROUND OF THE INVENTION

This invention relates to an asymmetrical, electro-mechanical device which may act as a motor or a generator. In particular, the invention relates to an improved and efficient generator/motor.

Of course, electro-mechanical devices which act as motors and generators are known. However, it is always important to improve upon the prior electro-mechanical devices and, in particular, to improve the efficiency of those devices.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to at least partially improve upon the prior art devices, particularly by improving the efficiency of the prior art devices. Also, it is an object of this invention to provide an alternative type of electro-mechanical device, namely an asymmetrical electro-mechanical device.

Accordingly, in one of its broad aspects, this invention resides in providing an asymmetrical, electro-mechanical device comprising:

(a) a geometrically-magnetically-asymmetrical stator means comprising:

a non-continuous stator magnetic flux path extending from a first stator portion to a second stator portion;

stator air gap extending from the second stator portion to the first stator portion; and

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a stator face having a plurality of armature conductors extending substantially transversely across the stator face;

5 (b) a rotor means having a rotor face and moving along a rotor movement path;

(c) a rotor/stator air gap between the rotor face and the stator face when the rotor face and the stator face are adjacent each other;

10 (d) a continuous magnetic flux path extending along at least a portion of the stator magnetic flux path, through the stator face, through the rotor/stator air gap, into or out of the rotor face, through the rotor means, and through at least one magnetic flux connecting means which enables the magnetic flux path to be continuous;

15 (e) magnetic flux generating means for generating magnetic flux to pass through the continuous magnetic flux path;

(f) wherein the rotor means is capable of cyclically moving relative to the stator means in a direction along a rotor movement path which is outside of the stator magnetic flux path, wherein:

25 (i) a first part of the rotor movement path is adjacent to the stator magnetic path, and a second part of the rotor movement path is not adjacent to the stator magnetic path such that magnetic flux, except magnetic flux leakage, cannot pass through the rotor face to or from the

stator magnetic flux path;

5 (ii) beginning at time zero until time critical, the rotor face moves away from both a first portion of the stator face and the stator magnetic flux path such that magnetic flux, except magnetic flux leakage, does not pass through the rotor face into or out of the stator magnetic flux path, then toward a second portion of the stator face, and then such that the rotor face is adjacent to and overlapping with the stator face such that operational magnetic flux passes through the rotor face into or out of the stator magnetic flux path;

10 (iii) at time critical, the rotor face moves into a position of maximal overlap with the stator face; and

15 (iv) from time critical until time end of cycle, the rotor face moves along at least a portion of the stator face and adjacent to the stator face in a direction of the stator magnetic path;

20 (g) wherein when the rotor face and the stator face move relative to and adjacent to each other an armature electric voltage and armature current having directions are developed in the plurality of armature conductors; and

25 (h) wherein when the plurality of armature conductors is closed or under load, the direction of the armature current reverses at time critical when the rotor face

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moves into a position of maximal overlap with the stator face, without the magnetic flux reversing direction and without the rotor means reversing direction.

Further aspects of the invention will become apparent upon reading the following detailed description and the drawings which illustrate the invention and preferred embodiments of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

10 In the drawings, which illustrate embodiments of the invention:

Figure 1 is a schematic view of one embodiment of the invention;

15 Figure 2 is a schematic, perspective view of another embodiment of the invention;

Figure 3 is a schematic, top view of another embodiment of the invention;

Figure 4 is a schematic, perspective view of a further embodiment of the invention;

20 Figure 5 is a schematic, perspective view of yet a further embodiment of the invention; and

Figure 6 is a schematic, perspective view of yet a further embodiment of the invention.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS  
OF THE INVENTION

As shown in Figure 1, an asymmetrical, electro-mechanical device 10 of the invention includes a  
5 geometrically-magnetically-asymmetrical stator 12. Although the word "stator" is used to describe this feature and other similar features in this disclosure and the claims, the "stator" need not be "stationary".

The stator 12 has a non-continuous stator  
10 magnetic flux path 14 extending from a first stator portion 16 to a second stator portion 18.

There is also a stator air gap 20 which extends from the second stator portion 18 to the first stator portion 16. The stator air gap 20 may be an absolute air  
15 gap in the sense that the stator 12 is physically and completely discontinuous at the stator air gap 20. However, the stator air gap 20 may also be an effective air gap in the sense that the stator, for example only, as shown in Figure 1, could go into the plane of the paper  
20 beginning at the second stator portion 18 and extend sufficiently far from the remainder of the stator 12 and then return to the first stator portion 16. In this manner, there would be an effective air gap between the second stator portion 18 and the first stator portion 16  
25 when a rotor 22 passed along the stator from the second stator portion 18 to the first stator portion 16. A stator air gap will be created, whether actual or

effective, when magnetic flux, except leakage flux, will not pass from the rotor 22, specifically the rotor face 28, to the stator 12.

5 On at least some portion of the stator 12 there is a stator face 24. The stator face 24 has a plurality of armature conductors 26 extending substantially transversely across the stator face 24. The armature conductors 26 are substantially transverse to the direction of the stator magnetic flux path 14.

10 In Figure 1, the armature conductors 26 are coiled around a toroidally-shaped stator 12.

The rotor 22 has a rotor face 28. The rotor face 28 faces the stator face 24.

15 The rotor 22 moves along a rotor movement path 30. Preferably the rotor movement path 30 follows as closely as possible the stator magnetic flux path 14.

A rotor/stator air gap 32 exists between the rotor face 28 and the stator face 24 when the rotor face 28 and the stator face 24 are adjacent to each other.

20 The device 10 also has a continuous magnetic flux path 34 extending along at least a portion of the stator magnetic flux path 15. In the embodiment shown in Figure 1, the continuous magnetic flux path 34 extends along the entire portion of the stator flux path 14 from the first stator portion 16 to the second stator portion 18. The  
25 length of the continuous magnetic flux path 34 is variable in time as the rotor 22 moves along the rotor movement

path 30. This will be explained below.

The continuous magnetic flux path 34 passes through the rotor/stator air gap 32, through the stator face 24 and through at least one magnetic flux connecting means 36 which enables the continuous magnetic flux path 34 to be continuous.

In Figure 1, in the position where the rotor 22 is shown in solid lines, the continuous magnetic flux path 34 is very short. The continuous magnetic flux path 34 extends from the rotor face 28 through an arm 40 which connects the rotor face 28 to an input/output shaft 42. In this embodiment, the input/output shaft 42 is magnetically connected to the connecting means 36 by any appropriate means such as a friction fit (not shown), brushes (not shown), or an air gap 44.

In any case, the continuous magnetic flux path 34 passes from the rotor 22 (specifically from the rotor arm 40 in this embodiment) to the connecting means 36. The continuous magnetic flux path 34 then continues through the connecting means 36 to that portion of the stator face 24 which is immediately adjacent to the rotor face 28. The continuous magnetic flux path 34 which has just been described in association with the rotor 22 when it is in the position shown by solid lines in Figure 1 is essentially the shortest continuous magnetic flux path 34 which can be obtained in the embodiment shown in Figure 1.

The longest continuous magnetic flux path 34

which can be obtained in the embodiment of Figure 1 is shown when the rotor 22 is in the region of the first stator position 16 which is shown generally by the rotor 22A shown in dashed lines in Figure 1. In that  
5 embodiment, the portion of the continuous magnetic flux path 34 which extends through the stator flux path 14 extends from the position of the rotor face 28A (as shown with dashed lines in Figure 1) clockwise all the way around the stator flux path 14 to the second stator  
10 portion 18.

As the rotor 22 moves clockwise around the circular rotor movement path 30, the length of the actual continuous magnetic flux path 34 decreases.

There is also a magnetic flux generating means 46  
15 for generating magnetic flux F. This magnetic flux passes through the continuous magnetic flux path 34. In Figure 1, the magnetic flux generating means 46 is a coil 46 around the rotor arm 40. However, any other suitable magnetic flux generating means could be used anywhere in  
20 the magnetic flux path 34.

The rotor 22 is capable of cyclicly moving relative to the stator 12. Once again, as discussed with respect to the stator, although the word "rotor" is used to describe this feature 22, the rotor need not rotate and  
25 it need not even move. The important point is that there is relative movement between the rotor 22 and the stator 12.

In the embodiment of Figure 1, the rotor 22 moves in a direction (as shown by the arrow on the dashed representation of the rotor 22A in Figure 1) along the rotor movement path 30. The rotor movement path 30 is outside of the stator magnetic flux path 14. In essence, the rotor movement path 30 does not cross through and is not positioned within the stator magnetic flux path 14.

A first part of the rotor movement path 30 is adjacent to the stator magnetic path 14, preferably adjacent the stator face 24. In that way, a rotor/stator air gap 32 can be created and the continuous magnetic flux path 34 can be created. In Figure 1, this first part of the rotor movement path corresponds to the movement of the rotor from a position adjacent to the first stator position 16 to a position adjacent to the second stator portion 18.

There is also a second part of the rotor movement path 30 which is not adjacent to the stator magnetic path 14 such that the magnetic flux  $F$ , except for magnetic flux leakage, does not pass through the rotor face 28 to or from the stator magnetic flux path 14. In other words, during the second part of the rotor movement path 30, the rotor face is in such a position such that there is no continuous magnetic flux path 34 or otherwise in that particular position. This is accomplished by having the second part of the rotor movement path 30 pass by or through the stator air gap 20.

The second part of the rotor movement path 34, in the embodiment shown in Figure 1, is part of the rotor movement path 30 from the second stator flux portion 18 to the first stator portion 16. In other words, the second part of the rotor movement path 30 is when the rotor face 28 passes through or over the stator air gap 20.

Beginning at a time zero until a time critical, the rotor face 28 moves away from both a first portion 48 of the stator face 24 and the stator magnetic path 14. In the embodiment shown in Figure 1, the first part 48 of the stator face 24 corresponds to the second stator portion 18. This is because the stator face 24 in Figure 1 includes substantially all of the stator 14. However, it would be possible to have the armature conductors 26 extend only around a portion of the toroidally-shaped stator 14. In that situation, the first part 48 of the stator face 24 (which is really an end of the stator face 24) would not correspond to the first and second stator portions 16, 18.

During at least part of this time zero to time critical, magnetic flux  $F$ , except magnetic flux leakage, does not pass through the rotor face 28 into or out of the stator magnetic flux path 14. Therefore, during at least part of this time zero to time critical, there is no flux  $F$ , except leakage flux, passing through the continuous magnetic flux path 34.

During this time zero to time critical, after the

rotor face 28 moves away from the first portion 48 of the stator face 24, the rotor face 28 moves towards a second portion 50 of the stator face 24. Once again, in the embodiment shown in Figure 1, the second portion 50 of the stator face 24 corresponds to the first stator portion 16. This is because the armature conductors 26, as shown in Figure 1, are coiled substantially right to the end of the stator 14 where the stator air gap 20 begins. However, if the armature conductors 26 were not coiled right up to the end of the stator 14 at the stator air gap 20, the stator face 24 would have ended at a place different than the first stator means 16.

During this time zero to time critical, the rotor face 28 moves to a position adjacent to the second portion 50 of the stator face 24, and eventually overlaps with the second portion 50 of the stator face 24, such that operational magnetic flux  $F$  passes through the rotor face 28 into or out of the stator magnetic flux path 14. Thus, the continuous magnetic flux path 34 is brought into existence.

At time critical, the rotor face 28 moves into a position of maximum overlap with the stator face 24. In Figure 1, time critical occurs when the rotor 22A is in the position shown by dashed lines.

From time critical until time end of cycle, the rotor face 28 moves along at least a portion of the stator face 24 and adjacent to the stator face 24 in a direction

of the stator magnetic flux path 14.

When the rotor face 28 and stator face 24 move relative to and adjacent to each other, an armature electric voltage  $V_a$  and an armature current  $I_a$  having directions are developed in the plurality of armature conductors 26. In the embodiment shown in Figure 1, only the rotor 22 moves and the stator 14 remains stationary.

When the plurality of armature conductors 26 is closed or under load 52, the direction of the armature current  $I_a$  reverses at time critical when the rotor face 28 moves into a position of maximal overlap with the stator face 24, without the magnetic flux  $F$  reversing direction and without the rotor 28 reversing direction.

In the embodiment of the invention as shown in Figure 1, the stator is a toroidally-shaped body. A first end of the toroidally-shaped body corresponds to the first stator portion 16 and a second end of the toroidally-shaped body corresponds to the second stator portion 18. The stator extends toroidally for less than  $360^\circ$  from the first end to the second end. The gap between the first and second ends of the toroidally-shaped body is the stator air gap 20.

As noted previously, in the embodiment shown in Figure 1, the conductors of the plurality of armature conductors 26 are coiled around the toroidally-shaped body. As shown, there is one continuous coil. However, it would be possible to have other arrangements of the

armature conductor coils 26.

In the embodiment of Figure 1, the rotor 22 is connected by the rotor arm 40, which acts as a magnetic path connecting means, to complete the continuous magnetic flux path 34. The rotor 22 is connected to the input/output shaft 42 which is located concentrically within the toroidally-shaped stator 12.

In the embodiment shown in Figure 1, during the time from time zero to time critical, the rotor face 28 passes by the stator air gap 20 such that magnetic flux F, other than leakage flux, cannot pass through the rotor face 28 into or out of the stator magnetic flux path 14.

Another embodiment of the invention is shown in Figure 2. Respecting the embodiment of Figure 2, as well as in the embodiments of Figure 3, 4, 5 and 6, the numeric references will have three digits. The first digit will correspond to the particular Figure number and the last two digits will correspond to the numeric reference of the corresponding like feature in the embodiment described with reference to Figure 1.

In the embodiment of Figure 2, as well as in the embodiments of Figure 3, 4, 5 and 6, when the rotor face 228 and stator face 224 are adjacent to each other and overlap with each other, the rotor 222 is positioned between the stator face 224 and a second stator face 224'. The second stator face 224' is spaced apart from the first stator face 224 such that a second rotor

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face 228' on the rotor means 222 is adjacent to and overlaps the second stator face 224'.

As with the embodiments described in Figure 1, the stator face 224 has a first end 252 and a second end 254. Also, the second stator face 224' has a first end 256 and a second end 258.

In this second embodiment, the non-continuous stator magnetic flux path 214 extends from the first end 252 of the first stator face 224 to the second end 254 of the first stator face 224. The non-continuous stator magnetic flux path 214 passes through a stator path member 260 extending from at least the second end 254 of the stator face 224 to the first end 256 of the second stator face 224'. The non-continuous stator magnetic flux path 214 then passes from the first end 256 of the second stator face 224' to the second end 258 of the second stator face 224'. It will be understood that the stator path member 260 and the the non-continuous stator magnetic flux path 214 are arranged in a manner so as to not impede the relative movement between the rotor 222 and the stator 212.

In the embodiment shown in Figure 2, the rotor 222 may move in the direction shown as "D" in Figure 2. Similarly, the entire stator 212 may move and the rotor 222 may remain stationary.

While the rotor 222 is positioned between the first stator face 224 and the second stator face 224', the

continuous magnetic flux path 234 passes through the rotor 222.

The stator air gap in Figure 2 is shown as 220. The armature conductors are shown as 226 in Figure 2 and  
5 the magnetic flux generating means is shown as 246.

Although the second stator face 224' is shown as being substantially in a plane parallel to the first stator face 224 in Figure 2, it is possible that the second stator face 224' could be perpendicular to the  
10 first stator face 224 and come face to face with the rotor 222 in a region generally shown as P in Figure 2.

In a preferred embodiment of the invention, the Lorentz force equal to  $B \cdot l \cdot i$  does not create any more than a negligible negative torque on the input/output shaft  
15 connected to either of the moving rotor 12 or to the moving stator 12, if the stator moves. A negative torque is one which opposes the desired movement of the rotor 22 and is shown as  $T_n$  in the Figures.

In regard to this invention, "B" of the Lorentz  
20 force is a magnetic flux through the rotor/stator air gap 32. Also, "l" is the length of that portion of the armature conductor 26 passing across the stator face 24 and through the rotor/stator air gap 32. The length "l" is shown as reference 54 in Figure 1.

25 Also, "i" is the armature current  $I_a$ .

In a further preferred embodiment of the invention, the device 10 is operable such that between

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time zero and time critical, the armature current  $I_a$  creates a magnetic flux  $F$  in the stator magnetic flux path 14 which contributes to a positive torque  $T_p$  on the input/output shaft 42.

5           In a further preferred embodiment of the invention, the positive torque  $T_p$  described above, between time zero and time critical, is created when the following features of the device 10 are properly adjusted:

10           resistance  $R$  of the load 52 connected to the armature conductors 26;  
            capacitance  $C$  of the load 52;  
            length  $L_1$  from the first portion 48 of the stator face 24 to the second portion 50 of the stator face 24 during which the magnetic flux  $F$ , except  
15           magnetic flux leakage, does not pass through the rotor face 28 into or out of the stator magnetic flux path 14;  
            shape  $S$  of the rotor face 28; and  
            length  $L_2$  of the rotor face 28.

20           In a further specific embodiment of the invention, as shown in Figure 2, the first and second rotor faces 228, 228' are in separate planes which are substantially parallel to each other. Also, the non-continuous stator magnetic flux path 214 comprises a first  
25           path member 262 extending from the second end 254 of the first stator face 224 in a plane substantially parallel to the plane of the first rotor face 222 to a second path

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member 264. The second path member 264 is part of the stator path member 260. The second path member 264 extends in a plane substantially perpendicular to the planes of the rotor faces 224 and 224'. The non-  
5 continuous stator magnetic flux path 214 further comprises the second path member 264 and a third path member 266 which extends from the second path member 264 in a plane substantially parallel to the plane of the second rotor face 228' to the first end 256 of the second stator face  
10 224'.

In a further preferred embodiment of the invention, as shown in Figure 3, each of the first and second rotor faces is configured in an arc in its respective plane. In Figure 3, which is a top view, there  
15 are actually two first rotor faces 328A and 328B shown. However, in one embodiment, there need only be one first rotor face 328A or 328B. It is preferred that there be at least two rotor faces 328A and 328B, in order that an embodiment as described below will be balanced. However,  
20 for the time being, consider, as this embodiment of the invention only, the rotor 322A and stator 312A.

In this embodiment, the rotor 322A rotates around the input/output shaft 342 in a circular path 330. Also, each of the first and second stator faces 328A and 328A'  
25 (not shown) is configured in an arc along at least a part of the circular path of the rotor 322A.

Essentially, the rotor 322A and the stator 312A

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in Figure 3 is a top view of a specific embodiment of the more-general embodiment shown in Figure 2.

In a further embodiment of the invention, two of the devices 310A and 310B are combined. The two devices  
5 310A and 310B are similar electro-magnetic devices. The two devices 310A and 310B are configured such that the rotors 322A and 322B are magnetically insulated from the rotor 322B, 322A of the other device. The rotor 322A, 322B of each of the devices 310A, 310B is connected to a  
10 common input/output shaft 342 in a balanced configuration and rotates around the shaft 342 in a common circular path 330 such that the rotor 322A, 322B of each device 310A, 310B passes between the stator faces 324A, 324A' and 324B, 324B' of each of the other devices.

15 In another preferred embodiment of the invention, as shown in Figure 4, the device 410 has first and second rotor faces 428 and 428' which are spaced apart in a first direction FD. The first and second rotor faces 428, 428' have curved surfaces which are substantially parallel to  
20 each other. The non-continuous stator magnetic flux path 414 comprises a first path member 462 extending from the second end 454 of the first stator face 424 in a plane substantially perpendicular to the surface of the first rotor face 428 to a second path member 464 extending in a  
25 direction substantially parallel to the first direction FD in which the rotor faces 424, 424' are spaced apart.

The non-continuous stator magnetic flux path 414

also comprises the second path member 464 and a third path member 466 which extends from the second path member 464 in a plane substantially perpendicular to the plane of the second rotor face 424' to the first end 456 of the second stator face 458.

In this embodiment, the rotor 422 rotates along the rotor movement path which is a circular path around the input/output shaft 442. Thus, the continuous magnetic flux path is in existence when the rotor 422 rotates such that the rotor faces 428, 428' are adjacent to the stator faces 424, 424'.

In a further preferred embodiment of the invention, the rotor 422 moves relative to the stator 412 around the input/output shaft 442 in a circular path 430. Also, each of the first and second rotor faces 428, 428' is positioned at substantially the same distance from the input/output shaft 442. Also, the length of each rotor face in the direction of the circular path is less than 360°.

In a further preferred embodiment of the invention, the rotor 422 is connected to and rotates with the input/output shaft 442 as shown in Figure 4. Also, the rotor 422 is positioned closer to the input/output shaft 442 than is the stator 412.

In a further preferred embodiment of the invention, as shown in Figure 5, there are at least two similar electro-magnetic devices 510A and 510B. However,

for purposes of illustration, all of the stator 512B of device 510B is not shown. In this embodiment, the rotor 522 is positioned further from the input/output shaft 542 than is each of the stators 512A and 512B.

5           In this embodiment, each of the stators 510, 510B is connected to the input/output shaft 542. However, the rotor 522 could be configured so as to rotate around the shaft 542 and be connected to another shaft (not shown) which acts as an input/output shaft. For example, the  
10           shaft 542 could terminate as shown in Figure 5 and the shafts 568 and 570 could extend further and then be connected to radial spokes (not shown) which could be connected to a central longitudinal shaft (not shown) which acts as an input/output shaft.

15           In any case, it is preferred that the rotor 522 is positioned in a balanced configuration. Thus, a second rotor 522B could be positioned directly opposite the rotor 522. Alternately, a simple counterweight could be used to balance the rotor 522 in place of the second rotor 522B.

20           In any case, it is preferred that the rotor 522 moves in a circular path such that the first and second rotor faces 528A and 528A' of device 510A and 528B and 528B' of device 510B pass by the corresponding stator faces 524A and 524B of each of the other devices 510A,  
25           510B.

          Thus, in this particular embodiment, the flux connecting means 536A is connected by an additional flux

connecting means 574 to the flux connecting means 536B of the device 510B. Thus, in this embodiment, there is a shared or common stator magnetic flux path 514.

5 In the embodiment shown in Figure 5, the two stators 512A and 512B are connected to the same input/output shaft 542.

In yet a further embodiment of the invention, each of the stator faces 524A and 524B has a length in the direction of the circular path of rotation of the stator faces 524A, 524B which is less than  $360^\circ$ . Preferably, the length is also greater than about  $240^\circ$ .

10 In a further preferred embodiment of the invention, as shown in Figure 6, the rotor means is connected to and rotates with the input/output shaft 642. Also, the rotor 622A is positioned closer to the input/output shaft 642 than is the stator 612A.

Moreover, the embodiment shown in Figure 6 includes a stationary flux connecting means 636 which includes a flux path which is common to both the stator flux path (not shown) of stator 612A and a second stator flux path (not shown) of a second stator (not shown).

20 It will be understood that, although various features of the invention have been described with respect to one or another of the embodiments of the invention, the various features and embodiments of the invention may be combined or used in conjunction with other features and  
25 embodiments of the invention as described and illustrated

herein.

Although this disclosure has described and illustrated certain preferred embodiments of the invention, it is to be understood that the invention is not restricted to these particular embodiments. Rather, the invention includes all embodiments which are functional or mechanical equivalents of the specific embodiments and features that have been described and illustrated herein.

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The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

5 1. An asymmetrical, electro-mechanical device comprising:

(a) a geometrically-magnetically-asymmetrical stator means comprising:

10 a non-continuous stator magnetic flux path extending from a first stator portion to a second stator portion;

stator air gap extending from the second stator portion to the first stator portion; and

15 a stator face having a plurality of armature conductors extending substantially transversely across the stator face;

(b) a rotor means having a rotor face and moving along a rotor movement path;

20 (c) a rotor/stator air gap between the rotor face and the stator face when the rotor face and the stator face are adjacent each other;

25 (d) a continuous magnetic flux path extending along at least a portion of the stator magnetic flux path, through the stator face, through the rotor/stator air gap, into or out of the rotor face, through the rotor means, and through at least one magnetic flux connecting means which enables the magnetic flux path to be continuous;

(e) magnetic flux generating means for generating magnetic flux to pass through the continuous magnetic flux path;

(f) wherein the rotor means is capable of cyclically moving relative to the stator means in a direction along a rotor movement path which is outside of the stator magnetic flux path, wherein:

(i) a first part of the rotor movement path is adjacent to the stator magnetic path, and a second part of the rotor movement path is not adjacent to the stator magnetic path such that magnetic flux, except magnetic flux leakage, cannot pass through the rotor face to or from the stator magnetic flux path;

(ii) beginning at time zero until time critical, the rotor face moves away from both a first portion of the stator face and the stator magnetic flux path such that magnetic flux, except magnetic flux leakage, does not pass through the rotor face into or out of the stator magnetic flux path, then toward a second portion of the stator face, and then such that the rotor face is adjacent to and overlapping with the stator face such that operational magnetic flux passes through the rotor face into or out of the stator magnetic flux path;

(iii) at time critical, the rotor face moves into a position of maximal overlap with the stator face;

and

(iv) from time critical until time end of cycle, the rotor face moves along at least a portion of the stator face and adjacent to the stator face in a direction of the stator magnetic path;

(g) wherein when the rotor face and the stator face move relative to and adjacent to each other an armature electric voltage and armature current having directions are developed in the plurality of armature conductors; and

(h) wherein when the plurality of armature conductors is closed or under load, the direction of the armature current reverses at time critical when the rotor face moves into a position of maximal overlap with the stator face, without the magnetic flux reversing direction and without the rotor means reversing direction.

2. An electro-magnetic device as defined in claim 1 wherein:

the stator means is a toroidally-shaped body having a first end and a second end, and extending toroidally for less than 360° from the first end to the second end;

the first and second ends of the toroidally-shaped body are the first and second stator portions, respectively, and the stator air gap is a gap between the second end and first end of the toroidally-shaped body;

the conductors of the plurality of armature conductors are coiled around the toroidally-shaped body;

the rotor means is connected by a first magnetic path connecting means to a shaft located concentrically within the toroidally-shaped stator means; and

during a time from time zero to time critical the rotor face passes by the stator air gap such that magnetic flux cannot pass through the rotor face into or out of the stator magnetic flux path.

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3. An electro-magnetic device as defined in claim 1 wherein:

when the rotor face and stator face are adjacent to each other and overlapped with each other, the rotor means is positioned between the stator face and a second stator face which is spaced apart from the stator face such that a second rotor face on the rotor means is adjacent to and overlaps the second stator face;

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the stator face has a first end and a second end;

the second stator face has a first end and a second end; and

the non-continuous stator magnetic flux path extends from the first end of the stator face to the second end of the stator face, through a stator path member extending from the second end of the stator face to the first end of the second stator face, and then from the

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first end of the second stator face to the second end of the second stator face in a manner so as to not impede the relative movement between the rotor means and the stator means.

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4. An electro-magnetic device as defined in claim 2 wherein a Lorentz force equal to  $B \cdot l \cdot i$  does not create any more than a negligible negative torque on an input/output shaft connected to either the moving rotor means or the moving stator means,

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where: "B" is magnetic flux through the rotor/stator air gap;

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"l" is a length of that portion of the armature conductor passing across the stator face and through the rotor/stator air gap; and

"i" is the armature electric current.

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5. An electro-magnetic device as defined in claim 4 wherein the device is operable such that between time zero and time critical the armature electric current creates a magnetic flux in the stator magnetic flux path contributing to a positive torque on the input/output shaft.

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6. An electro-magnetic device as defined in claim 5 wherein the positive torque is created when the following features of the device are properly adjusted:

5 resistance of a load connected to the armature conductors;

capacitance of the load;

10 length from the first portion of the stator face to the second portion of the stator face during which the magnetic flux, except magnetic flux leakage, does not pass through the rotor face into or out of the stator magnetic flux path;

shape of the rotor face; and

length of the rotor face.

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7. An electro-magnetic device as defined in claim 3 wherein a Lorentz force equal to  $B \cdot l \cdot i$  does not create any more than a negligible negative torque on an input/output shaft connected to either the moving rotor means or the moving stator means,

20 where: "B" is magnetic flux through the rotor/stator air gap;

"l" is a length of that portion of the armature conductor passing across the stator face and through the rotor/stator

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air gap; and

"i" is the armature electric current.

5       8.       An electro-magnetic device as defined in claim 7  
wherein the device is operable such that between time zero  
and time critical the armature electric current creates a  
magnetic flux in the stator magnetic flux path  
contributing to a positive torque on the input/output  
10 shaft.

9.       An electro-magnetic device as defined in claim 8  
wherein the positive torque is created when the following  
15 features of the device are properly adjusted:

resistance of a load connected to the armature  
conductors;

capacitance of the load;

length from the first portion of the stator face  
20 to the second portion of the stator face during  
which the magnetic flux, except magnetic flux  
leakage, does not pass through the rotor face into  
or out of the stator magnetic flux path;

shape of the rotor face; and

25 length of the rotor face.

10. An electro-magnetic device as defined in claim 9 wherein the first and second rotor faces are in separate planes which are substantially parallel to each other; and the non-continuous stator magnetic flux path comprises a first path member extending from the second end of the stator face in a plane substantially parallel to the plane of the first rotor face to a second path member extending in a plane substantially perpendicular to the planes of the rotor faces, the second path member, and a third path member extending from the second path member in a plane substantially parallel to the plane of the second rotor face to the first end of the second stator face.

11. An electro-magnetic device as defined in claim 10 wherein each of the first and second rotor faces is configured in an arc in its respective plane; the rotor means rotates around the input/output shaft in a circular path; and each of the first and second stator faces is configured in an arc along at least a part of the circular path of the rotor means.

12. An electro-magnetic device as defined in claim 11 further comprising at least one other similar electro-magnetic device wherein the rotor means of each of the devices is magnetically insulated from the rotor means of

each other device; the rotor means of each of the devices is connected to a common input/output shaft in a balanced configuration and rotates around the shaft in a common circular path such that the rotor means of each device passes between the stator faces of each of the other devices.

13. An electro-magnetic device as defined in claim 9 wherein the first and second rotor faces are spaced apart in a first direction; the first and second rotor faces have curved surfaces which are substantially parallel to each other; and the non-continuous stator magnetic flux path comprises a first path member extending from the second end of the stator face in a plane substantially perpendicular to the surface of the first rotor face to a second path member extending in a direction substantially parallel to the first direction in which the rotor faces are spaced apart, the second path member, and a third path member extending from the second path member in a plane substantially perpendicular to the plane of the second rotor face to the first end of the second stator face.

14. An electro-magnetic device as defined in claim 13 wherein the rotor means moves relative to the stator means around the input/output shaft in a circular path; each of

the first and second rotor faces is positioned at substantially the same distance from the input/output shaft; and the length of each rotor face in the direction of the circular path is less than 360'.

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15. An electro-magnetic device as defined in claim 14 wherein the rotor means is connected to and rotates with the input/output shaft and is positioned closer to the input/output shaft than is the stator means.

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16. An electro-magnetic device as defined in claim 15 further comprising at least one other similar electro-magnetic device wherein the rotor means of each of the devices is magnetically insulated from the rotor means of each other device; the rotor means of each of the devices is connected to a common input/output shaft in a balanced configuration and rotates around the shaft in a common circular path such that the first and second rotor faces of the rotor means of each device pass by the corresponding stator faces of the stator means of each of the other devices.

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17. An electro-magnetic device as defined in claim 14 wherein each of the stator faces has a length in the

direction of the circular path which is less than 360' and greater than about 240'.

5 18. An electro-magnetic device as defined in claim 17 wherein the rotor means is connected to and rotates with the input/output shaft and is positioned closer to the input/output shaft than is the stator means.

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19. An electro-magnetic device as defined in claim 14 wherein the stator means is connected to and rotates with the input/output shaft and is positioned closer to the input/output shaft than is the rotor means.

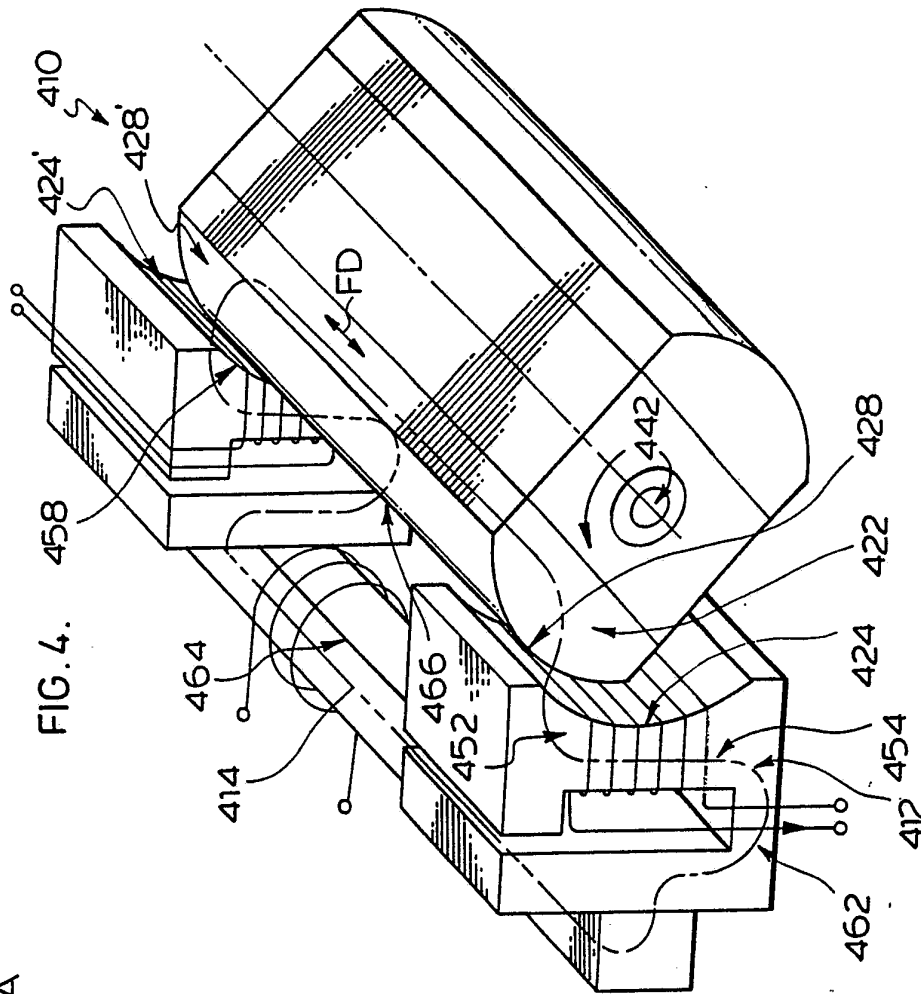
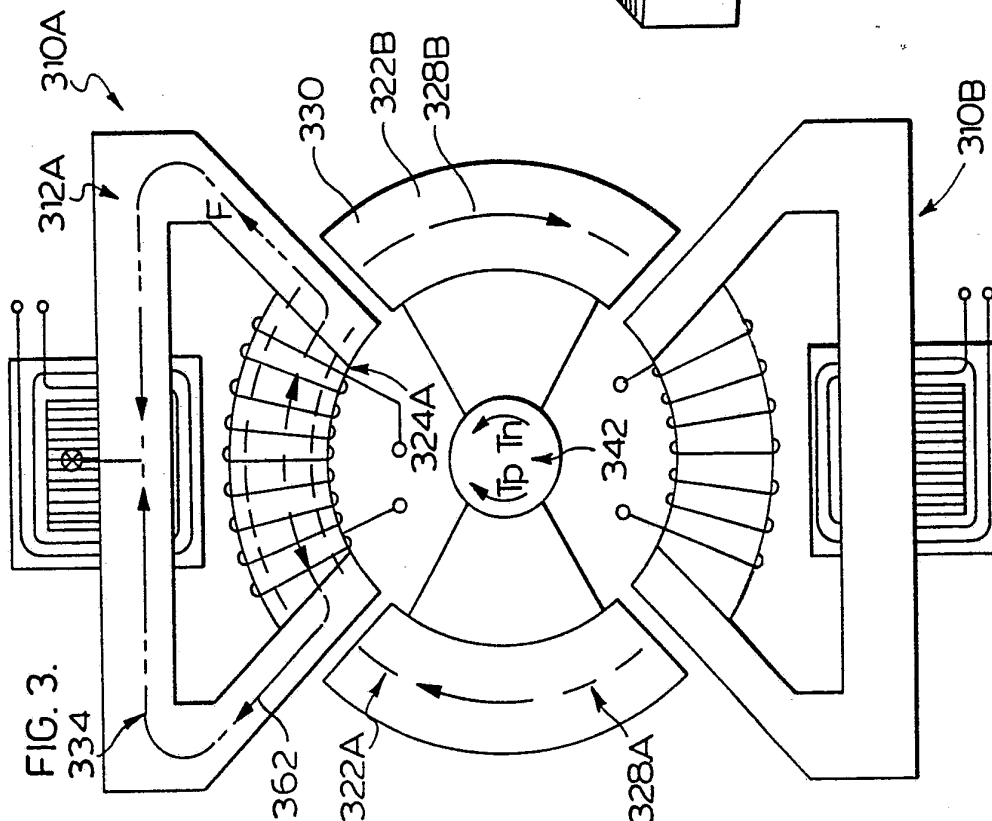
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20. An electro-magnetic device as defined in claim 17 wherein the stator means is connected to and rotates with the input/output shaft and is positioned closer to the input/output shaft than is the rotor means.

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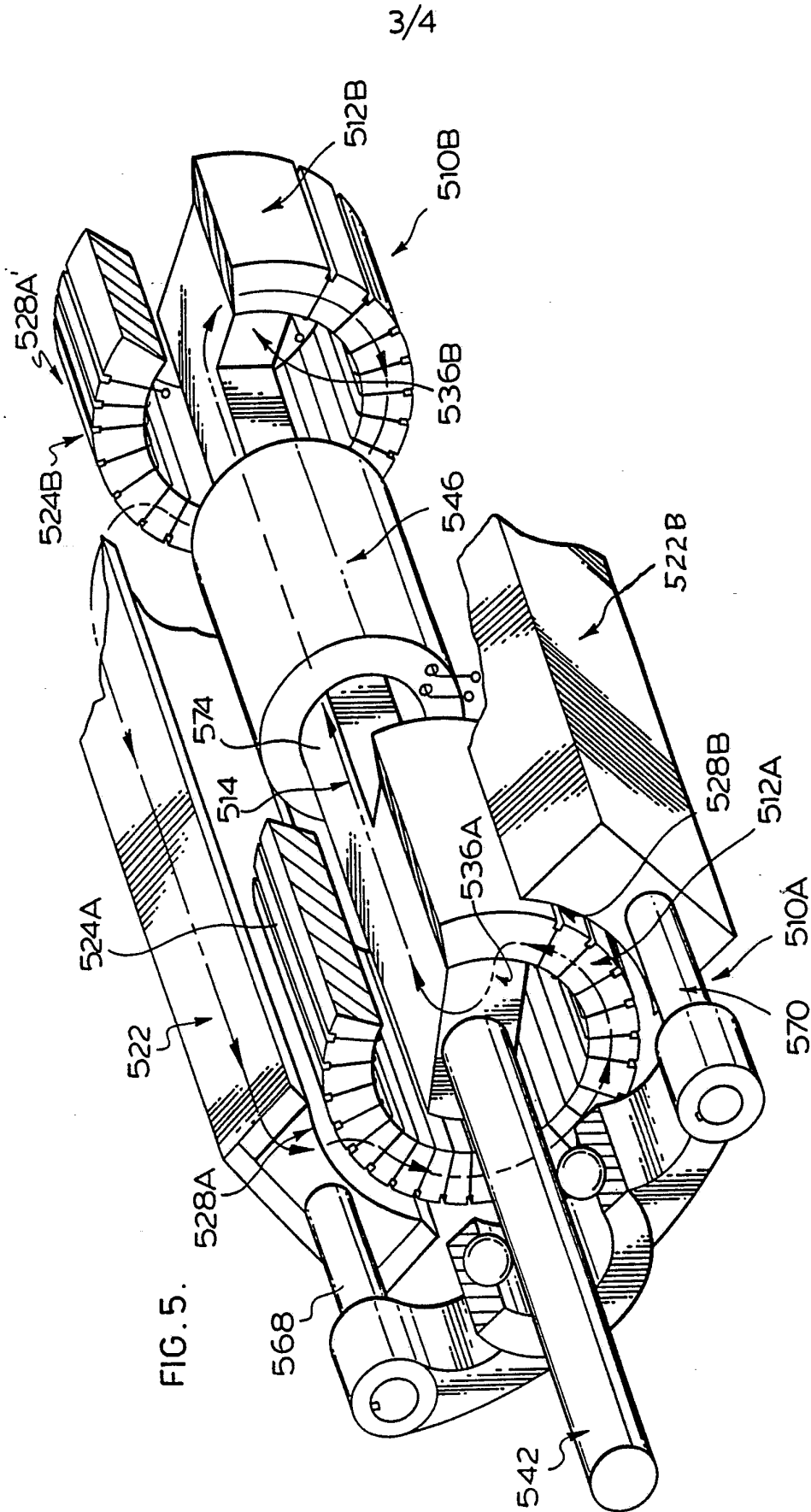


FIG. 5.

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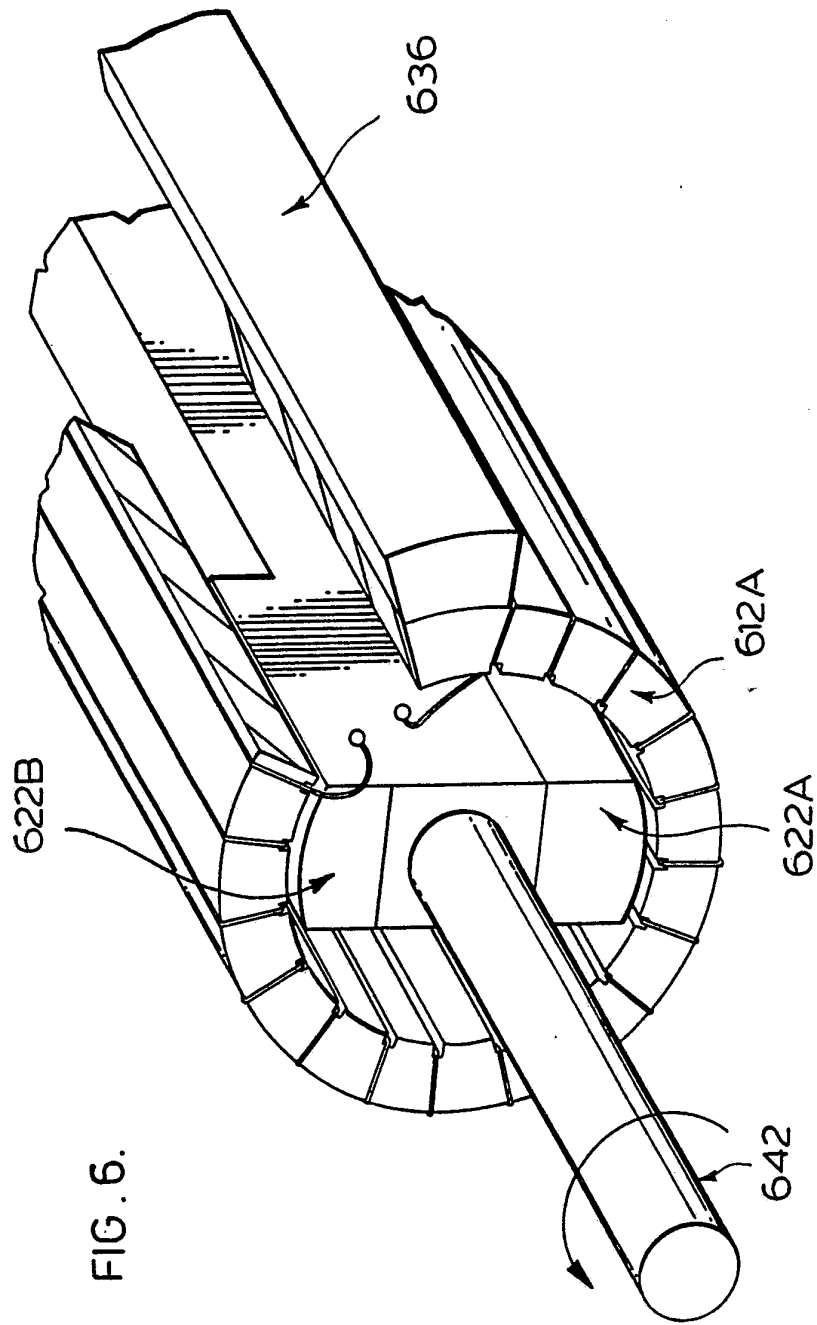


FIG. 6.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 93/00088

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC Int.Cl. 5 H02K19/18; H02K19/20		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl. 5	H02K	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	FR,A,2 603 433 (HINDRE) 4 March 1988  see page 2, line 5 - page 4, line 30; figures 1,2	1, 2, 8, 10, 13-15, 17, 18
Y	---	4, 5, 7
Y	DE,A,1 935 657 (MÜLLER) 28 January 1971 see page 1, line 1 - page 2, line 14; figure 1	4, 5, 7
X	FR,A,2 616 980 (HINDRE) 23 December 1988 see page 1, line 24 - page 5, line 15; figures 1,2	1, 2, 12, 16
Y	---	6, 9
	---	---/---
<p><sup>10</sup> Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
05 JULY 1993	1 6. 07. 93	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	TIO K.H.	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
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X	US,A,3 864 588 (INABA) 4 February 1975 see column 4, line 39 - column 6, line 15; figures 1-6	1,3,11
Y	---	19,20
Y	FR,A,2 632 133 (LEE ET AL) 1 December 1989 see page 7, line 2 - line 10; figure 2 ---	19,20
P,X	US,A,5 130 593 (CONNELL) 14 July 1992 see column 5, line 50 - column 10, line 32; figures 4-6,8,9 -----	1,3,11

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

CA 9300088  
SA 72145

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

05/07/93

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