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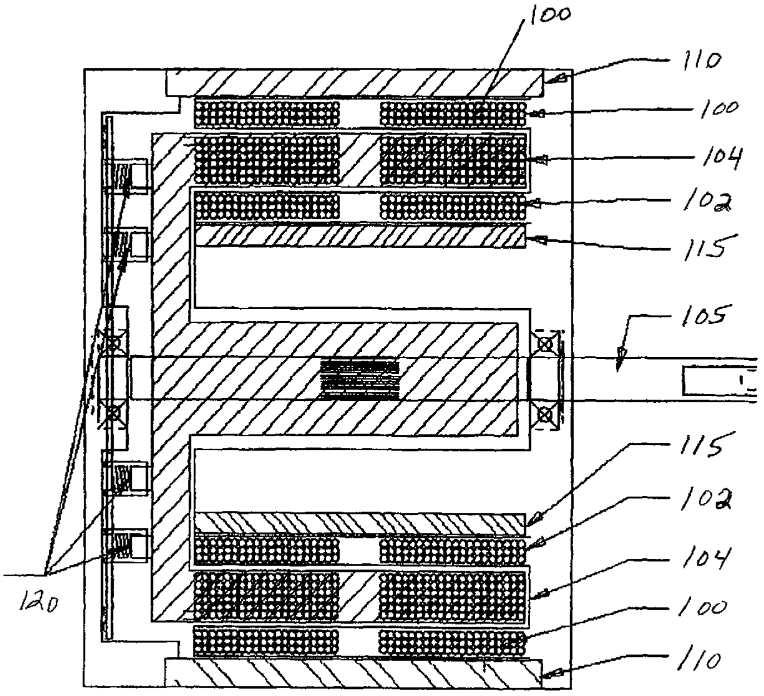

(57) Abstract: An electomotive mechanism is provided including a stator assembly and rotor assembly. The stator assembly is provided with a plurality of stator rings, defining an annular aperture therebetween. A rotor assembly is disposable within the annular aperture and rotatable therebetween. In the preferred embodiment the stator assembly includes a wound stator and the rotor assembly includes a wound rotor.

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ELECTROMOTIVE MECHANISM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a non-provisional application claiming priority to United States Provisional Patent Application Serial No. 60/293,339, entitled Two-Phase Motor, Filed May 23, 2001.

FIELD OF THE INVENTION

The present invention relates to improvements in two-phase AC electrical motors, and the like, and particularly to variable speed to-phase AC electrical motors that do not require a permanent magnet rotor or stator.

BACKGROUND OF THE INVENTION

Motors of this invention are known as two-phase electric motors. A phase is generally considered an electrical current path that induces an electro-motive force (magnetic flux) and is electrically isolated and independent from all other windings contained within a common electromotive device. An aspect of the electric machine described herein is that the rotor windings are excited via slip rings thus allowing for a motor phase to be comprised of a stator and rotor winding connected in electrical series or parallel. All windings contained within the stator and rotor are electrically isolated and thus can be excited or provide electrical output independently one from the other. Additionally, the wound rotor eliminates the "magnetic polar dead band" associated with permanent magnet rotors.

The slip rings provide for a constant uninterrupted transfer of current to the rotor windings. The slip rings are therefore not a communication device. Commuters are segmented and provide for mechanical electrical switching of current flow each time the brush or wiper transitions a commutator segment or bar. Therefore this invention could be classified as a brushless machine with dynamic rotor/armature capabilities. This electric machine design does not include a mechanical commutator nor does it possess internal residual magnetic properties.

Two-phase motors, by virtue of their even number of phases and symmetrical windings, are generally unpredictable with regard to the direction the motor assumes. A feature of certain embodiments of this invention is implementation of a magnetic bias constituted by additional wire turns and offset near the physical center of one or more the winding for the purpose of introducing a predisposition that results in the rotor adopting, upon "power up", a position in a predetermined direction causing the rotor winding to orient toward and into the stator winding side of rotational progression.

Another feature of certain embodiments of this invention is the introduction of a flux gradient into more than one winding to cause rotor displacement to a state of balance between it and the resulting rotational direction being established by phase shift induced by the drive electronics.

A significant aspect of the invention is the ability of exciting either the rotor or stator or a combination of both. Bipolar flux fields are established in each phase and these fields attract and repel alternately. Both phases can be simultaneously excited via a bipolar driver and attract/repel each other. As a result, there are reduced power losses since all of the windings are used to induce flux throughout each electrical motor cycle. Power developed in each phase is proportional one to the other.

Another significant aspect of this invention is that no permanent magnetic structure is required. Permanent magnet machines are designed and conceived based on the premise the magnet energy product of the permanent magnet component contained within the device establishes the baseline for the magnetic flux levels necessary to achieve the required torque/force by virtue of an equal flux product be established by electrical current flow in the windings. Moreover, permanent magnets can exhibit reduced magnetic properties when exposed to heat. Permanent magnets are also subject to demagnetization when exposed to high flux fields of the opposite polarity.

An aspect of this invention is that it is not limited to rotating electric machines and can also be applied to linear and partial-rotational devices.

Another aspect of the invention is that, unlike traditional electrical machines applied in the motor mode that utilize either a permanent magnet or as in the case of induction motors rotor excitation from the fields or stator windings, the present invention enables the independent excitation of each winding.

Another novel aspect of the invention is that no energized winding is required to act or react to an arbitrary pre-established or calculated flux field. Rather, the preferred embodiments facilitate, for each phase in the motor mode, inducing torque or force by virtue of one phase acting upon the other.

Another aspect of the invention is enabling use of ironless or coreless windings. Alternatively, the use of iron core or laminations is not precluded when for applications in which magnetic flux direction and/or concentration is desirable, such as, for example, certain servomotor applications.

Another aspect of the invention is that the preferred embodiment does not require incorporation of so-called inactive segments: Rather a virtue of the design maximizes "copper fill" so as to enhance efficiency and eliminate all magnet flux dead band. This aspect of the design provides for high starting torque.

Another aspect of one of the preferred embodiments of the invention is a motor in which the rotor winding rotates concentrically with inner and outer stator windings to thereby reduce the total flux path, enhance starting torque and decreased inertia.

SUMMARY OF THE INVENTION

An electomotive mechanism is provided including a stator assembly and rotor assembly. The stator assembly is provided with a plurality of stator rings, defining an annular aperture therebetween. A rotor assembly is disposable within the annular aperture and rotatable therebetween. In the preferred embodiment the stator assembly includes a wound stator and the rotor assembly includes a wound rotor. The stator assembly may include a plurality of axially segmented stator coils, and the rotor assembly may include a plurality of axially segmented rotor coils. The stator coil segments and rotor coil segments may be disposed in corresponding space opposed relation, wherein the rotor coil segments are disposable substantially adjacent the stator coil segments.

The stator coils and rotor coils may be excited by a common switched signal from a switching circuit. The stator coils and rotor coils may be disposed in serial electrical connection, or in parallel electrical connection.

The stator coils and rotor coils are excitable to radiate a coaxial flux pattern therebetween, which operates to generate a rotational force to rotate the rotor assembly.

In the absence of a permanent magnetic core, or other iron core, the rotational force applied to the rotor will remain substantially in the same direction, notwithstanding relative position of the rotor in relation to coil excitement timing or coil excitement rate. As such, the rotational speed and position may be relatively asynchronous with respect to coil excitement.

In the preferred embodiment the stator assembly may be formed to include a stator support member formed of insulating material, in which the stator coil is wholly or partially encapsulated. The rotor assembly may similarly include a body of insulating material supporting the rotor coils, and partially or wholly encapsulating the rotor coils.

The mechanism may further include a conductive cylindrical return member disposed in abutting contact with the stator assembly, along the inner surface thereof. The return member may be stationary relative to the stator assembly, and operative to facilitate a return path.

The stator coils may further include one or more biasing coils connected to the stator coils, and extending therefrom. The biasing coils being operative to urge the rotor/rotor coils to a position offset from the stator coils, to facilitate unidirectional or bidirectional rotation of the rotor assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

These as well as other features of the present invention will become more apparent upon reference to the drawings wherein:

Figure 1 is a cross-sectional view of a preferred embodiment of a two-phase AC motor constructed in accordance with this invention;

Figure 2 is a cross-sectional view of the motor of Figure 1, taken along line 2-2 0f Figure 1;

Figure 3 is a photograph showing a perspective view of a winding representative of the stator and rotor windings of the motor shown in Figures 1 and 2;

Figure 4 is a photograph showing a front elevational view of the winding of Figure 3;

Figure 5 is a photograph showing an end elevational view of the winding of Figure 3;

Figure 6 is a top elevational view of the slip rings and brush of the motor of Figure 1;

Figure 7 is a diagrammatic illustration of the polar orientation of the magnetic field generated by the stator windings;

Figure 8 is a diagrammatic illustration of the polar orientation of the magnetic field generated by the rotor windings;

Figure 9 is a cross-sectional view of the rotor of the motor of Figure 1;

Figure 10 is a cross-sectional view of the stator of the motor of Figure 1;

Figure 11 is a perspective view of a winding having additional wire turns to create a magnetic bias for unidirectional starting of the motor;

Figure 12 is a front elevational view of the winding of Figure 11;

Figure 13 is an end elevational view of the winding of Figure 11;

Figure 14 is a schematic illustration of the bipolar flux fields established in each phase;

Figure 15 is an electrical schematic diagram showing stator and rotor windings connected in series;

Figure 16 is an electrical schematic diagram showing stator and rotor windings connected in parallel;

Figure 17 is an electrical schematic diagram showing each winding independently driven by a control circuit;

Figure 18 is a cross-sectional view of a two-phase motor having four stator and four rotor windings;

Figure 19 is a cross-sectional view of a two-phase motor having six stator and six rotor windings;

Figure 20 is a top elevational view of the windings of a pancake motor constructed in accordance with this invention;

Figure 21 is a cross-sectional view of the pancake motor; Figure 22 is a cross sectional view of a motor having stator windings that magnetically interface the rotor from both polar orientations;

Figure 23A is a front view of a split stator assembly;

Figure 23B is a crossectional view of the split stator assembly;

Figure 24A is a front view of a rotor assembly;

Figure 24B is a cross-sectional view of the rotor end cap assembly;

Figure 25 is a front view of the rotor and stator assemblies, including additional unidirectional biasing coils;

Figure 26 is a front view of the rotor and stator assemblies including a pair of biasing coils for bidirectional rotation;

Figure 27 illustrates an exemplary start up biasing of the rotor assembly to 30 degrees;

Figure 28 illustrates a 60 degree rotation of the rotor assembly;

Figure 29 illustrates a 90 degree rotation of the rotor assembly;

Figure 30 illustrates an exemplary wiring diagram for unidirectional rotation of the rotor assembly; and

Figure 31 is an exemplary wiring diagram to facilitate bidirectional rotation of the rotor assembly.

Figure 32 illustrates coaxial field patterns generated in accordance with a feature of the present invention.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENT

Referring to Figures 1,2,9 and 10, two-phase motor 20 includes a cylindrical stator shell 21 and a cylindrical rotor shell 22. Stator 21 and rotor 22 are advantageously machined from a magnetic steel, one specific example , such being hyperco, an iron-cobalt alloy. Alternatively, either the stator or rotor or both can be made with laminations of thin steel plates. Circular end plate 23 and slip ring holder 24 are secured at or near the opposite ends of rotor shell 22. Output shaft 25 is fixed at the center of this end plate 23 and holder 24 concentric with the longitudinal axis of the shell 22.

Circular end plates 30,31 attached to stator shell 21 enclose the opposite ends of the motor 20. Roller bearings 35,36 are respectively fixed to these end plates 30,31 and rotatably support output shaft 25 and its attached rotor shell 22.

Figures 3,4 and 5 illustrate the overall structure of a winding 40 used in motor 20. In the specific embodiment shown, a plurality of turns of insulated copper wire 41 are wound into a generally oval configuration. This oval configuration is curved to confirm to the radius of curvature of the stator 21 or rotor 22, depending upon which component the coils are utilized. It will be understood that the preferred windings will be wound by machines well known in the art.

A significant feature of the preferred embodiments constructed in accordance with this invention is illustrated in the cross-sectional drawings of Figures 1 and 2. As shown, a maximum "copper fill" is provided within a predetermined area to provide additional windings in a given cross-sectional area so as to enhance efficiency, increase starting torque and eliminate magnetic flux dead bands. Copper fill is further enhanced using copper wire having a square cross-sectional configuration to minimize the air gaps between respective windings. Ribbon wire is another example of a useable wire for the winding 40.

Referring again to Figures 1 and 2, a pair of stator coils 40a and 40b are oppositely disposed around the inner wall of stator 21. Likewise, a pair of rotor coils 40c and 40d are oppositely disposed around the exterior wall of rotor 22. Advantageously, stator 21 and coils 40a, 40b are permanently bonded together by casting them together using a thermoset plastic resin. Likewise, rotor coils 40c and 40d are advantageously bonded to the exterior of rotor 22 using thermoset plastic.

A significant feature of the present invention is that both the stator and rotor windings can be excited independently. This is accomplished as shown in Figures 1,6 and 9 by respectively attaching the ends of the rotor coils to concentric slip rings 50,51,52 and 53. Thus, the end leads 45A, 45B of rotor coil 40C are respectively connected to slip rings 50,53. The end leads 45C, 45D of rotor coil 40D are respectively connected to slip rings 51 and 52.

Slip rings 50-53 are continuous circles of copper or other conductive material. Suitable brushes or other electrical contacts 60,61,62 and 63 are advantageously mounted to the stator end plate 31. Specific examples of the slip rings and brushes are illustrated in Figure 6.

The slip rings and brushes provided for a continuous uninterrupted transfer of current to the rotor.

The operation of the motor described is as follows. Magnetic fields are produced by passing alternatively current through the respective stator and rotor electromagnetic coils. As shown in Figures 7 and 8, magnetic return paths are provided by the magnetic steel stator 21 and rotor 22. Referring to Figure 14, application of alternating current in the stator and rotor windings results in bipolar flux fields being established in each phase and these fields alternatively attach and repel. Motors constructed in accordance with the preferred embodiments possess winding and internal motor connections that facilitate the ability for a phase to be constituted by a winding contained both in the stator and rotor. For example, rotor and stator windings can be connected so that one phase is derived by the appropriate excitation of only the stator windings and the other phase by excitation of the rotor windings. The transfer of electrical current to the rotor windings is accomplished by means of the slip rings. In one embodiment shown schematically in Figure 15, the stator winding 40A and rotor winding 40C are connected in series via slip rings 50 and 53 to a source 75 of alternating current. Source 75 is also applied, through a phase shift circuit, to stator winding 40B and rotor winding 40D via slip rings 51,52.

Figure 16 illustrates another embodiment in which the stator and rotor windings are connected in parallel.

If the respective windings are symmetrical, a two-phase AC motor is unpredictable with regard to the direction the motor will start. In the coil embodiments of Figures 11,12 and 13, a magnetic bias in one direction is provided by additional wire turns 80 that are offset the physical center of one or more of the windings 40 for the purpose of introducing a predisposition that results in the rotor 22 adopting a "power up" position in a predetermined direction.

In another embodiment shown in Figure 17, each winding is independently excited so that the flux density produced by each winding is independently controlled. This Control provides for precise speed control of the two-phase motor ans is advantageously implemented using stepper motor integrated circuitry having H-bridge output stages typically used for driving stopper motors.

Further embodiments of the invention shown in Figures 18 and 19 include additional rotor and stator windings while maintaining the two-phase operational characteristics. Thus, the motor of Figure 18 has four stator and four rotor windings, and the motor of Figure 19 has six stator and six rotor windings.

Figures 20 and 21 illustrate a "pancake" two-phase electrical AC motor constructed in accordance with this invention.

In each of the embodiments of Figures 18,19,20 and 21, the respective rotor windings are advantageously connected to continuous slip rings to obtain the advantages described above.

Figure 22 illustrates an additional preferred embodiment of the motor constructed in accordance with this invention in which the stator windings are in two sections 100 and 102 that magnetically interface the rotor 103 from both polar orientations in a "coaxial" configuration. Rotor 103 is attached to output shaft 105.

The motor housing 110 provides the outer flux return path and the inner flex return path is provided by a cylindrically shaped magnetic member 115 attached to the stator. Slip rings 120 function to continuously connect to the rotor windings as in the foregoing embodiments.

A feature of the motor of Figure 22 is improved efficiency and torque. An inherent problem with ironless motors or motors without laminations relates to the smaller wire sizes needed to maintain a minimal mean air gap. Laminations provide essentially a core upon which the wire is wound and stacked and flux transferred to a (salient) pole. Relating to coreless (ironless) motors, ideally the largest wire diameter possible is used for the purpose of minimizing coil resistance thus reducing power consumed by the motor. This is simply expressed as I^2R losses. Based on the fundamental laws of magnetics, and the need to obtain sufficient ampere-turns to achieve the required torque, the balance between wire sizes, needing winding height and compromised proximity of one coil to another is a design issue that is sometimes difficult to resolve, i.e., the question is whether to increase wire size to reduce electrical resistance and by necessity deal with the need to accept a taller winding or apply smaller wire thus keeping the mean air-gap smaller but tolerate higher electrical resistance.

The motor of Figure 22 is an effective remedy to this dilemma. Separating the stator coil into two or more coaxial units while allowing the rotor winding to pass between them affords the use of a significantly larger wire size while ensuring a cumulative air-gap reduction of approximately 30%. Of major importance for consideration is the physical law, which states flux density, decreases inversely to the square of the distance or the mean air-gap. The aforementioned percentage of physical interactive coil proximity improvement considered in conjunction with an inverse square function translates to a major improvement in coil to flux interaction and thus overall motor performance ans efficiency. Thus, the mean air gap can be reduced on the order of 30% which enables a substantial increase in flux density since magnetic flux density decreases inversely proportional to the square of the distance.

Another feature of the motor of figure 22 is that the inner return path provided by member 15 is stationary and does not rotate. The net result is significantly reduced rotor inertia. The virtue of this is a substantial reduction of rotor inertia, decreased rotor inertia results in a much reduced mechanical time constant(the amount of time required to accelerate the rotor to 63.2% of a predetermined speed) or simply faster acceleration time. Also and related to the aforementioned, there exists the option to use a return path component of substantial mass so as to facilitate the utilization of extremely high flux densities to provide for very rapid acceleration and/or braking. The advantages of the motor of Figure 22 thus includes:

a) Magnetic flux interacts evenly with both sides of the rotor windings. The total flux path distance is reduced.

b) Symmetric draw and repulsion forces are in line with the fundamental direction of rotation. This contributes to enhanced starting torque; less motor generated audible noise and reduced vibration at slow motor speeds.

c) The stationary inner return path provides for the mass of this motor element to be as large as required to support the desired motor flux density without contributing to increased rotor inertia.

d) Flux is introduced to both sides of the rotor coil. Active flux is introduced from both planes resulting in a rotor penetration that is equal on both sides while both stator windings have a balanced gradient toward the center of the rotor winding.

Machines constructed in accordance with this invention can be used as motors, generators, or electric brakes using drive/controller electronics in such a way that a phase is constituted by the electrical current flow through a stator and rotor winding both connected in electrical series or parallel. Rotor excitation is accomplished by the use of slip rings or other devices providing for the transfer of electrical current to a dynamic electro-magnetic assembly.

Additionally, the invention is also classifiable as a novel embodiment of step motor that adjusts substantially unlimitedly the energy product of all magnetic flux sources thus affording high versatility in terms of power application thereby enhancing achievable efficiencies. Also, the invention enables no torque affording the ability to "back drive" the device. That is not typically possible with the conventional permanent magnet step motor. The appropriate description pertaining to step motor properties is best described as a universal device that would replace a variable reluctance or permanent magnet design. Thus the machines of this invention are applicable to either unipolar or bipolar excitation capable of complete and total user control of all magnetic flux densities. When used as a generator/alternator, the frequency and voltage output are user controllable.

Accordingly, a principal feature of the present invention concerns the use of a wound stator and wound rotor. As used herein the term "wound" means that the stator assembly and rotor assembly are devoid of permanent magnetic materials, or iron cores, such as laminations, which produce characteristic magnetic flux patterns when the associated coils are excited. The use of a wound stator and wound rotor provide significant advantages both in terms of weight, ease of production, and more rotational uniformity of magnetic flux patterns, and mitigation of control circuitry to synchronized coil switching with the rotor rotational position. However, as noted below, it is to be understood that aspects of the present invention also have advantageous application to motors/generators having iron cores or permanent magnetic materials.

Figures 23A,B illustrate an exemplary split stator assembly 140 that may be used within the construction illustrated at Figure 22. As shown therein the stator assembly includes one or more coils disposed about cylindrical outer ring 135, and one or more coils disposed about cylindrical inner ring 137. The rings define an annular aperture 139 for receiving the rotor assembly 150.(shown at Figure 24). The rings 135, 137 are coaxial and concentric, at radially spaced locations (radii)from axis 160. The stator windings may be viewed as radially segmented between inner ring 127 and outer ring 135. As shown at Figure 23B, the windings may be axially segmented as well. Coil segments 141 and 143 are axially segmented coils disposed on outer ring 135. Coil segments 142,144 are axially segmented coils disposed on inner ring 137. The outer ring 135 and inner ring 137 may be collectively part of the stator support member 133. As noted above the stator assembly may be formed by encasing at least a portion of the stator coils with in a support member 133, such that the coils form an integral part of the support member for economy of the manufacture and ease of assembly.

The inner ring 135 may be in frictional engagement with the cylindrical return member, implemented as collar 145, that forms the stator flux return path. Collar 145 remains stationary relative to the stator assembly 140, such that frictional losses are avoided and efficiencies are thereby enhanced.

In the presently preferred embodiment the stator windings are connected in pairs of coils 130,132,134 and 136. The particular wiring arrangement of the coils may be varied, as indicated above.

Exemplary wiring diagrams to facilitate unidirectional rotation of the stator, and bidirectional rotation of the stator, are shown at Figures 30, 31, respectively. The wire diagrams illustrated at Figures 30, 31 are arranged such that the rotor coils and stator coils are disposed in series relationship. However, it is to be understood that alternative wiring diagrams may be implemented in the broader aspects of the present invention.

Figure 24 illustrates exemplary construction of the rotor assembly 150 adapted to rotate within the stator annular recess 139, shown in Figure 23. The rotor assembly 150 may be formed to include a rotor and a plurality of rotor coils, that may be connected in pairs, such as 134, 136. The coils are arranged concentrically about a common axis 160. The coils 142, 144 may be axially segmented in the same manner as stator coils 141,143 (Figure 23B).

The rotor assembly 150 may include a support member with the stator coils formed thereon. In one embodiment the stator coils are formed integral with the rotor support member, such that at least a portion of the rotor coils are embedded in the support member. The support member may be formed of material such as thermal setting plastic resin.

As shown at Figure 24B, an end cap 170 may be provided that may be disposed adjacent to the rotor assembly to facilitate electrical connection to the rotor assembly at, as it rotates about the axis 160.

Figure 25 illustrates the joined stator and rotor assemblies. As shown therein the stator assembly may include additional biasing coils or shading, 142, 144 which tend to rotate the rotor assembly clockwise at initial start up. The biasing coils 142, 144 are asymmetrical so as to induce the rotor assembly to move towards the biasing coils when power is first applied. As the power transitions, polarity, the rotor assembly is urged by repulsive forces to continue movement in the same direction, i.e. clockwise, toward the biasing coils, whereupon clockwise rotation follows. As shown in Figures 27,28,29, rotor assembly may be biased to a variety of different starting positions, whereby the bias angle α^1, will be 30 degrees, 60 degrees, 90 degrees, or some other relative radial rotation with respect to the stator assembly. The particular biasing angle may be selected in accordance with a particular application requirements, and may be selected to enhance repulsive forces that produce high torque as the signal transitions and the rotor assembly begins to rotate. In practice, rotor biasing or predisposition, may be significantly less than the illustrated displacement, e.g. in the range of 10 degrees. Upon initial power up the rotor assumes an orientation predicated upon the biasing of the stator windings. During the next electrical cycle, the polarity of all windings inverses such that the magnetic dynamics of repulsion and attraction occur.

Figure 26 illustrates a construction where in the stator assembly includes a pair of biasing coils 142, 144 that may be used to facilitate selective bidirectional rotation of the rotor assembly.

The stator assembly 140 and rotor assembly 150 are preferably formed to close tolerance such that air gaps 151, 153(Figure 25)are small. The narrow air gap and the split arrangement of the stator coils provides greater flux density over a rotational angle segment to enhance rotational torque. The flux interaction between the rotor coils and the closely adjacent stator coils, disposed on both sides of the rotor coils is believed to be significantly greater than achieved by means of a single ring of stator coils.

Figure 32 illustrates coaxial flux patterns generated as a result of the present invention. Shown therein are rotors segments 180,182, and stator segments 184,186. As the stator and rotor segments are excited coaxial magnetic fields 190,192 are generated, with a resulting Force applying a rotational Force to the rotor, inducing the rotor to rotate in direction R. As the rotor rotates and switching occurs, the opposing rotor and stator segments remain relatively the same, albeit at different, changing polarities. As shown in Figure 2 rotor segment 180 is in an attractive field, whereas rotor segment 182 is in a repulsive field.

Further, as noted above, the stator and rotor assemblies may be constructed as molded plastic pieces with the coils encased therein. Such a construction permits economy of manufacture and the ease of assembly. The absence of a permanent magnet or iron core advances such economies, while also avoiding performance limitations arising from saturation characteristics of the iron or the permanent magnetic material.

In the presently preferred embodiment the coils are excited by An H-bridge circuit of the type commonly available in the field. The H-bridge circuit may be, for example, an integrated circuit such as the SGS Thompson L203 Controller. Varying the circuit voltage will operate to vary frequency and current communicated to the coils, thereby varying rotational speed of the rotor assembly. Insofar as the rotor assembly preferably includes no permanent magnetic material or iron core(a wired rotor) the rotor assembly does not predispose to a particular orientation and associated speed limitations are avoided.

In the presently preferred embodiment the rotor assembly will normally rotate at 1,000 to 5,000 rpm, with the coils operating at 2,000 to 10,000 cycles per second. When the number of coils are expanded the operating frequency will increase accordingly.

As one of ordinary skill will recognize, the switching circuitry need not be implemented as an H-bridge, but may be implemented as any variety of other switching circuits. Insofar as the same switching current may be applied to the stator and rotor coils It is also anticipated that the coils could operate, albeit less efficiently, by a direct connection to a AC source. However, the inclusion of the signal conditioning circuitry would reduce vibration and enhance the effectiveness of a direct AC signal. Commonly available switching circuitry would provide greater efficiency.

Although the preceding discussion has been primarily in connection with a wired stator and rotor (i.e. without permanent magnets or iron cores), it should be understood that the present invention includes design and features that may be beneficial to iron core motors or permanent magnet constructions. For example, flux density enhancements arising from the split stator construction may have advantageous applications to iron core motors as well. As such, the invention is not intended to be limited in application to wired motors, generators or other electromagnetic devices.

Certain features of the invention are, however, particularly advantageous in relation to wired stators and rotors. Insofar as iron core motors typically exhibit a dominant magnetic orientation, coil switching circuitry may be constrained by a need to maintain significant synchronization between the magnetic field generation pattern and the switching speed. Hall effect sensors are commonly used for such applications.

Typically, interactive motor poles or coils approach each other from lateral parallel planes whose vectorial prospective transition from a minor angular value to perpendicularity. During this transition, lateral or forces along the force vector become increasingly displaced from the arc or movement to approach pure perpendicular if not for the commutaton process denergizing the relevant windings. However, in the present invention, the dominant force vectors remain oriented primarily in a rotational direction such that the force direction remains substantially the same, even where the switching circuit outruns the rotor rotational speed, or the rotor rotational speed outruns the switching circuit. Insofar as the rotor and stator coils are excited by the same switching signal switching circuit, the relative magnetic polarity remains the same and motor direction is a function of preestablished direction. As such the switching circuit may operate relatively asynchronously with respect to rotor rotational speed/position. This mitigates constraints upon motor operation, and associated production expense. The absence of an iron core also mitigates magnetic saturation limitations that can constrain switching speed or other functions. Accordingly, the application of the present invention to coreless motors provides for economic savings and enhances motor compatibility with high speed switching circuitry.

As will be recognized by those skilled in the art, the principal features of the present invention have been described in connection with a particular embodiment, recognized in connection with certain contemporary applications of the inventions. However, the invention may be implemented in relation to numerous other embodiments. Though described primarily in relation to applications for motors, features of the invention have analogous application to generators, electrical brakes, and other devices wherein common components are used. Further, features of the invention may be implemented in alternate constructions, including but not limited to, a system level redistribution of the component features and a component level substitution of equivalent circuitry or structure.

What is Claimed Is:

1. An electromotive mechanism comprising:

(a) a stator assembly having the plurality of stator rings defining an annular aperture therebetween; and

(b) a rotor assembly disposable within the annular aperture and rotatable therein.

2. The mechanism as recited in Claim 1 further comprising a stator coil(s)formed upon each of the stator rings , and a rotor coil(s) formed upon the rotor.

3. The mechanism as recited in Claim 2 wherein the stator coil(s) and rotor coil(s) are disposable in corresponding space opposed annular segments, wherein the rotor coil annular segment(s) is rotatable with respect to the stator coil annular segment(s).

4. The mechanism as recited in Claim 3 wherein the rotor coil annular segment(s) and the stator coil annular segment(s) are excitable to generate a rotational force applied to the rotor, the rotational force being operative to rotate the rotor with respect to the stator.

5. The mechanism as recited in Claim 4 further comprising a switching circuit for regulating excitement of the stator coil(s) and rotor coil(s) to affect variable speed rotation of the rotor.

6. The mechanism as recited in Claim 5 wherein the dominant rotational force applied to the rotor remains substantially in the same direction when the switching circuit excitement outruns rotor rotational speed.

7. The mechanism as recited in Claim 5 wherein the dominant rotational force moving substantially in the same direction when the rotor rotational speed outruns the

switching circuit excitement.

8. The mechanism as recited in Claim 1 wherein rotor rotational position is asynchronous with respect to coil excitement timing.

9. The mechanism recited in Claim 5 wherein rotor rotational speed is asynchronous with respect to coil excitement rate.

10. The mechanism as recited in Claim 2 wherein the stator is a wired stator.

11. The mechanism as recited in Claim 9 wherein the rotor is a wired rotor.

12. The mechanism as recited in Claim 1 further comprising a stator support member formed of insulating material, wherein at least a portion of the stator coil is encapsulated, the insulating material forming the stator support member.

13. The mechanism as recited in Claim 2 wherein the stator coil(s) and the rotor coil(s)operate to radiate a coaxial flux pattern(s) therebetween.

14. The mechanism recited in Claim 2 wherein the stator coil(s) comprises a plurality of axially spaced stator coils.

15. The mechanism recited in Claim 2 wherein the rotor coil(s) comprises a plurality of axially spaced rotor coils.

16. The mechanism as recited in Claim 2 further comprising a conductive cylindrical return member disposed in abutting contact with the stator assembly, the return member being stationary relative to the stator assembly and

operative to facilitate a magnetic return path.

17. The mechanism as recited in Claim 2 wherein the stator coil(s) further includes a biasing coil(s) connected to at least one of the stator coil(s), and extending therefrom, the biasing coil(s) being operative to urge the rotor coil(s) to a position offset from the stator coil(s) to facilitate unidirectional rotation of the rotor assembly.

18. The mechanism as recited in Claim 3 wherein the stator coil(s) include a plurality of biasing coils, each biasing coil connected to an associated stator coil and extending therefrom, the biasing coils being selectively excitable to induce bidirectional rotation of the rotor assembly with respect to the stator assembly.

19. The mechanism as recited in Claim 5 wherein the stator coil(s) and the rotor coil(s) are serially connected to the switching circuit.

20. The mechanism as recited in Claim 5 wherein the stator coil(s) and the rotor coil(s) receive a common switched signal from the switching circuit.

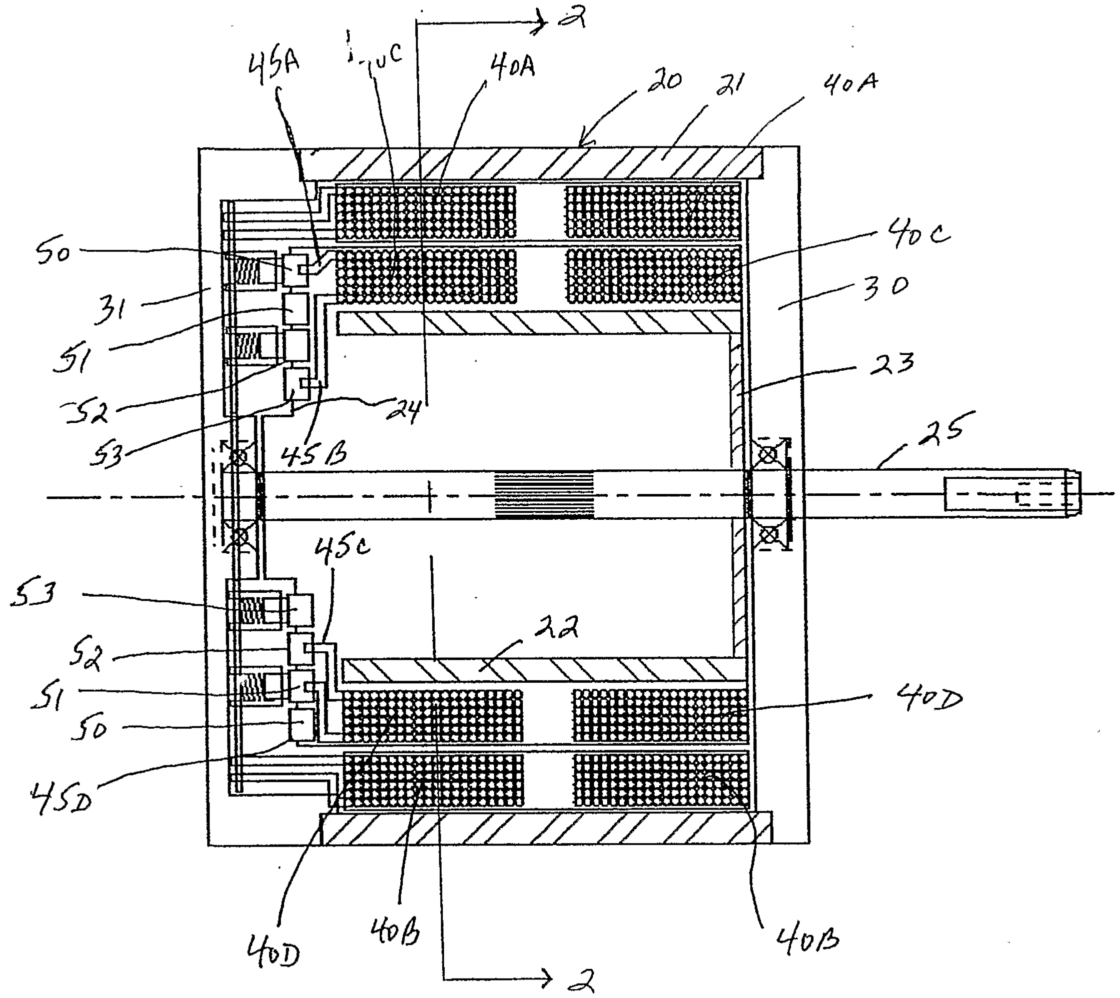

2
45A
40C
40A
20
21
40A
50
40C
30
31
51
23
52
24
53
45B
25
45C
53
22
52
51
50
40D
45D
40D
40B
40B
2

FIGURE 1

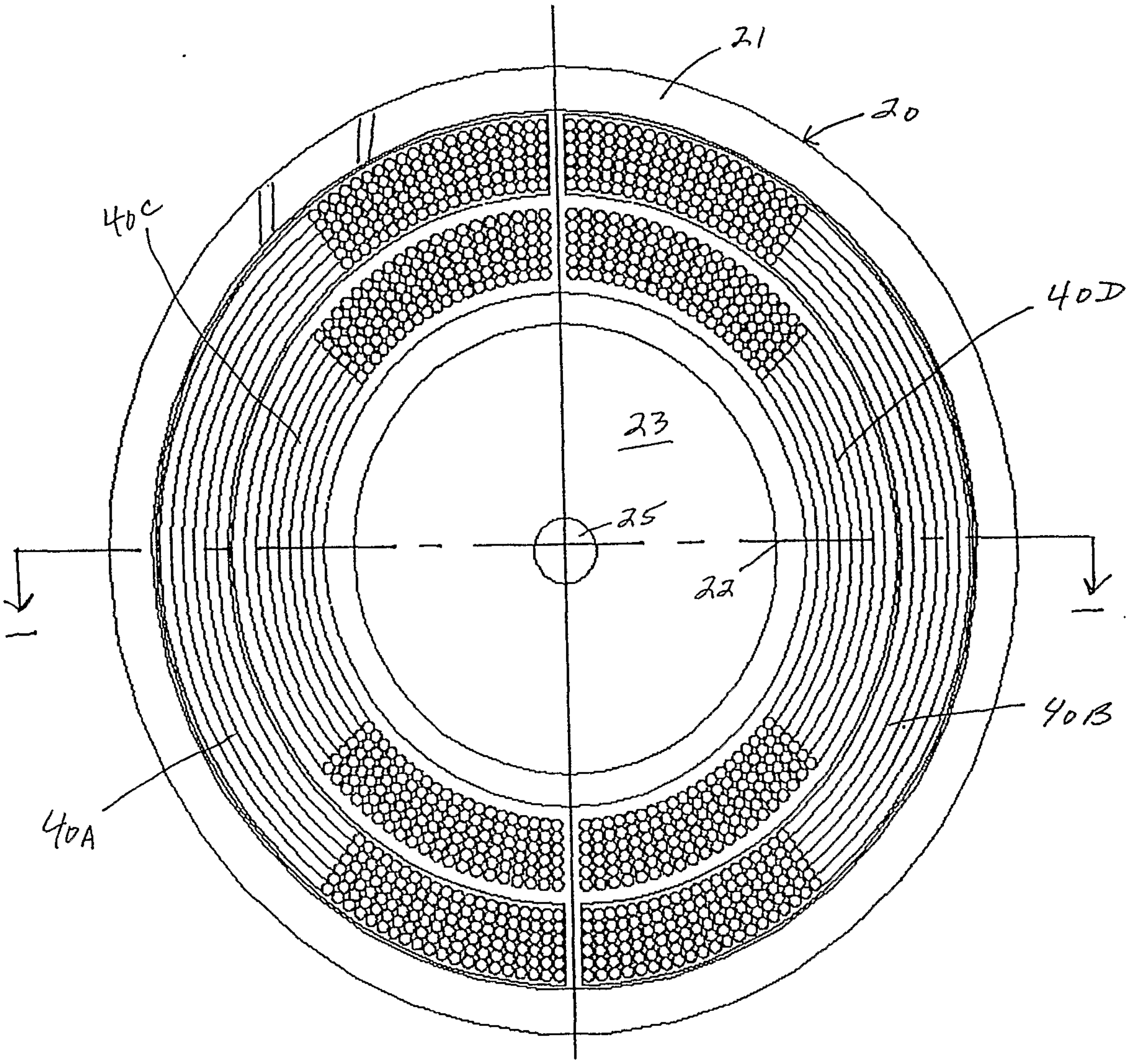


FIGURE 2

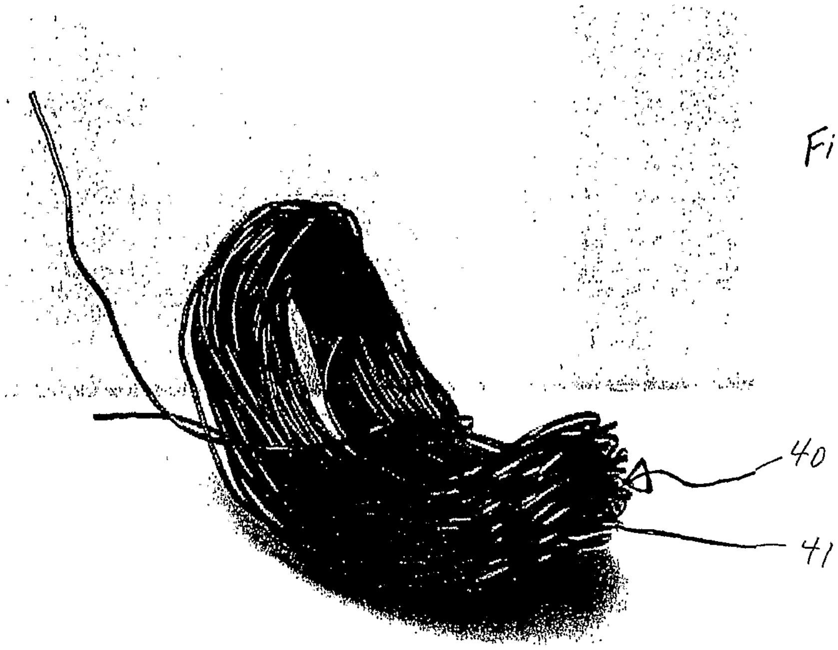


Figure 3

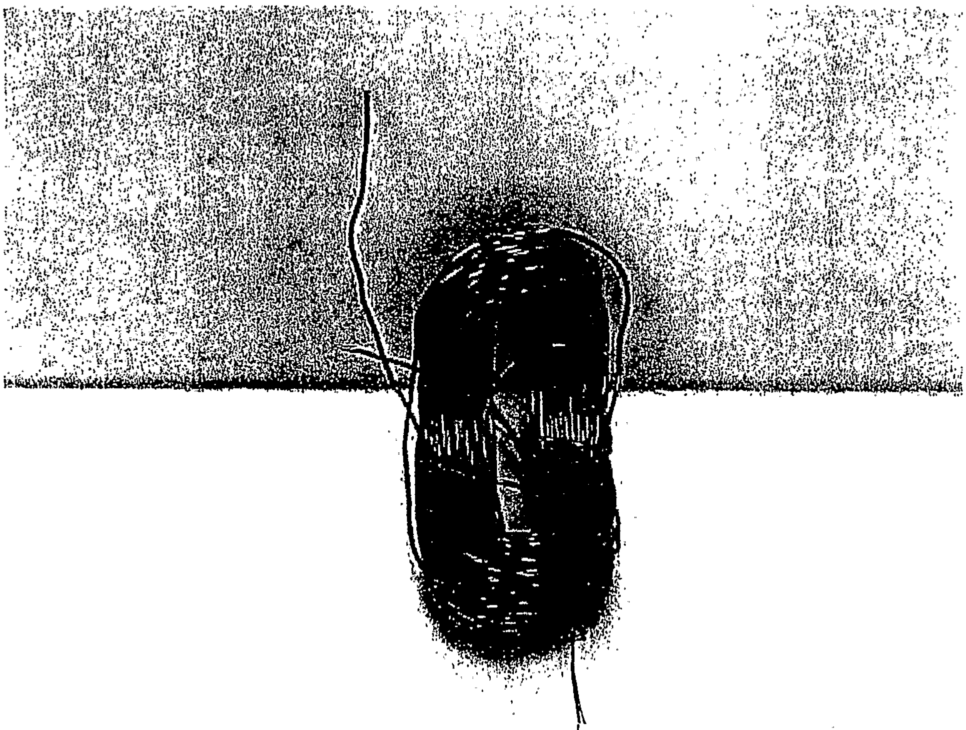


Figure 4

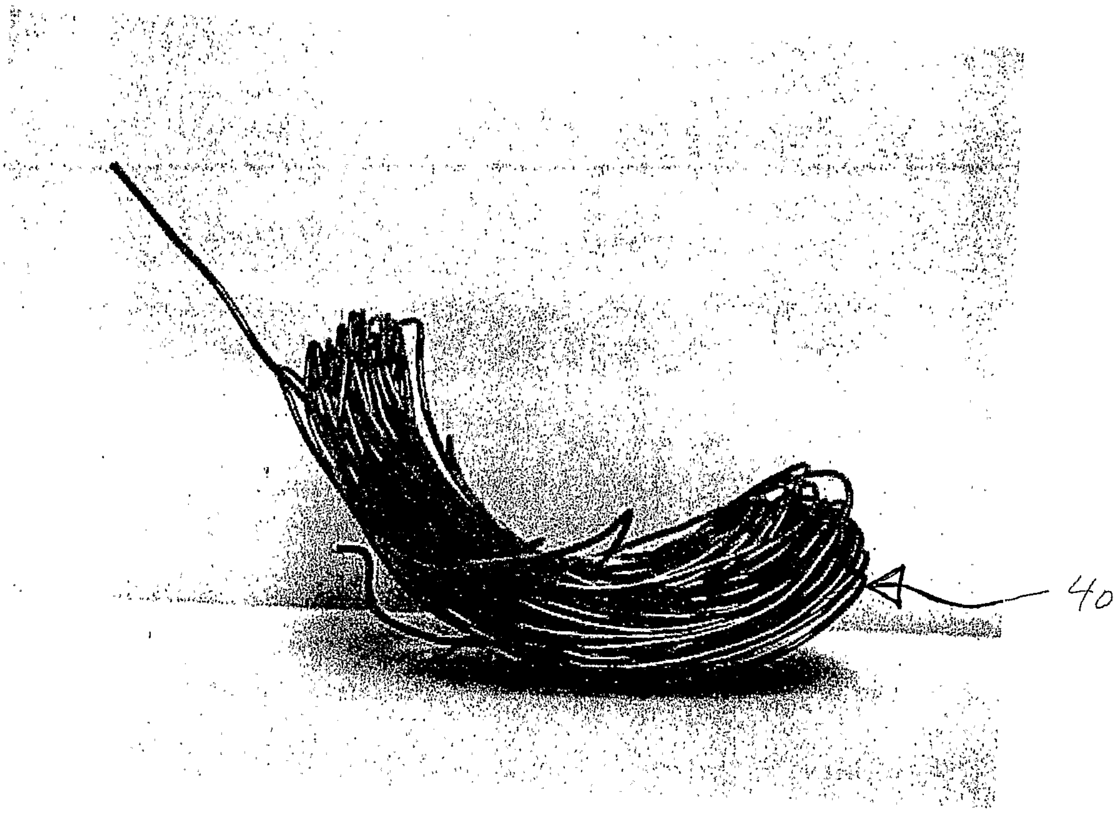


FIGURE 5

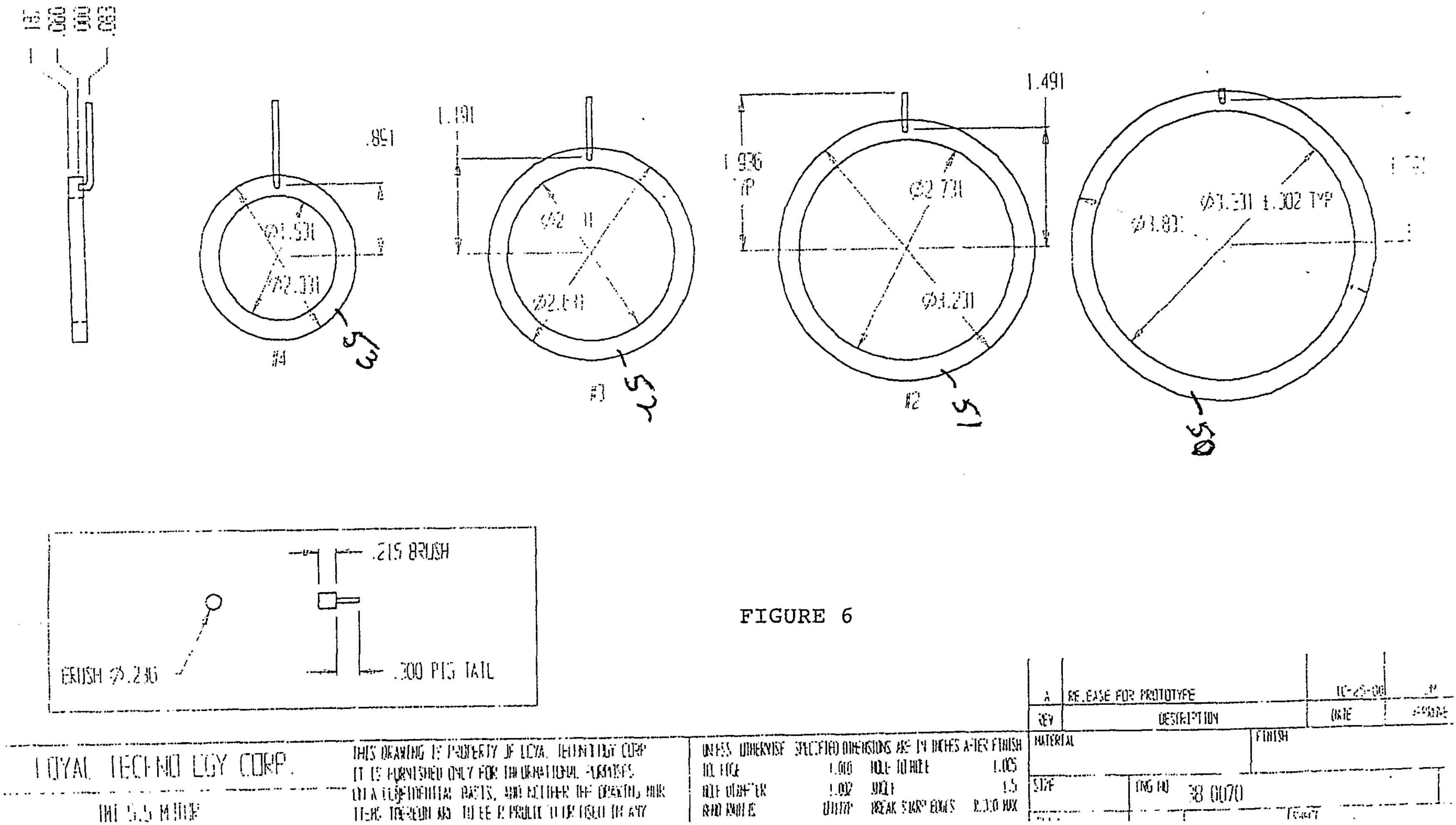
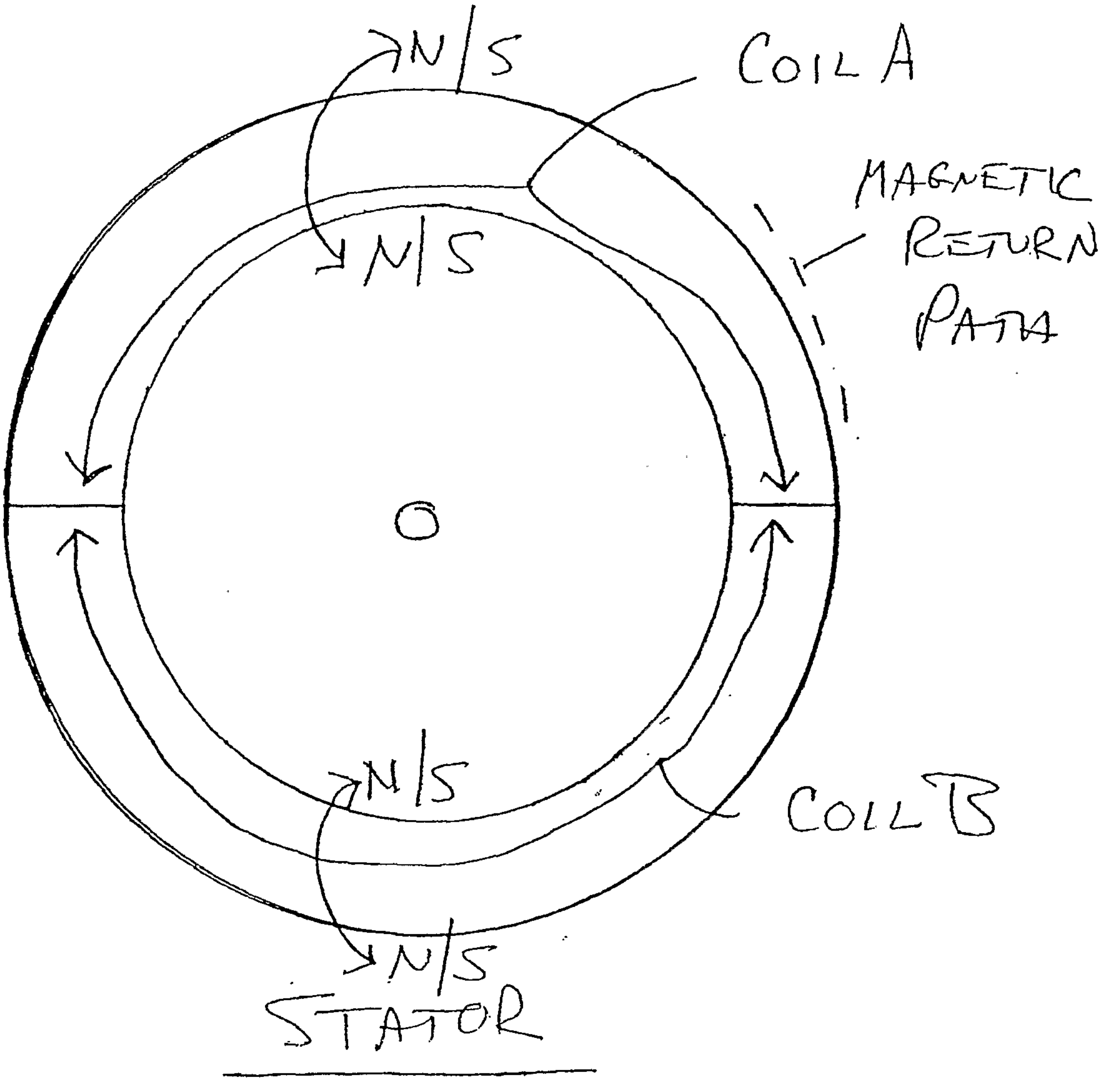
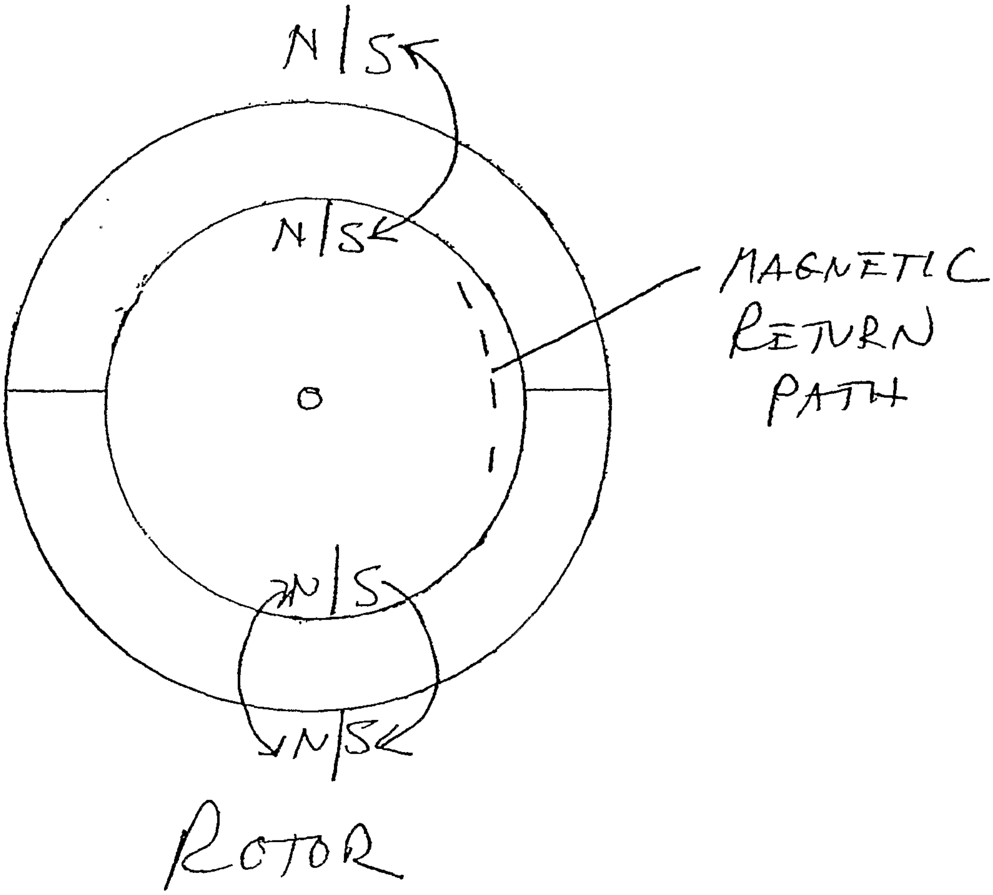

.083
.000
.020
.181
.851
Ø1.531
Ø2.031
#4
53
1.191
Ø2 11
Ø2.611
#3
52
1.936
TYP
1.491
Ø2.731
Ø3.231
#2
51
Ø1.831
Ø3.331 ±.002 TYP
50
.215 BRUSH
BRUSH Ø.236
.300 PIG TAIL
LOYAL TECHNOLOGY CORP.
THE 5.5 MOTOR
THIS DRAWING IS PROPERTY OF LOYAL TECHNOLOGY CORP
IT IS FURNISHED ONLY FOR INFORMATIONAL PURPOSES
ON A CONFIDENTIAL BASIS, AND NEITHER THE DRAWING NOR
ITEMS THEREON ARE TO BE REPRODUCED OR USED IN ANY
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER FINISH
TOL EDGE 1.010
HOLE TO HOLE 1.005
HOLE DIAMETER 1.002
ANGLE 1.5
AND ANGLE
BREAK SHARP EDGES 0.010 MAX
A
RELEASE FOR PROTOTYPE
10-25-00
REV
DESCRIPTION
DATE
APPROVE
MATERIAL
FINISH
SIZE
DWG NO 38 0070

FIGURE 6



EACH COIL WOUND ON 180° RADIUS - POLAR ORIENTATION IS PERPENDICULAR TO CENTER

FIGURE 7



ROTOR EXCITED VIA SLIP RINGS

FIGURE 8

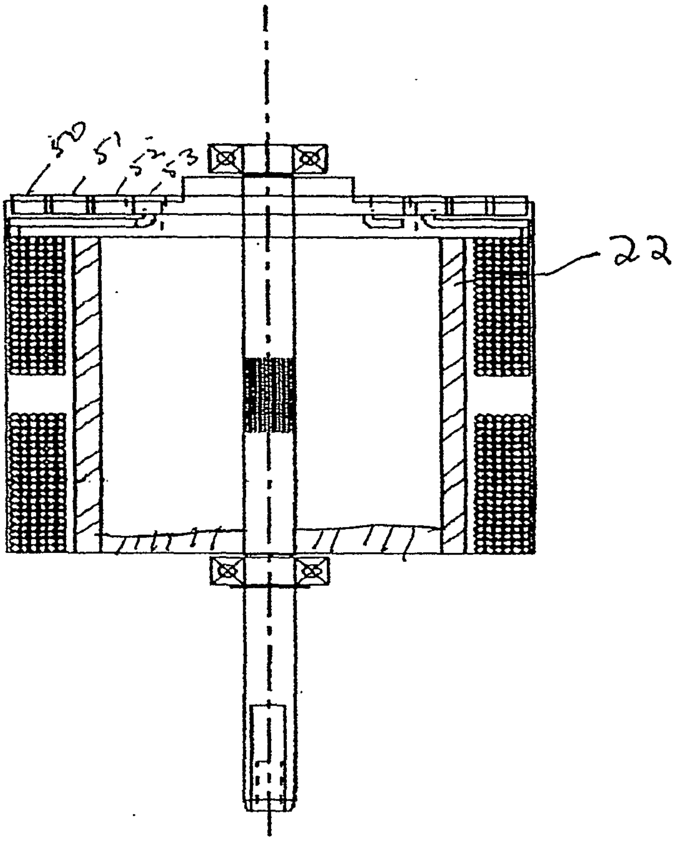


FIGURE 9

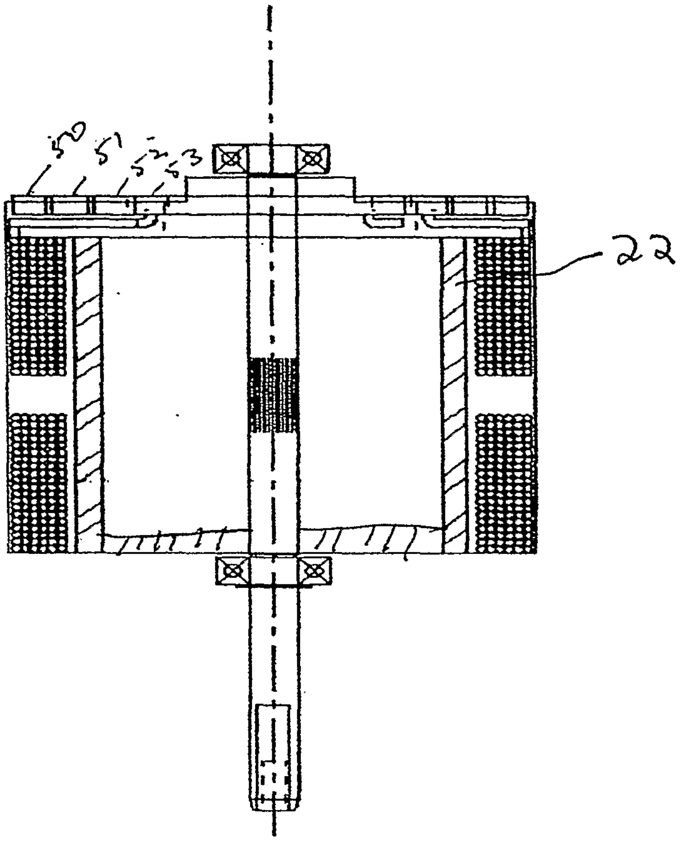


FIGURE 9

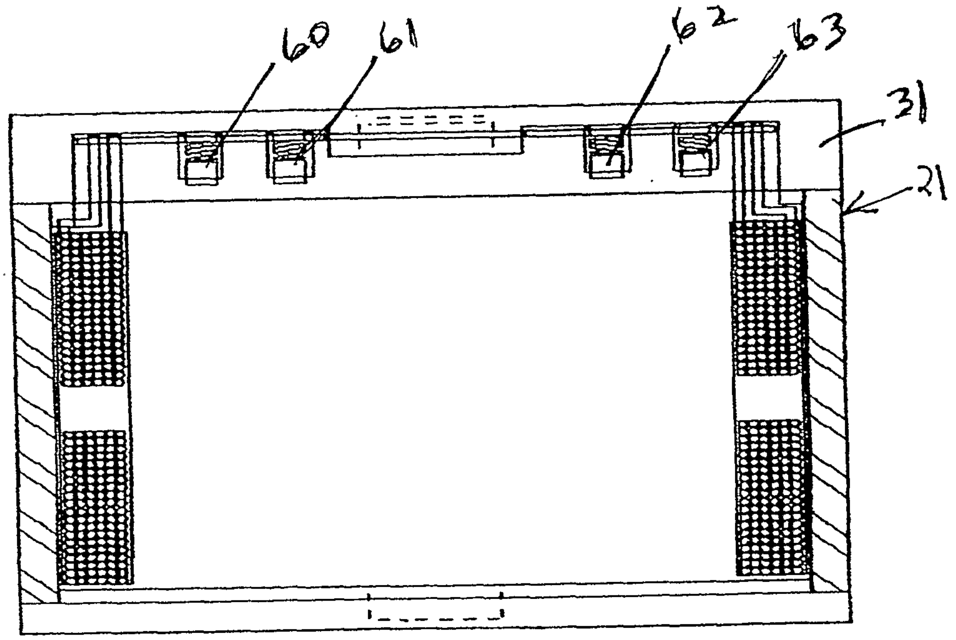


FIGURE 10

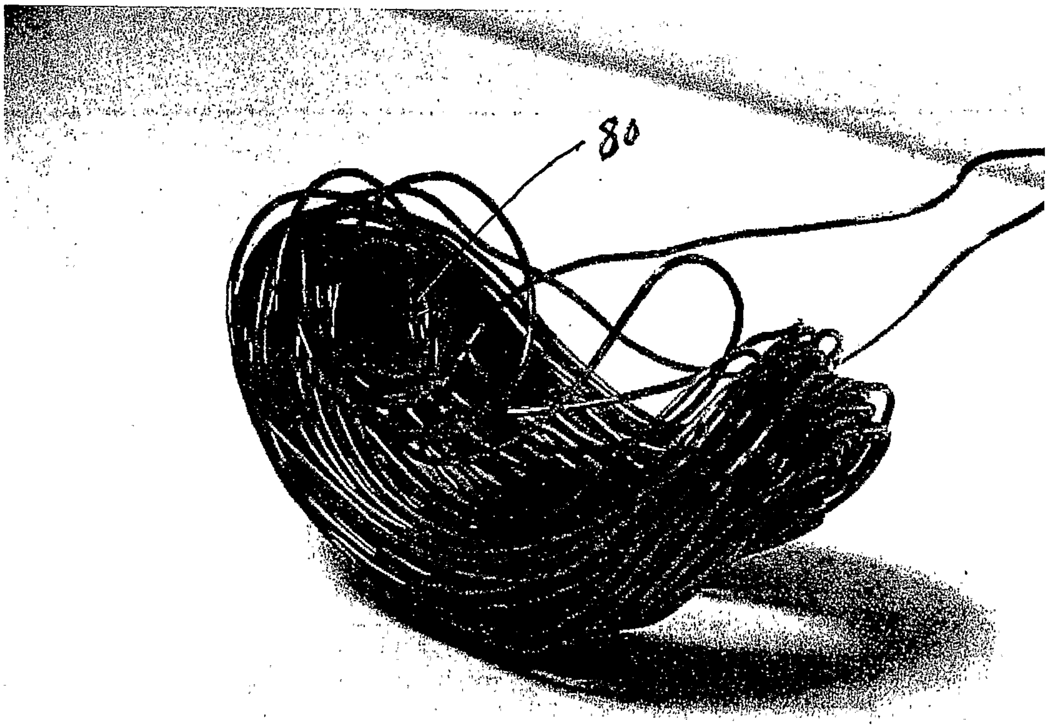


FIGURE 11

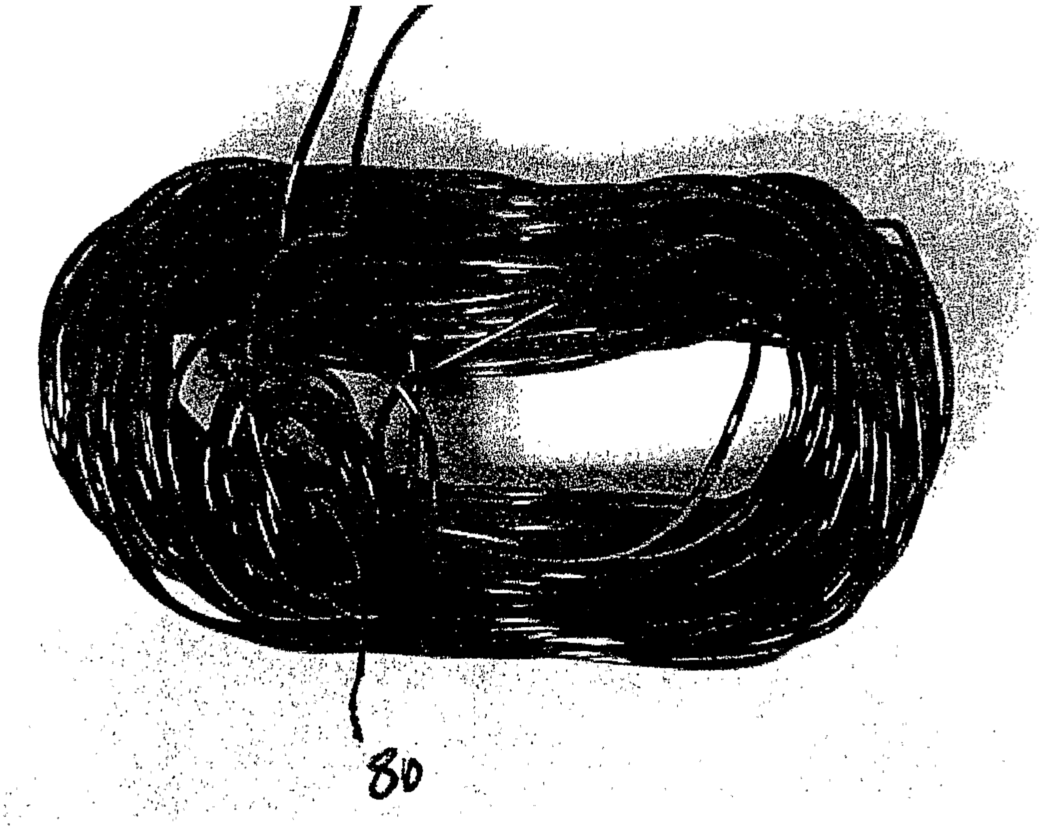


FIGURE 12

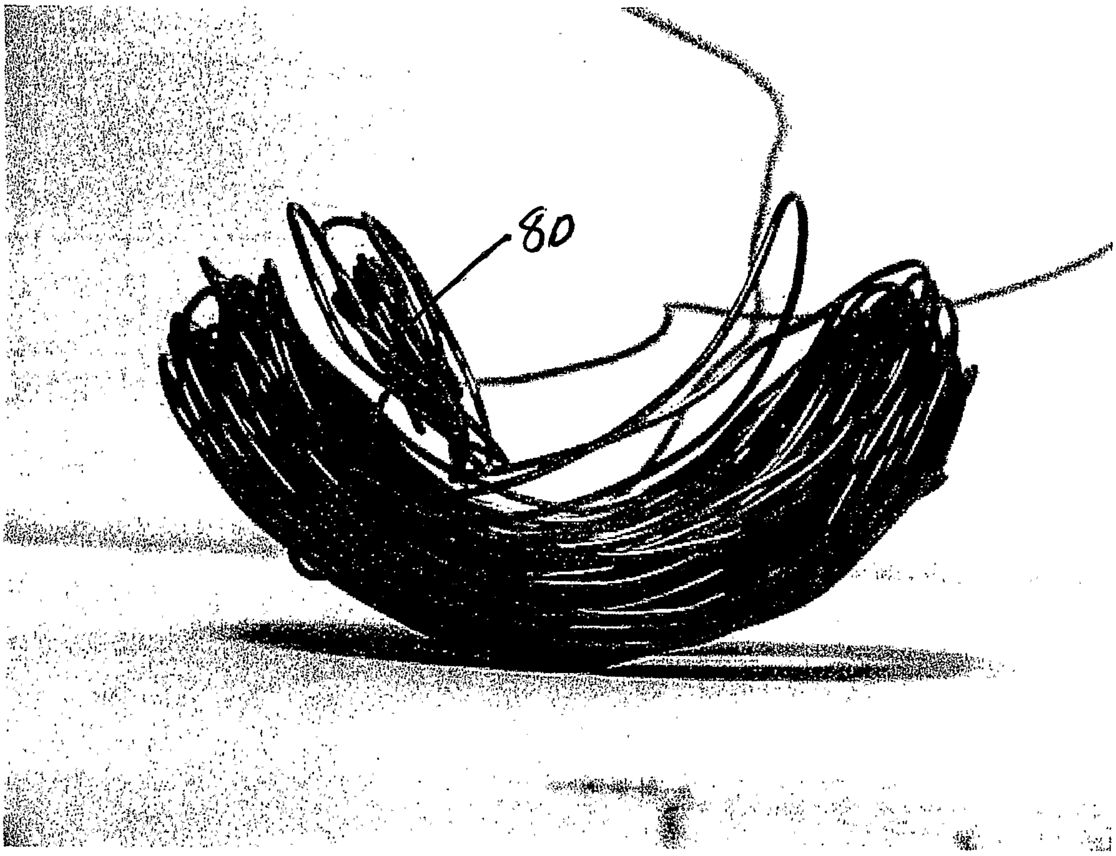


FIGURE 13

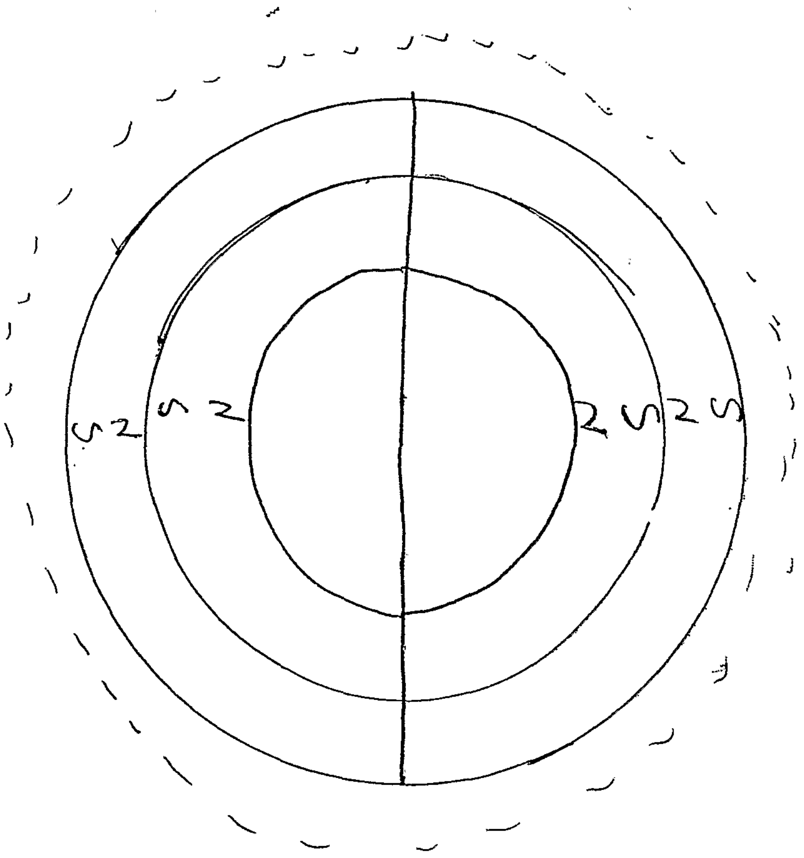


FIGURE 14

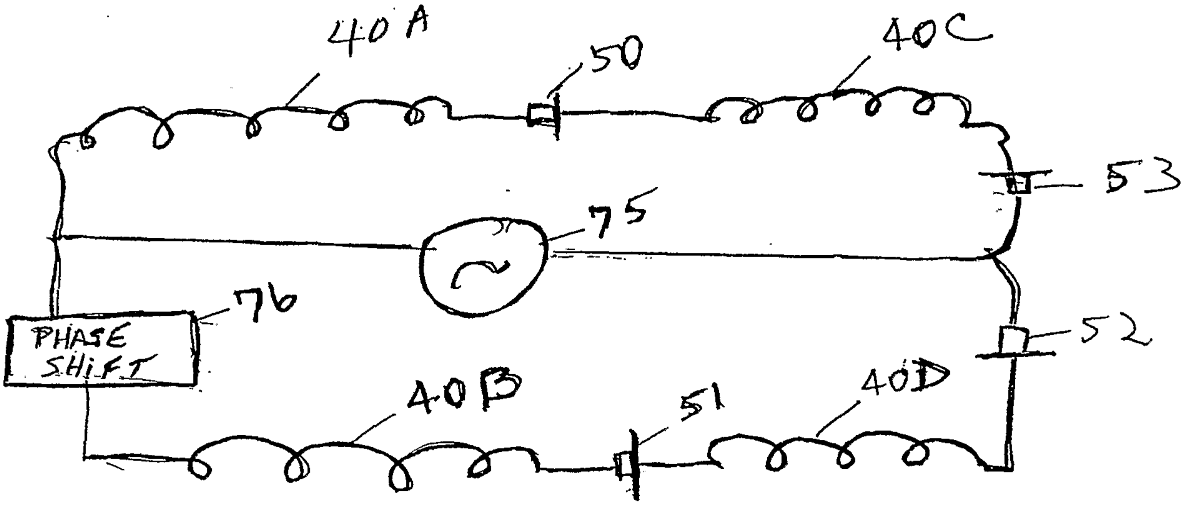


FIGURE 15

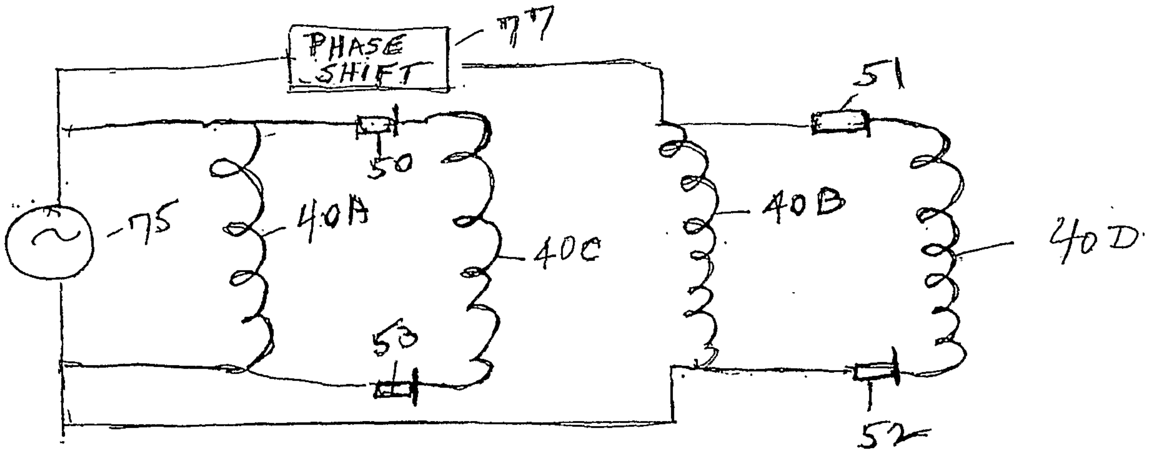


FIGURE 16

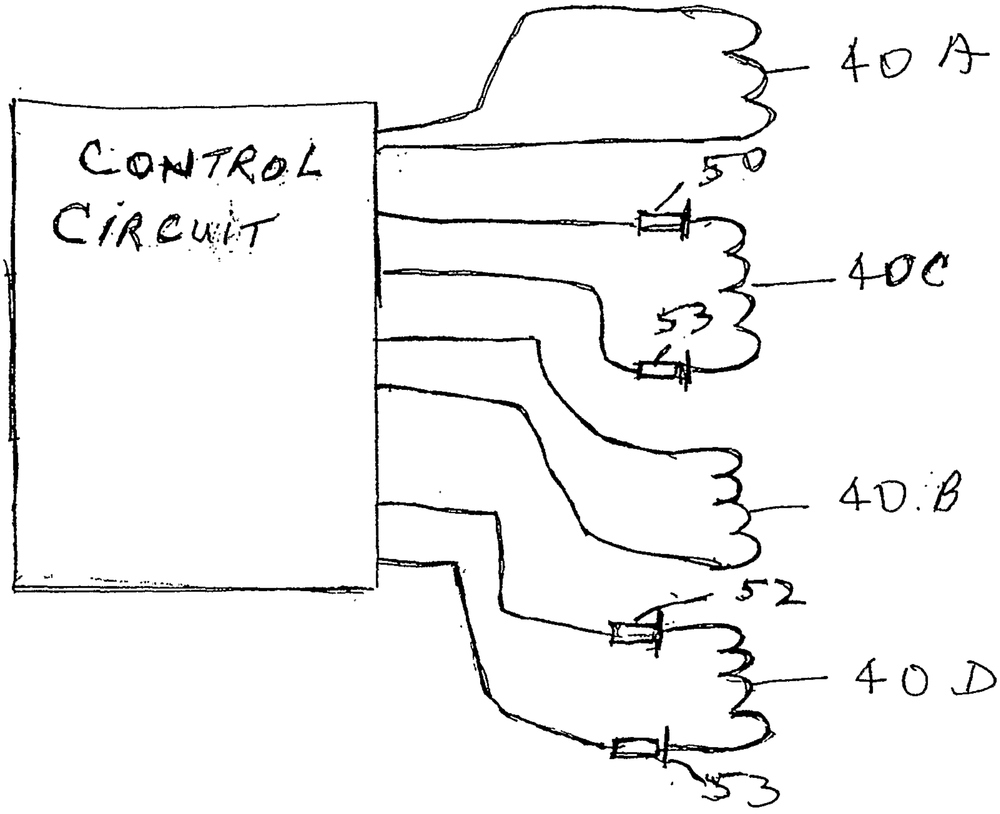


FIGURE 17

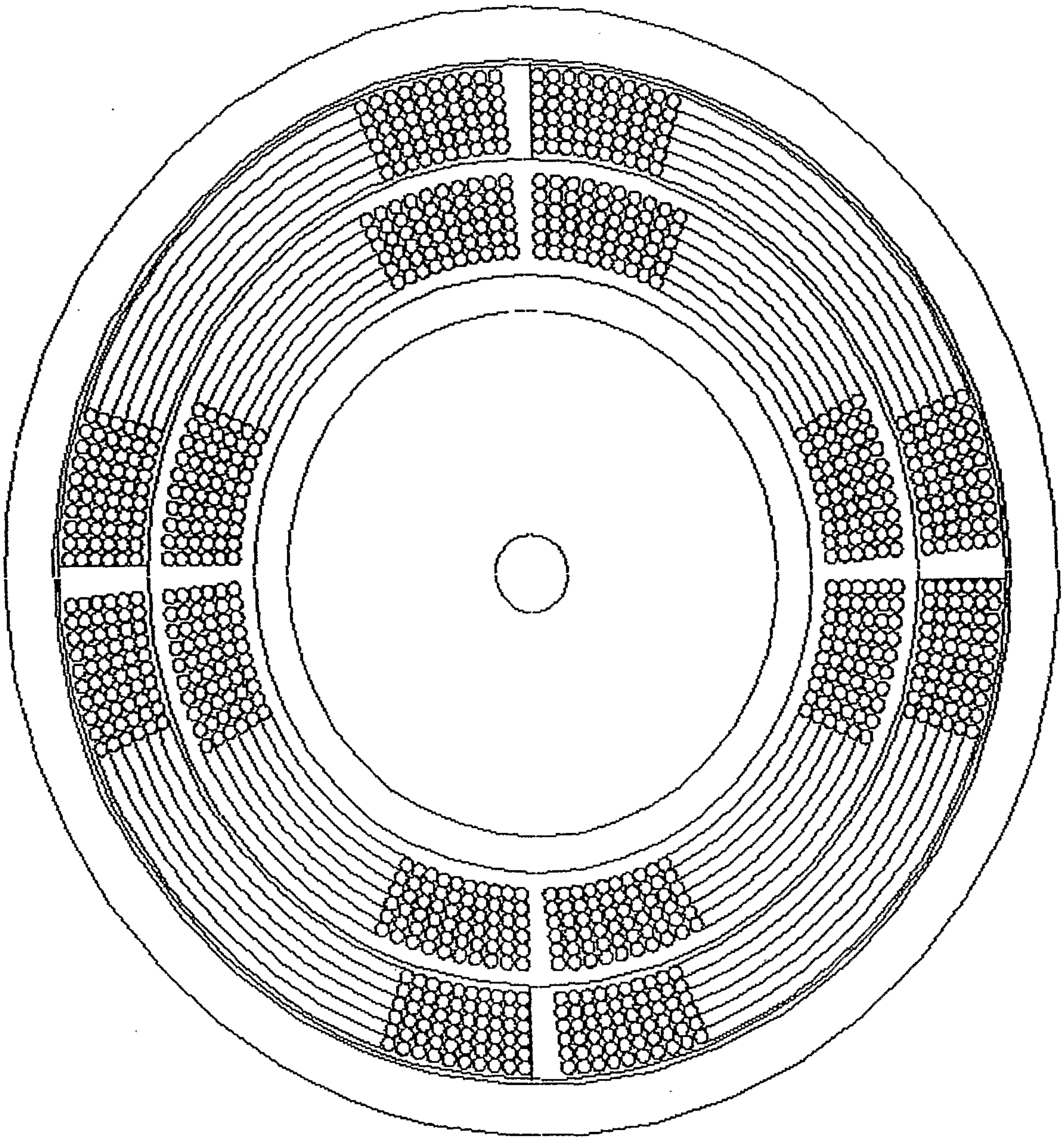


FIGURE 18

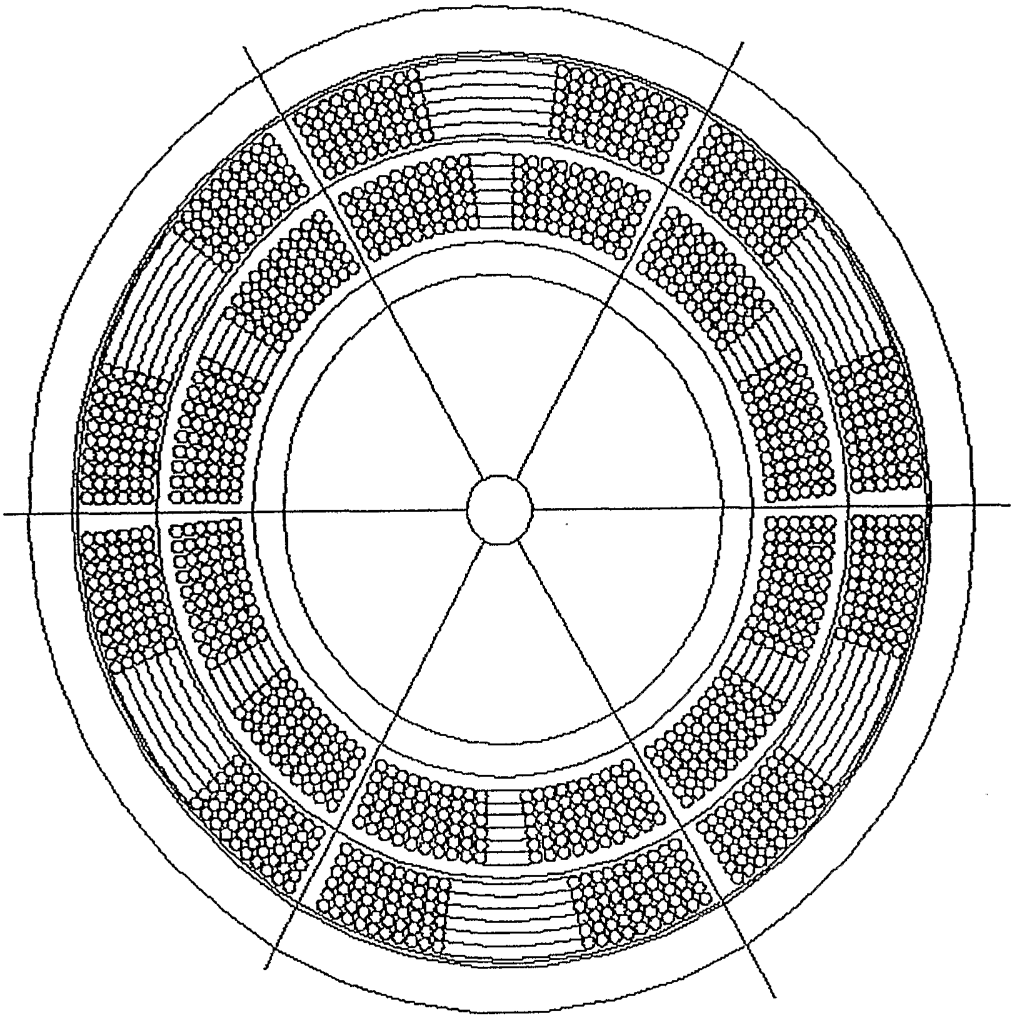


FIGURE 19

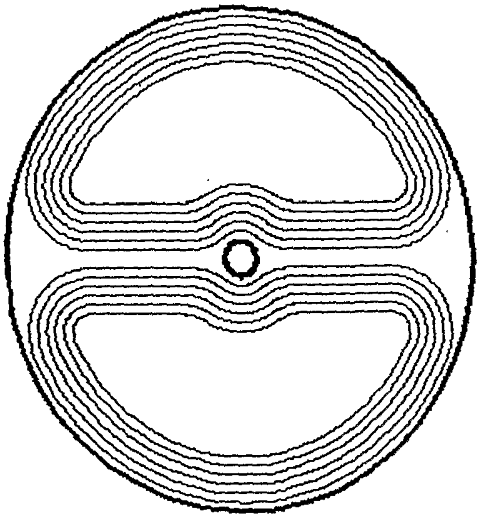


FIGURE 20

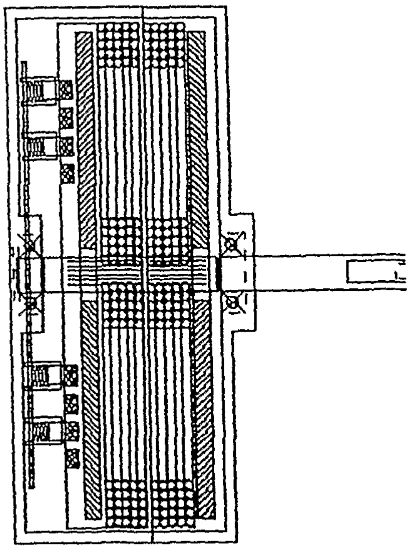


FIGURE 21

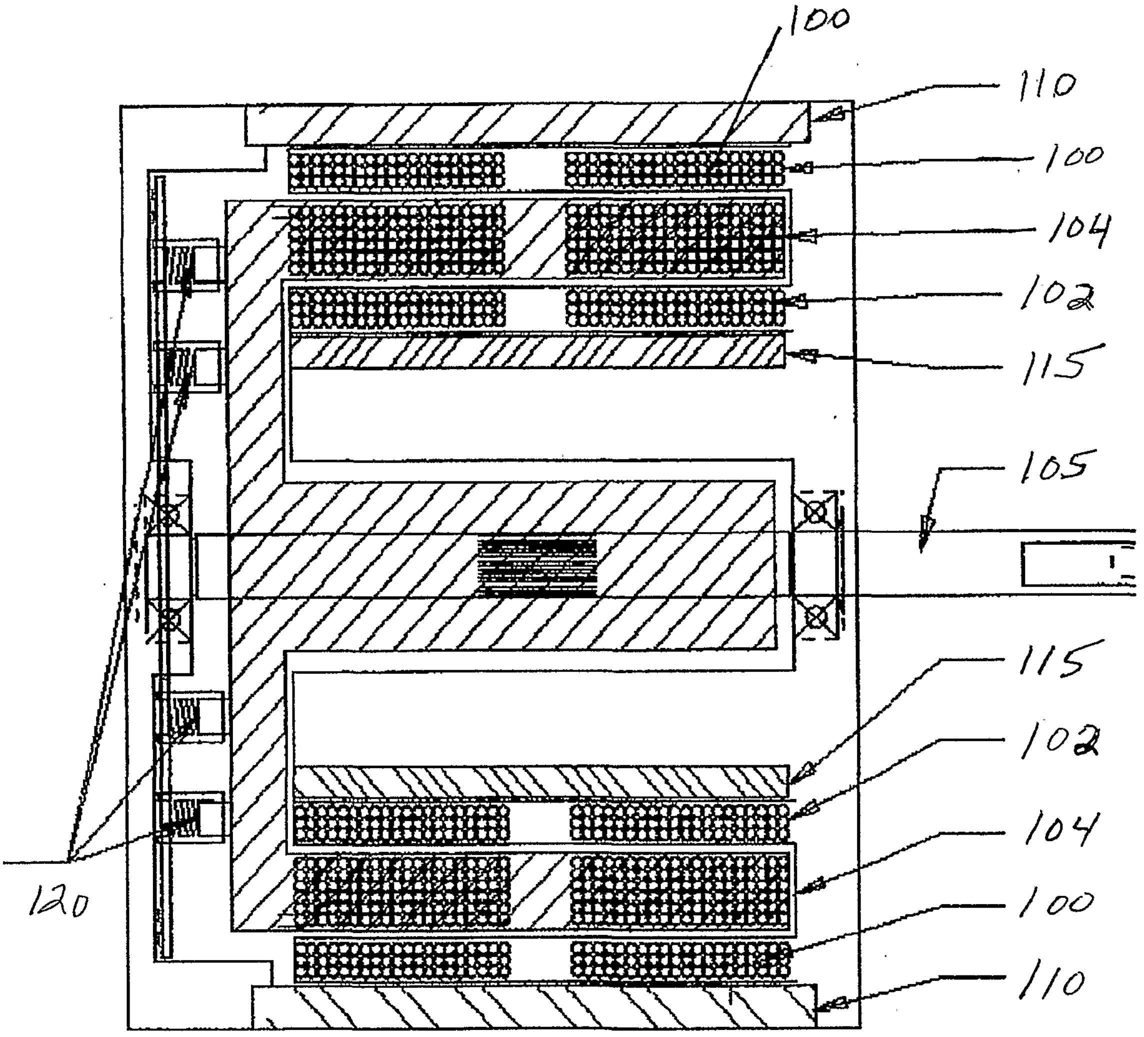
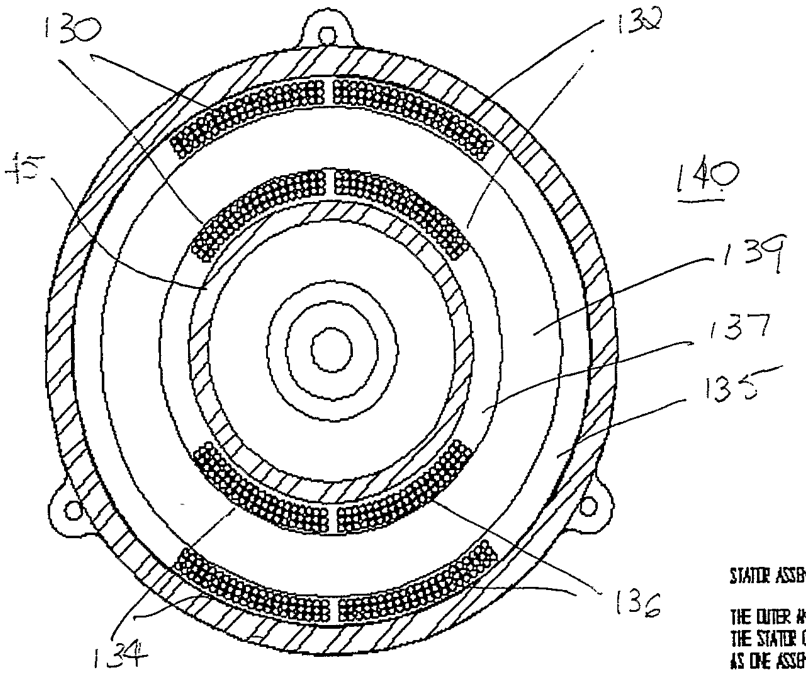


FIGURE 22

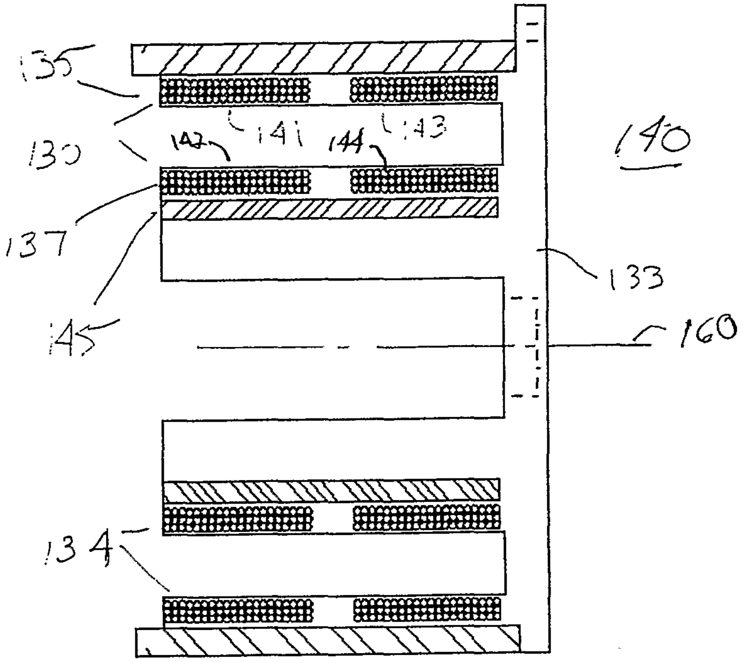
Fig 23A



STATOR ASSEMBLY

THE OUTER AND INNER RETURN PATH ALONG WITH THE STATOR COILS ARE MOLDED IN THERMAL PLASTIC AS ONE ASSEMBLE.

Fig 23B



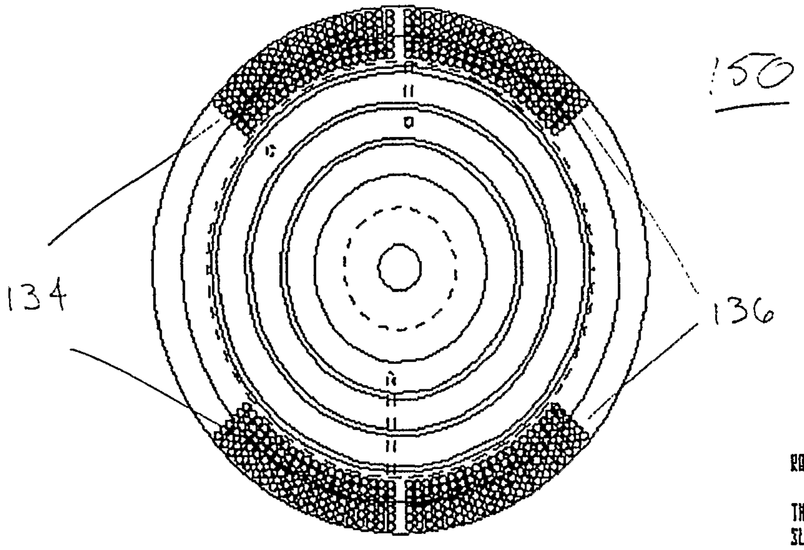


Fig 24A

ROTOR ASSEMBLY

THE ROTOR ASSEMBLY CONTAINS THE ROTOR COILS,
SLIP RINGS, AND SHAFT. dLL ARE ASSEMBLED BY MOLDING
IN THERMAL PLASTIC

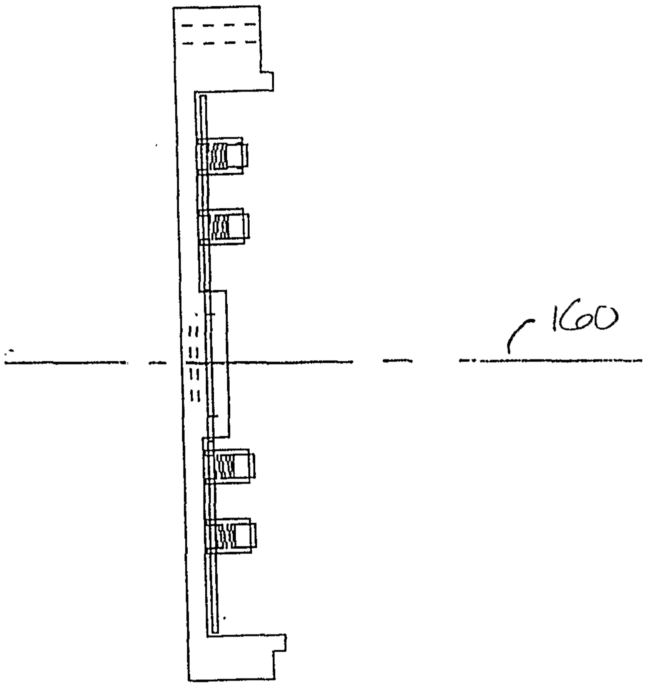
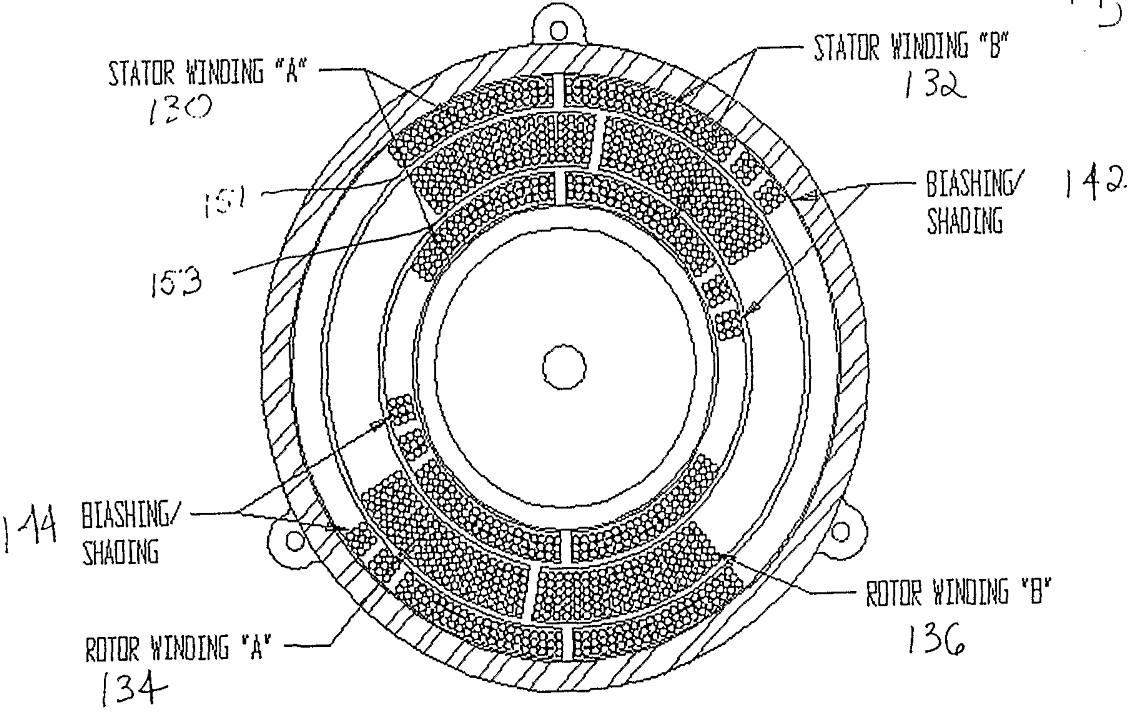


Fig 24B

1A UNIDIRECTIONAL MOTOR ROTATION

Fig 25



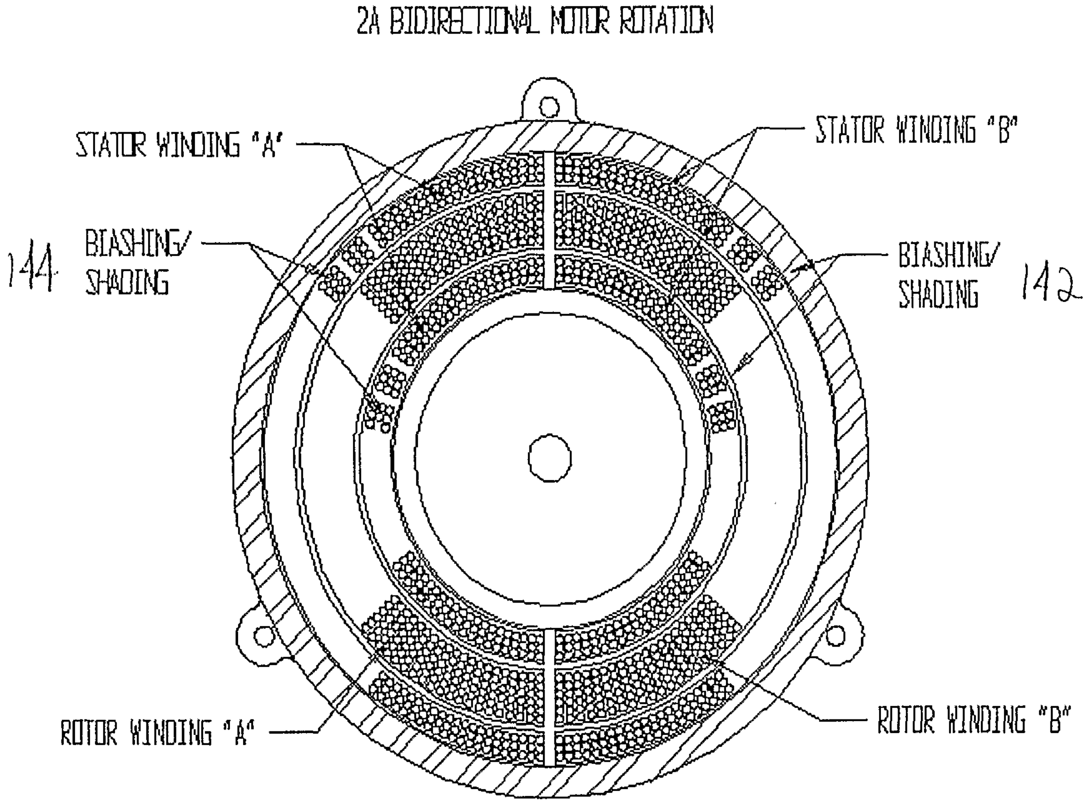

2A BIDIRECTIONAL MOTOR ROTATION
STATOR WINDING "A"
STATOR WINDING "B"
144
BIASHING/
SHADING
BIASHING/
SHADING
142
ROTOR WINDING "A"
ROTOR WINDING "B"

Fig 26

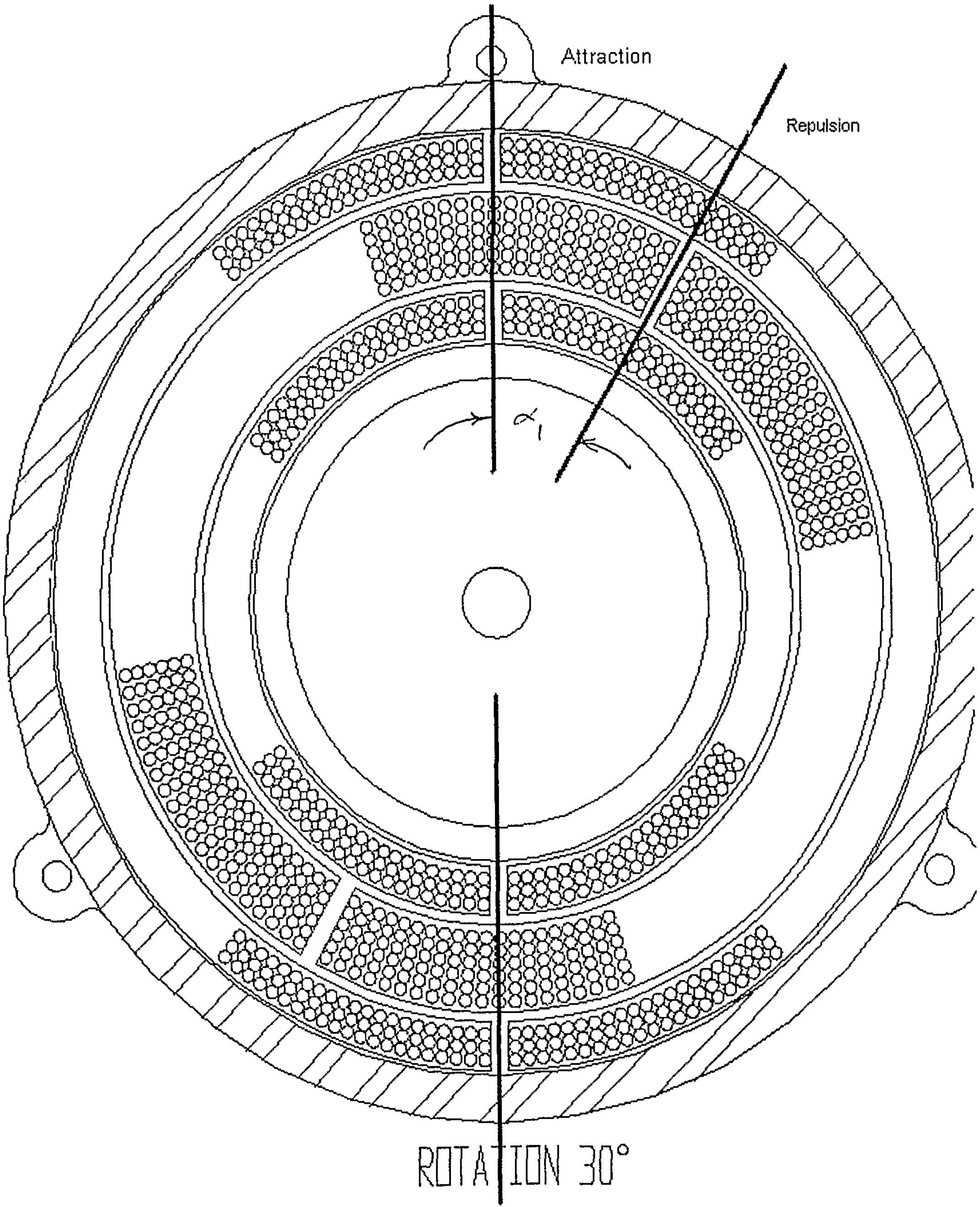
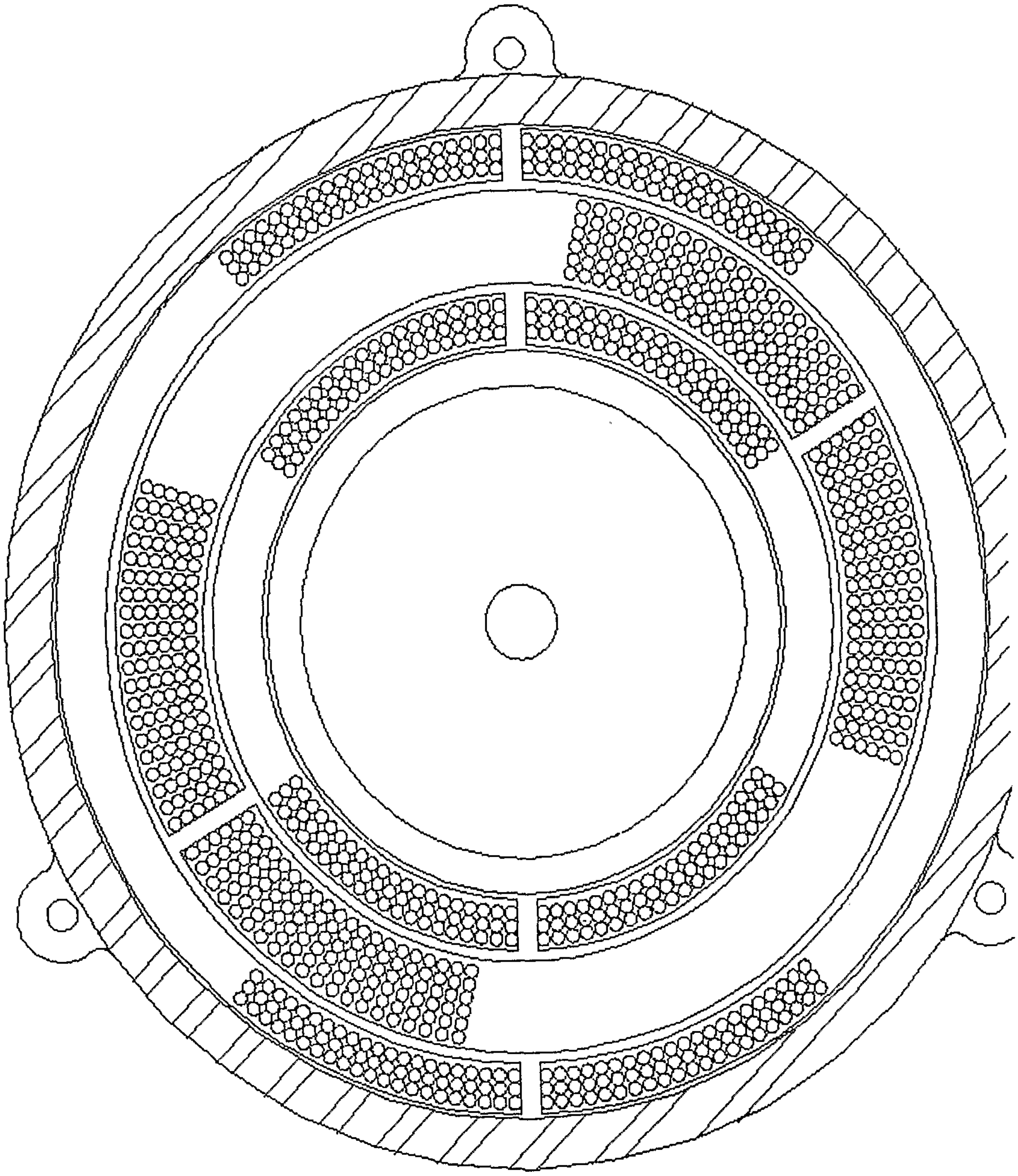
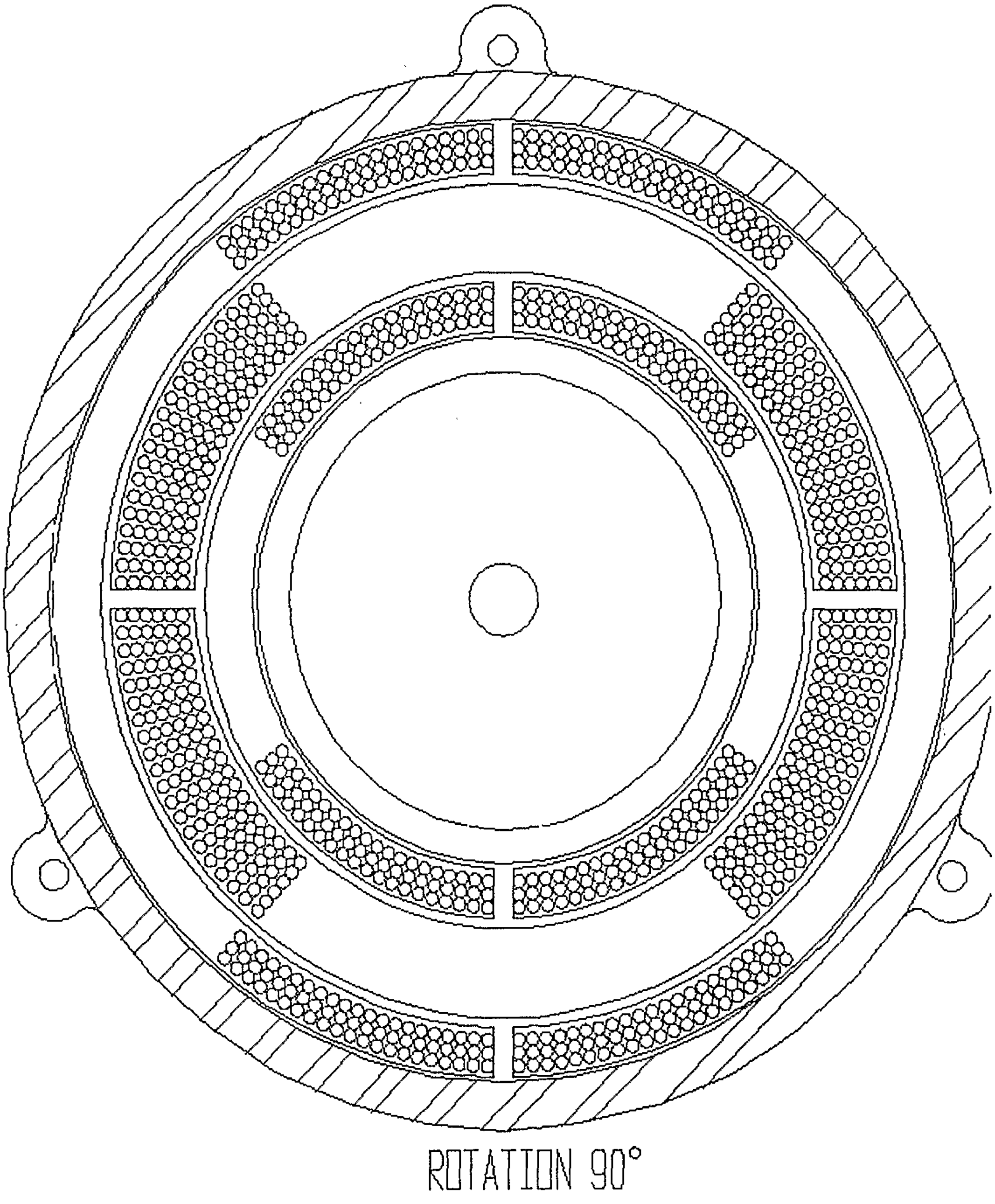


Fig 27



ROTATION 60°

Fig 28



ROTATION 90°

Fig 29

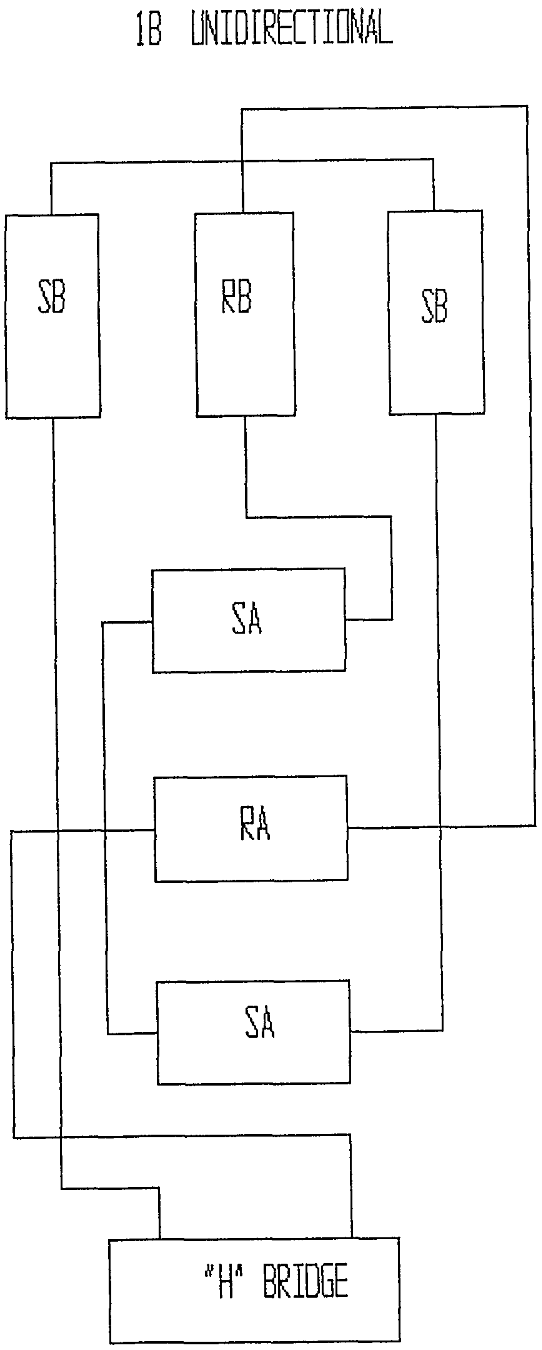


Fig 30

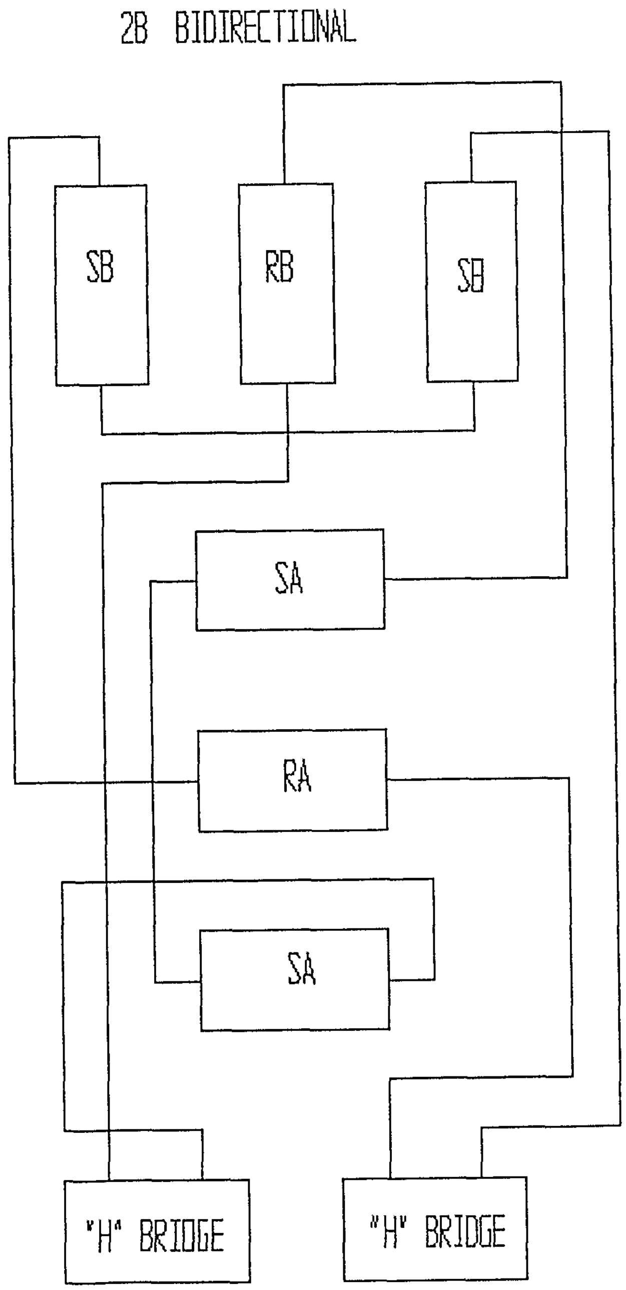


Fig 31

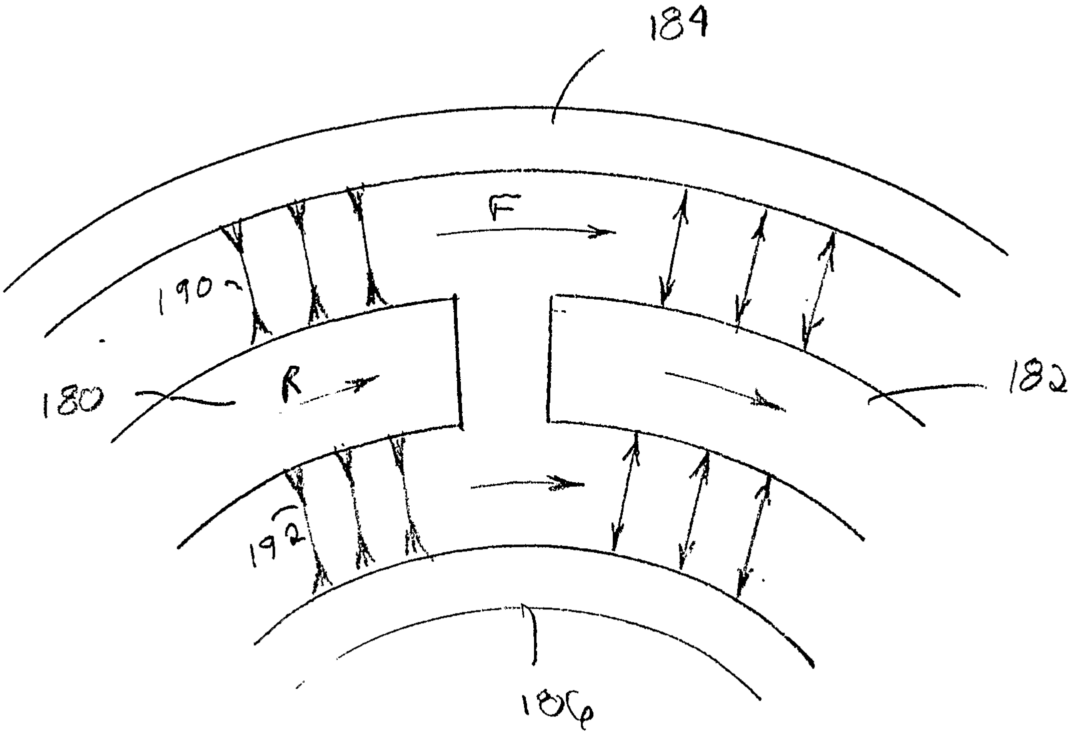


Fig 32

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/16396

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H02K 01/12, 01/22, 01/00
US CL :310/199, 254, 258,259, 261, 267, 268, 208
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 310/199, 254, 258,259, 261, 267, 268, 208

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,503,377 A (KITABAYASHI et al.) 05 March 1985 (05.03.1985), col. 4, lines 57-70, col. 5 lines 1-23 and fig. 3-4	1-20
Y	US 3,809,933 A (SUGAWARA et al.) 07 May 1974 (07.05.1974), COL. 5, LINES 32-68, COL. 6, LINES 1-27 AND FIGS.2-4.	3-4

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"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
"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)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 24 AUGUST 2002	Date of mailing of the international search report 12 SEP 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Sharon D. Hopper THANH LAM Telephone No. (703) 308-7626