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Chabrerie et al.

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[45] **July 3, 1973**

[54] **HOMOPOLAR MACHINES WITH CONTACTS OF LIQUID METAL**

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[52] **U.S. Cl.** **310/178**

[51] **Int. Cl.** **H02k 31/00**

[58] **Field of Search** 310/178; 322/48

[56] **References Cited**

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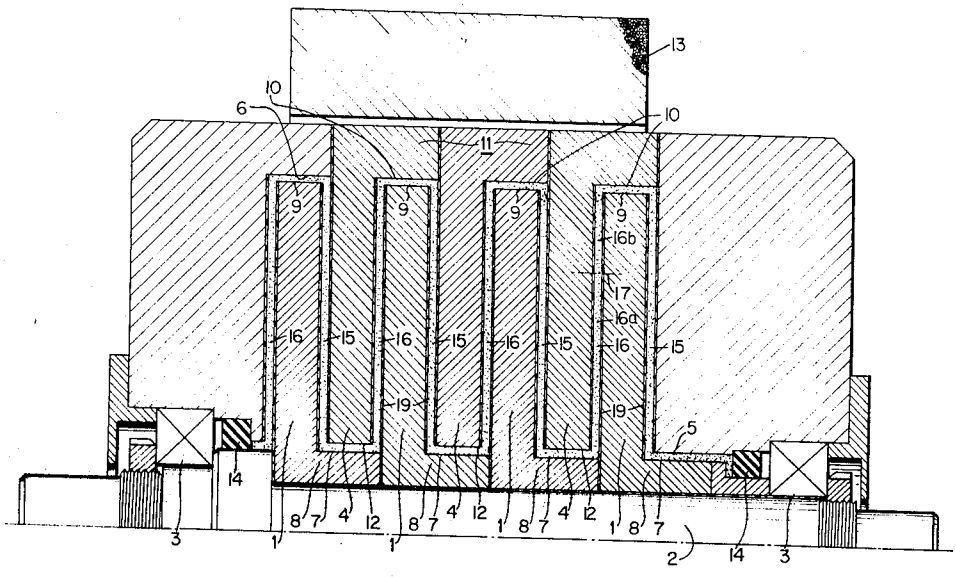
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[57] **ABSTRACT**

Homopolar motors or generators in which electrical contacts are made by filling the space between the rotor and stator with a liquid metal and especially machines of this type with a plurality of discs. An annular liquid body with ends electrically joined to the peripheral and central contacts of a fixed counter disc is divided into two concentric annuluses, and one of these is rotated in the direction of rotation of the rotor. The other annulus automatically rotates in the opposite direction. The radial widths of these annuluses are so selected that the electromotive forces which are induced therein cancel each other and the centrifugal pressures offset and counterbalance the centrifugal pressure due to movable bodies of liquid having their ends at the terminals of the electric contacts of the corresponding movable discs.

8 Claims, 5 Drawing Figures



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2 Sheets-Sheet 1

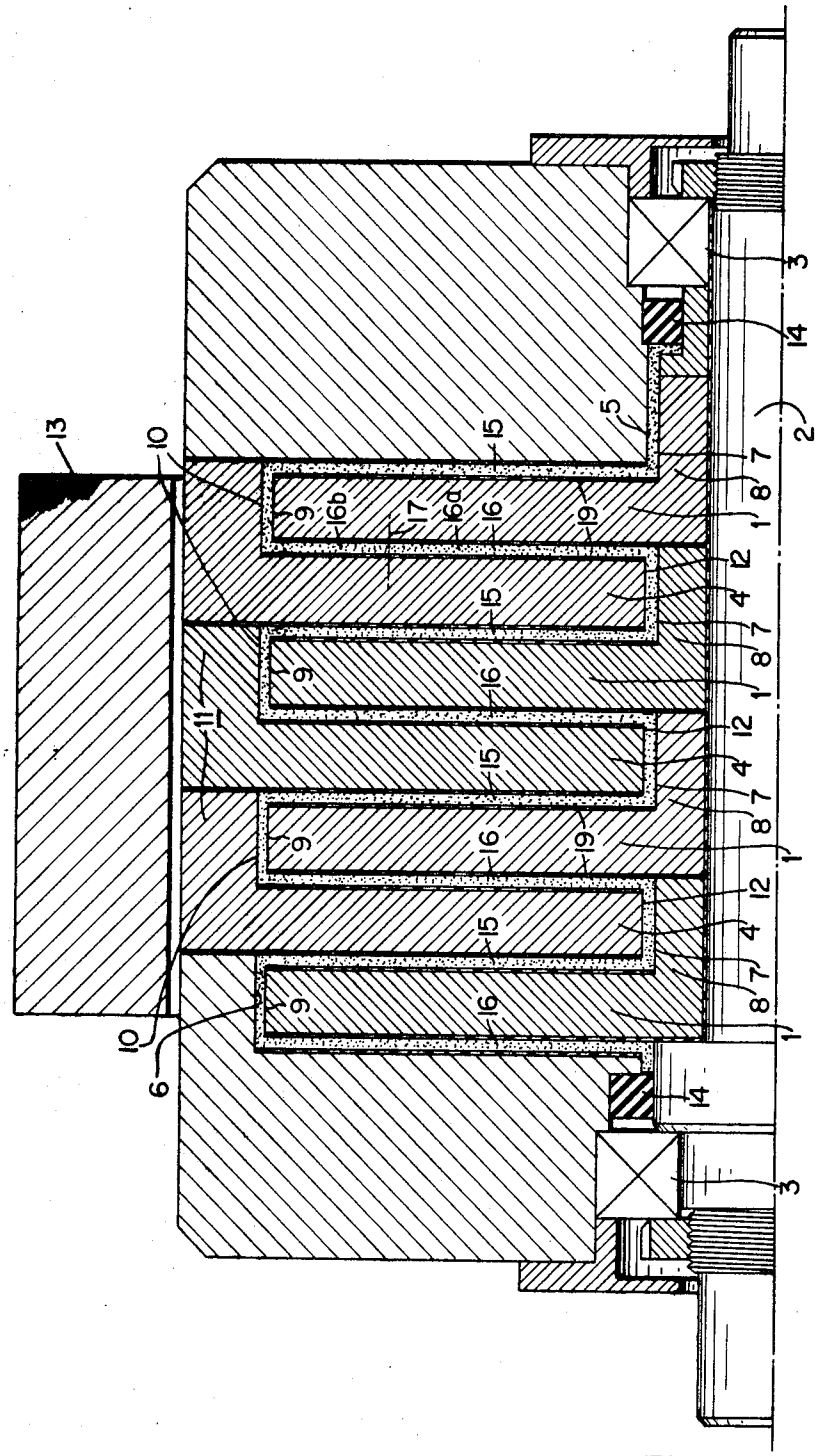


FIG. 1

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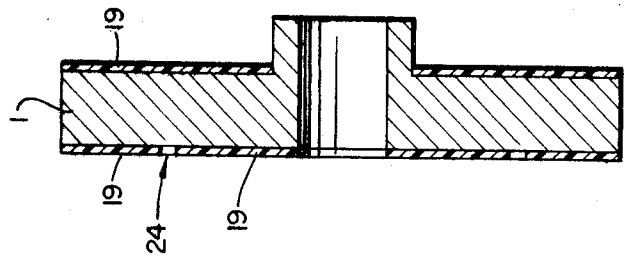


FIG. 5

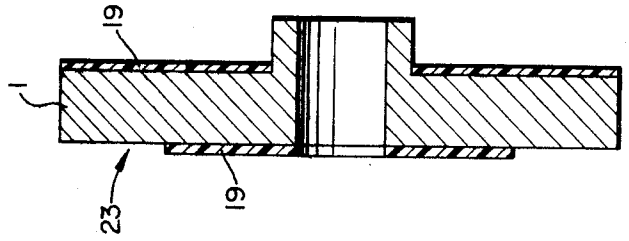


FIG. 4

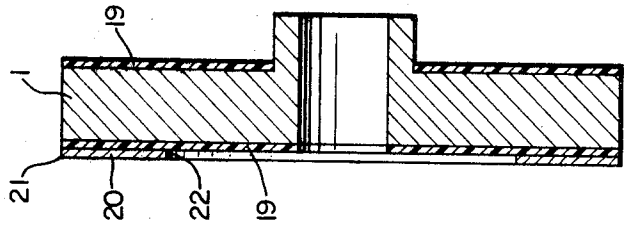


FIG. 3

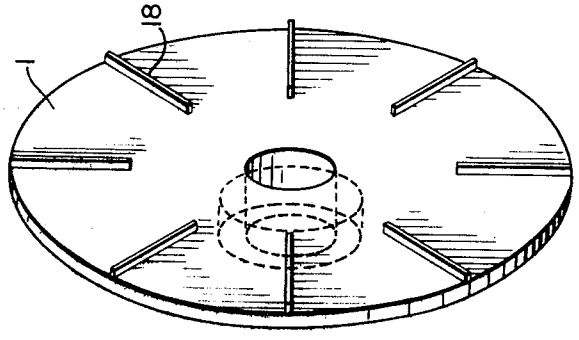


FIG. 2

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HOMOPOLAR MACHINES WITH CONTACTS OF LIQUID METAL

The invention relates to homopolar motors or generators in which the electrical contacts between the rotating and fixed components are effected by filling the spaces therebetween with a conductive liquid and especially machines of this type which have a plurality of discs. This technique is entirely satisfactory when the rotor consist of a single cylinder (Poulain machine). However, its use in the case of multiple disc machines leads to serious difficulty.

The technique just described can be used only if each liquid body which has at its terminals a difference of potential with respect to a movable disc rotates at a speed at which the counter electromotive force generated in the liquid substantially cancels the current induced in this layer. However, any liquid body that has at its opposite ends a difference in potential (practically zero) of a fixed counter disc can at most not rotate to any extent. This asymmetrical behavior creates an imbalance of centrifugal pressures in the liquid bodies on opposite sides of each movable disc. In multiple disc machines, these forces are additive, leading to the buildup of high pressures at one end of the machine with a sufficient number of discs. These pressures can lead in some cases to bursting of the machine, or at least to the loss of liquid metal and also to a strong axial thrust on the rotor assembly, which entails technological difficulties of a mechanical nature in manufacture.

The object of the invention is to develop a device which allows constant and automatic balancing of the centrifugal forces and, therefore, the elimination of the harmful pressures at one end of the machine.

To accomplish this we divide the annular bodies of liquid having ends electrically joined to the peripheral and central contacts of the fixed counter discs into two concentric annuluses and rotate one of these in the direction of rotation of the rotor, the other annulus automatically going into rotation in the reverse direction. The widths in the radial direction of these annuluses are so selected that the electromotive forces that are induced in the liquid will compensate each other while the centrifugal pressures will be additive and will counterbalance the centrifugal pressure due to the normally movable bodies of liquid; i.e., those having ends at the terminals of the electric contacts of the corresponding movable discs.

The rotation of one of the concentric annuluses can be effected by blades having a length corresponding to the width of the annulus and rigidly connected to the movable disc; by covering part of the movable disc with a conductive annulus insulated from the rest of the disc; by baring the metal of the movable disc over a certain width; or by omitting the insulation of the movable disc on the desired side in a very narrow annulus disposed between its center and periphery.

In order to better understand the subject of the invention, there will now be described as an illustration, without any limitative character, various embodiments, taken as examples and illustrated in the attached drawing, in which:

FIG. 1 is half of an axial section through a homopolar machine with four rotatable discs;

FIG. 2 shows in presepctive one form of movable disc in accord with the present invention; and

FIGS. 3, 4, and 5 are sections through three other types of movable discs in accord with the invention.

The homopolar machine illustrated in FIG. 1 has a known arrangement of four movable discs 1 rigidly connected to a shaft 2 which rotates in two roller bearings 3. In the spaces between the movable discs 1 are disposed three fixed discs 4. In FIG. 1 close double lines indicate portions of the fixed and movable discs that are insulated by a coating of insulation. The plain lines, on the contrary, represent the parts of these discs where the metal is bare. The two terminals of the machine are joined to surfaces 5 and 6 where the metal is likewise bare. The electric current flows, for example, from terminal surface 5 via the bare surface 7 of the hub 8 of first disc 1, then radially across this disc and from the bare outer surface 9 of disc 1 to the bare internal cylindrical surface 10 of annulus 11 of the first fixed disc 4. It then flows radially to the internal bare surface 12, and so on from disc to disc until it reaches the final surface terminal 6.

The functioning of the machine requires good electric contact between opposite surfaces 5 and 7, 12 and 7, and 9 and 10, while the machine is subjected to an intense magnetic field by wound inductor 13.

The necessary contacts can be effected by various techniques including that of filling the space between the stator and the rotor with a conductive liquid metal such as mercury or a mercury alloy. There are two sealing joints 14 between the rotor and stator at opposite ends of the machine to prevent the escape of liquid.

This technique of providing electrical contacts may look paradoxical at first. The liquid metal provides conduction of current directly between opposing surfaces 5 and 7, 12 and 7, and 9 and 10. It also ensures direct conduction between the surfaces 7 and 9 of each movable disc as they are at different potentials. It would therefore appear that a direct short circuit between surfaces 5 and 6 would develop. In reality this does not happen because any current passing radially through one of the annular liquid bodies between adjacent discs in the presence of the axial magnetic induction produced by device 13, sets this body of liquid into rotation about the axis of rotation of shaft 2 inducing a counter electromotive force which opposes passage of the current.

To understand this phenomenon, a distinction must be made between the annular liquid bodies that connect the surfaces 7 and 9 of the movable discs 1 and the liquid bodies 16 that connect surfaces 10 and 12 of a fixed disc.

Magnetic induction does not bring about any difference of potential in the fixed discs between surfaces 10 and 12 so these two surfaces are at practially the same potential. Consequently, the liquid annuluses 16 remain practically motionless. If it were otherwise, the magnetic field would induce in these bodies of liquid a difference of potential and consequently a current across the fixed disc, which would immediately brake the rotation of the liquid.

As far as liquid bodies 15 are concerned, with the magnetic induction in each movable disc 1 inducing a difference in potential between its surfaces 7 and 9, the associated annular liquid body 15 must rotate at the same speed as the disc so that the magnetic induction will induce in it the same difference of potential. Otherwise, a radial current that would accelerate or brake this body of liquid would develop.

The electric equilibrium of the machine thus requires that all annular liquid bodies **15** turn at the speed of discs **1** and that all liquid bodies **16** be motionless. With the machine thus in equilibrium, centrifugal force produces at the periphery of the liquid body **15** farthest to the right as shown in FIG. **1** an increase in pressure that is transmitted by stationary liquid body **16** to the next rotating body **15** where the pressure is increased and so on to the other end of the machine where there is finally a pressure that is four times as great as that produced by a single rotating liquid body. Therefore, with a sufficient number of discs, the pressure of the liquid metal is very high at one side of the machine. This can cause leaks or rupture components of the machine, and, in any case, produces a strong axial thrust on shaft **2** of the rotor (this force is from left to right in the machine of FIG. **1**). This thrust is harmful because it must be borne by roller bearings **3**, increasing wear as well as causing certain technical difficulties.

In our invention, the disadvantages of the conventional multiple disc homopolar machines just described are eliminated without altering the electrical conditions necessary for proper functioning of the machine and without in any way modifying the movement of rotating fluid bodies **15** as described above. However, each normally stationary liquid body **16** is divided at **17** into two concentric annuluses **16***a* and **16***b;* and one of these, e.g., annulus **16**b, is set into rotation. When this is done, the other annulus **16**a will automatically start to turn in the opposite direction at a speed such that the difference of the potential induced in annulus **16***a* by magnetic induction will be equal in magnitude and opposite in polarity to the potential induced in annulus **16***b* by magnetic induction. Thus there will still be no difference in potential between conductive surfaces **10** and **12.** The width in a radial direction of each annulus **16***b* and the speed of its rotation are so selected that the increase in pressure in the liquid due to the centrifugal force produced by the rotation of annulus **16***b* will balance the increase in pressure due to the rotation of the associated liquid body **15.**

In practice, the simplest thing is to drive one of the two annuluses in each normally stationary liquid body (for example annulus **16***b*) at the same speed as the movable disc **1** which bounds it. This will satisfy the pressure conditions discussed above as annulus **16***a* will also turn at a speed close to that of the movable disc **1,** but in the opposite direction (the pressures attributable to centrifugal force are not dependent upon the direction of rotation of the liquid). It is then necessary only to select the width of annulus **16***b* necessary for the difference in potential induced in it to balance that which is induced in annulus **16***a*. This width may be computed mathematically, taking into account especially the radial variation of the induction.

We have developed several methods for rotating the liquid annuluses **16***a* (or **16***b*) at the speed of disc **1.**

First, as shown in FIG. **2,** a series of radial blades **18** can be formed on or fixed to the face of each disc **1** bounding the adjacent fluid body **16.** These blades are of a height that is less than the width of the space between the disc **1** and adjacent stationary disc **4** and of a radial length substantially equal to the width of annulus **16***b* which has been selected. Each disc **1** thus functions like a centrifugal pump, the central liquid annulus **16***a*, however, turning in a direction opposite to that of the outer liquid annulus **16***b*.

We have also developed a purely electrical procedure for rotating the liquid. Specifically, we fix a conductive annulus **20** made of metal and of a thickness suitable to ensure entrainment of annulus **16***b* to the insulation **19** on the surface of each disc **1** facing annulus **16***b*. As the two edges **21** and **22** of these movable conductive annuluses **20** are at the same potential as the liquid metal opposite them, the annulus **16***b* of liquid metal which is opposite the annulus **20** will turn at the same speed as the latter (if annulus **20** presents a significant resistance, a small correction in its width may be required.)

As shown in FIG. **4,** one can also bare the metal of each movable disc **1** over an appropriate area, preferably near the periphery of the disc as shown at **23.** The effect that is obtained is the same as above, conduction occurring directly via the movable disc.

Finally, as shown in FIG. **5,** insulation **19** may be eliminated in a narrow annulus **24** disposed at a specific distance from the axis of the movable disc. As above, this causes entrainment and rotation of the liquid annulus by direct conduction from the metal of the movable disc **1.**

In all of the above examples, if the various radii are correctly calculated and adjusted, the hydrostatic pressure created by annuluses **15** and **16** on opposite sides of each disc **1** will be balanced exactly; and the absolute pressure in the gaps between the fixed discs will be exactly the same. Thus the homopolar machine will be entirely in equilibrium, no matter how many discs it may contain. The pressure that exists in the passages at the peripheries of the movable discs will be the same throughout, equaling that which corresponds to a single disc.

It will thus be appreciated that the device of the invention affords compensation for the defects of conventional homopolar machines in an extremely economical manner.

It is understood that the embodiments described above are not intended to be limiting and that they may be modified as desired without exceeding the scope of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A multi-disc homopolar machine comprising: a plurality of fixed discs; a plurality of movable discs alternated with and spaced from the fixed discs; a liquid metal filling the spaces between the fixed and movable discs, said liquid metal being formed alternately into bodies that are normally stationary and bodies that are normally movable, each normally stationary liquid body being in contact with the periphery and the center of a single fixed disc and being dividable into two concentric annuluses; and driving means for rotating one of the annuluses of each of the normally stationary liquid bodies in the same direction and at substantially the same speed as the movable discs and for causing the other of the annuluses of said liquid bodies to turn automatically under the effect of induction in the opposite direction and thereby eliminate electrical potentials across the liquid bodies in a radial direction, the radii of the annuluses being such that the hydrostatic pressure produced by centrifugal force in the liquid bodies in which the contra-rotating annuluses are formed will balance the hydrostatic pressure in the movable bodies of liquid metal on the other sides of the rotatable discs therefrom.

2. A homopolar machine as in claim 1, characterized in that said driving means rotates the outer annulus of liquid in the same direction as the movable discs.

3. A multi-disc homopolar machine comprising a plurality of fixed discs; a plurality of movable discs; contacts of a liquid metal formed alternately into bodies that are normally stationary and bodies that are normally movable, each normally stationary liquid body being in contact with the periphery and the center of a single fixed disc and being divided into two concentric annuluses; and driving means for rotating one of the annuluses in each normally stationary liquid body in the same direction and at substantially the same speed as the movable discs with another annulus of each said body turning automatically under the effect of induction in the opposite direction and at a speed suitable to eliminate electrical potential across the liquid body in a radial direction, said dirving means comprising blades fixed on the sides of the movable discs facing the normally stationary liquid bodies, said blades each having a height that is less than the space between adjacent movable and fixed discs and a radial length that corresponds to the width of the annulus which is to be rotated, and the radii of the annuluses being such that the hydrostatic pressure of the liquid metal produced by the centrifugal force at the periphery of the liquid bodies in which the contra-rotating annuluses are formed will balance the hydrostatic pressure in the movable bodies of liquid metal on the other sides of the rotatable discs therefrom.

4. A multi-disc homopolar machine comprising a plurality of fixed discs; a plurality of movable discs alternated with and spaced from the fixed discs; a liquid metal filling the spaces between the fixed and movable discs, said liquid metal being formed alternately into bodies that are normally stationary and bodies that are normally movable, each normally stationary liquid body being in contact with the periphery and the center of a single fixed disc and being dividable into two concentric annuluses; and driving means for rotating one of the annuluses in each of the normally stationary liquid bodies in the same direction and at substantially the same speed as the movable discs and for causing another annulus of each said body to turn automatically under the effect of induction in the opposite direction and eliminate electrical potential across the liquid body in a radial direction, there being layers of electrical insulation substantially completely covering those sides of both the fixed and movable discs facing the normally stationary bodies of liquid metal, and said driving means comprising annuluses of a conductive material overlying the insulating layers on the movable discs and coextensive with those annuluses of the normally stationary bodies of liquid metal which it is desired to rotate in the same direction as the movable discs.

5. A multi-disc homopolar machine comprising a plurality of fixed discs; a plurality of movable discs alternated with and spaced from the fixed discs; a liquid metal filling the spaces between the fixed and movable discs, said liquid metal being formed alternately into bodies that are normally stationary and bodies that are normally movable; each normally stationary liquid body being in contact with the periphery and the center of a single fixed disc and being dividable into concentric annuluses; and there being an annular, insulation-free surface on the side of each movable disc facing a normally stationary body of liquid metal which is coextensive with one of the concentric annuluses into which the body is dividable and the remainder of each said side of each movable disc being insulated, whereby those annuluses in the normally stationary body of liquid metal with which said insulation-free areas are coextensive will be caused to rotate in the same direction as the movable discs and whereby said bodies will be caused to otherwise rotate in the opposite direction, thereby eliminating electrical potentials thereacross in a radial direction.

6. The multi-disc homopolar machine of claim 5, wherein the insulation free surfaces extend inwardly from the inner and outer peripheries of the movable discs.

7. The multi-disc homopolar machine of claim 5, wherein the insulation-free areas are located between the inner and outer peripheries of the movable discs and on those sides of the discs facing the normally stationary bodies of liquid metal.

8. A multi-disc homopolar machine, comprising: a plurality of annular fixed discs in parallel, spaced apart relationship; a plurality of concomitantly rotatable, annular discs alternated with said fixed discs with communicating annular spaces therebetween; a single mass of an electrically conductive metal which is a liquid at operating temperatures completely filling the spaces between the fixed and rotatable discs; means so insulating the sides of the fixed and rotatable discs that the bodies of metal in alternate ones of said spaces are each in electrical contact only with inner and outer peripheral portions of a single fixed disc and the bodies of metal in the remaining annular spaces are each in electrical contact only with inner and outer peripheral portions of a single rotatable disc and will thereby rotate with said discs; and means effective when said last-mentioned discs are rotating for rotating an annular portion of each body of metal electrically connected to the peripheral portions of a fixed disc in the direction of rotation of the rotatable discs and for causing a second annular portion of each of those bodies to rotate in the opposite direction, the radii of the annuluses being such that the hydrostatic pressure of the liquid metal produced by the centrifugal force in the liquid bodies in which the contra-rotating annuluses are formed will balance the hydrostatic pressure in the rotatable bodies of liquid metal on the other sides of the rotatable discs therefrom and such that there will be a zero electrical potential radially of the bodies in which the contra-rotating annuluses are formed.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,743,874 Dated July 3, 1973

Inventor(s) Jean Pierre Chaberie et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 39, change "annulus 16b" to --annuluses 16a and 16b--.

Signed and sealed this 26th day of March 1974.

(SEAL)
Attest:

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Attesting Officer

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Commissioner of Patents

FORM PO-1050 (10-69)

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