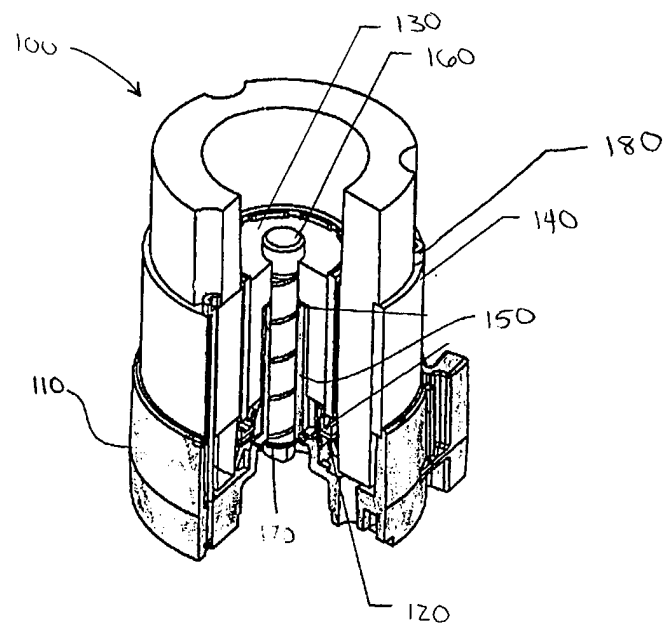




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁶ : H02K 1/00, 51/32, 5/15</p>	<p>A2</p>	<p>(11) International Publication Number: WO 98/37611 (43) International Publication Date: 27 August 1998 (27.08.98)</p>
<p>(21) International Application Number: PCT/US98/03119 (22) International Filing Date: 19 February 1998 (19.02.98) (30) Priority Data: 08/803,683 21 February 1997 (21.02.97) US (71) Applicant: EMERSON ELECTRIC CO. [US/US]; 8000 W. Florissant, St. Louis, MO 63136 (US). (72) Inventors: POAG, Andrew, F.; 7110 Horner, St. Louis, MO 63117 (US). TEVAARWERK, Joseph, L.; 708 Audubon Drive, Clayton, MO 63105 (US). HEILMAN, Ray, D.; 952 Marris, St. Louis, MO 63117 (US). GAVELLO, Mauro; Via Madonna, 2/A, I-14020 Camerano Casasco (IT). (74) Agent: MCAUGHAN, Robert, J., Jr.; Arnold, White & Durkee, P.O. Box 4433, Houston, TX 77210 (US).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>Without international search report and to be republished upon receipt of that report.</i></p>

(54) Title: ROTOR ASSEMBLY FOR A ROTATING MACHINE



(57) Abstract

A rotor assembly for a rotating machine includes a substantially cylindrical main rotor body having an outer surface. A plurality of longitudinal ribs project from the outer surface of the main rotor body. A plurality of primary recesses are defined by adjacent ribs and a secondary recess is defined in the outer surface within at least one primary recess. A magnet is positioned within at least one primary recess, and a layer of adhesive between the magnet and the outer surface of the main rotor body fills the secondary recess. Magnet retaining elements in the form of an encapsulation layer may also be used. The magnet retaining elements may be used alone or in combination with the adhesive layer between the magnets and the main rotor body.

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ROTOR ASSEMBLY FOR A ROTATING MACHINE

FIELD OF THE INVENTION

The present invention relates in general to rotor assemblies for use in rotating machines, and more specifically to rotor assemblies for use in rotating machines suitable for operation while immersed in an operating fluid.

BACKGROUND OF THE INVENTION

Rotating machines are commonly used to drive rotational loads such as pump impellers. In certain applications, the process fluid pumped by the impeller is not compatible with elements of the rotating machine. In such applications, the rotating machine must be isolated from the process fluid. Otherwise, the elements of the rotating machine must be constructed of materials compatible with the fluid. This specification describes a rotating machine adapted for use in an electro-hydraulic power steering unit, however other applications are contemplated.

In typical power steering pump designs, the motor drive has two endshields and uses ball bearings to reduce friction generated by rotation of the shaft. The motor is generally separated from the fluid by a seal on the shaft. The use of a ball bearing motor in the presence of hydraulic fluid limits the life expectancy of the ball bearings. Leakage of the hydraulic fluid past the shaft seal will contaminate the bearing lubricant, leading to the eventual demise of the ball bearings. It is therefore desirable for a rotating machine adapted for use in a pump application to be compatible with the process fluid being pumped. It is further desirable for a rotating machine adapted for use in a pump application to be capable of being immersed in the process fluid, thus obviating the need for a seal between the rotating machine and the pump.

In rotating machines using permanent magnet motors, it is common to attach permanent magnets on a rotor member to form a rotor assembly. The permanent magnets may be attached by retaining members or adhesives. In the process of attaching the magnets, the thickness and uniformity of the adhesive layer greatly determines the shear strength of the adhesive. It is desirable to control the thickness and uniformity of the adhesive layer to ensure adequate adhesion. It is also desirable to provide a back-up retention means should the adhesive layer fail.

Another important aspect in the assembly of a rotating machine lies in assuring alignment between the stator of the machine and the position sensors used to indicate the relative position of the rotor during operation and control of the machine. Typically Hall effect sensors are placed

near the rotor to sense magnetic field changes caused by the interaction between the magnets on the rotor and the stator poles, thus allowing the control electronics to time the switching on and off of the phase windings to control machine torque and speed. The alignment of the sensors relative the stator is crucial to this timing process. Typically, the sensors are adjusted after
5 fabrication of the rotating machine to ensure the proper timing. It is desirable for a rotating machine to have features which align the stator poles relative to the position sensors during the assembly process, thus obviating the need for further adjustment after assembly has been completed.

SUMMARY OF THE INVENTION

10 The present invention in a broad aspect addresses the problems and shortcomings mentioned above. More specifically, an aspect of the invention is seen in a rotor assembly for a rotating machine, comprising a substantially cylindrical main rotor body having an outer surface. A plurality of longitudinal ribs project from the outer surface of the main rotor body. A plurality of primary recesses are defined by adjacent ribs, and a secondary recess is defined in the outer
15 surface within at least one primary recess. A magnet is positioned within at least one primary recess, and a layer of adhesive between the magnet and the outer surface of the main rotor body substantially fills the secondary recess.

Another aspect of the invention is seen in a rotor assembly for a rotating machine, comprising a substantially cylindrical main rotor body having an outer surface. A plurality of
20 longitudinal ribs project from the outer surface of the main rotor body. A plurality of primary recesses are defined by adjacent ribs, and a magnet is positioned within at least one primary recess. A star-shaped retainer is located at at least one end of the main rotor body. The star-shaped retainer comprises a circular member including a plurality of radial projections extending outwardly from the circular member. The number of projections correspond to the number of ribs
25 defined in the outer surface of the main rotor body. Each projection exhibits a termination that engages a surface of the adjacent magnets.

A further aspect of the invention is seen in a rotor assembly for a rotating machine, comprising a substantially cylindrical main rotor body having an outer surface. A plurality of
30 longitudinal ribs project from the outer surface of the main rotor body. A plurality of primary recesses are defined by adjacent ribs, and a magnet is positioned within at least one primary recess. An elongated retaining member, is positioned over a rib and connected to the rotor body at each end thereof. A surface of the elongated retaining member engages a corresponding surface of the adjacent magnet.

An aspect of the invention is seen in a rotor assembly for a rotating machine, comprising, a substantially cylindrical main rotor body having an outer surface, a plurality of longitudinal ribs projecting from the outer surface of the main rotor body, a plurality of primary recesses defined by adjacent ribs, a magnet positioned within at least one primary recess, and a layer of encapsulation material positioned about the main rotor body and the at least one magnet.

Still another aspect of the invention is seen in a method of assembling a rotor assembly for a rotating machine. The rotor assembly comprises a main rotor body having an outer surface, a plurality of longitudinal ribs defined in the outer surface, a plurality of primary recesses defined by adjacent ribs, and a secondary recess defined in the outer surface within at least one of the plurality of primary recesses. The method comprises providing an adhesive layer within at least one primary recess and substantially filling the secondary recess with adhesive, positioning a magnet within at least one primary recess, and compressing the magnet against the main rotor body such that the adhesive is extruded from the primary recess.

An aspect of the invention is seen in a method of assembling a rotor assembly for a rotating machine, the rotor assembly comprising a main rotor body having an outer surface, a plurality of longitudinal ribs defined in the outer surface, and a plurality of magnet recesses defined by adjacent ribs. The method comprises positioning a magnet within at least one of the magnet recesses, and molding an encapsulation layer about the main rotor body and the magnet.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

5 Figure 1 illustrates a sectional isometric view of a rotating machine according to an embodiment of the present invention;

Figure 2a and 2b illustrate top and bottom isometric views of an endshield assembly of the rotating machine of Figure 1;

Figure 3 illustrates a simplified isometric view of a stator assembly of the rotating machine of Figure 1;

10 Figure 4a illustrates a diagram of the phase winding arrangement of the stator assembly of Figure 3;

Figure 4b illustrates a circuit diagram of the phase windings of the stator assembly of Figure 4a;

15 Figure 5 illustrates an isometric view of an embodiment of a sensor assembly of the rotating machine of Figure 1;

Figure 6 illustrates a bottom view of the sensor assembly of Figure 5;

Figure 7 illustrates an isometric view of the sensor assembly of Figure 5 positioned within the endshield assembly of Figure 2a and including wire leads exiting the endshield assembly;

20 Figure 8 illustrates a sectional isometric view of one embodiment of a rotor assembly of the rotating machine of Figure 1;

Figure 9a illustrates an end view of the rotor assembly of Figure 8;

Figure 9b illustrates a magnified view of a portion of the rotor assembly of Figure 9a without permanent magnets;

25 Figures 12a and 12b illustrate a rotor assembly according to an alternative embodiment including an encapsulating layer that cooperates with rib undercuts to secure the magnets to the rotor assembly of Figure 8;

Figure 13 illustrates a selective solder bath system used to couple the leads from the Hall effect devices and the printed circuit board leads to the printed circuit board array; and

30 Figure 14 illustrates a pressurized fluid system according to an embodiment of the invention.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Illustrative embodiments of the invention are described below as they might be employed in a rotating machine. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

Turning now to the drawings and referring initially to Figure 1, a pictorial representation of a rotating machine **100** in accordance with an embodiment of the present invention is provided. The illustrated embodiment shows a rotating machine **100** adapted for use in an electro-hydraulic power steering unit. The rotating machine **100** operates while immersed in hydraulic fluid. The hydraulic fluid lubricates and cools the components of the rotating machine during operation. It is contemplated that the rotating machine **100** of the invention has applications to a variety of situations including other harsh environments. It is appreciated that other applications can be made in other situations in light of the description of the invention herein.

The rotating machine **100** comprises four basic components: an endshield assembly **110**, a sensor assembly **120**, a rotor assembly **130**, and a stator assembly **140**. As illustrated in Figure 1, the sensor assembly **120** is located substantially within and is affixed to the endshield assembly **110**. The rotor assembly **130** includes a spiral-grooved shaft **160** which extends through an endshield protrusion **150** to form a hydro-dynamic bearing unit when the rotating machine **100** is operated while immersed in fluid (e.g. hydraulic fluid). The fluid acts as both a lubricant and a coolant. The rotor assembly **130** is axially secured in relation to the endshield **110** by a clip **170** positioned near one end of the shaft **160** beneath the endshield assembly **110**. The stator assembly **140** surrounds the rotor assembly **130** and may be secured to the endshield **110** by a plurality of fasteners such as bolts **180**.

Referring to Figures 2a and 2b, the endshield assembly **110** is shown in greater detail. In the illustrated embodiment, the endshield assembly **110** is formed from cast aluminum. Other materials and methods of construction are contemplated depending on the specific motor environment. The endshield assembly **110** exhibits several stator bolt holes **200** for attaching the

endshield assembly **110** to the stator assembly **140** via bolts **180** and several load bolt holes **210** for securing the endshield assembly **110** to a load (e.g. pump apparatus) attached to the rotating machine **100**. Additional circulation holes **245** are also defined in the endshield assembly **110** to allow fluid to circulate into and out of the cavities formed by the endshield walls **220** and the endshield protrusion **150**.

The endshield walls **220** include recesses that are designed to receive the stator assembly **140**. Formed within the endshield walls **220** is a stator assembly locating notch **230** that is used during assembly to orient the stator assembly **140** with respect to the endshield assembly **110**.

Referring now to Figure 3, a simplified view of the stator assembly **140** is provided. Tab **300** extends from the stator assembly **140** and fits within the stator assembly locating notch **230** to ensure that the stator assembly **140** is in a known position with respect to the endshield **110** when the rotating machine **100** is assembled. The stator assembly **140** is constructed in conventional fashion such as from laminated stock. The stator assembly **140** defines bolt clearances **310** to allow bolts to be inserted through holes **320** and corresponding stator bolt holes **200** in the endshield **110** in order to fasten the stator assembly **140** to the endshield **110**.

Figure 4a provides a diagram of the stator assembly **140** and Figure 4b illustrates a circuit diagram of the phase windings. The stator assembly **140** includes a twelve slot, eight pole stator, having three phase windings **410**, **420**, **430** where each phase winding comprises four coils connected in parallel and where each coil is wound about a single stator tooth **400**. The three phase windings **410**, **420**, **430** are Wye connected. In the illustrated embodiment each coil consists of 13 turns of : 1 of AWG 14.5; or 2 of AWG 7.5; or 4 of AWG 20.5.

Returning to Figure 2, two sensor assembly locating features are provided within the cavity formed by the walls **220** of the endshield **110**. These features each comprise a rest **240** and two posts **250**, **260**.

The sensor assembly **120** is shown in Figure 5, and includes a locator body **540** having a pair of openings **500**, **510** therein of a diameter substantially equal to the outer diameter of the two posts **250**, **260**. The sensor assembly **120** also includes a printed circuit board (PCB) array **520** with PCB lead wires **525** and three Hall effect devices **530**. The locator body **540** is a molded plastic part that is formed such that it defines three pockets **545** which receive the three Hall effect devices **530** and positively locate the Hall effect devices **530** in the locator body **540**. The center of each pocket is positioned at 30° from the adjacent pockets to control the frequency of the generated signals. The locator body **540** is preferably formed of glass-filled nylon or an engineering-approved equivalent material. In addition to positively positioning the Hall devices

530, the plastic locator body 540 prevents the PCB leads 525 from contacting the rotor assembly 130.

As shown in Figure 6, the PCB array 520 has openings 600 therein sized to accommodate leads which extend from the Hall effect devices 530. The PCB array 520 also has openings 610
5 therein for receiving the ends of the PCB lead wires 525. The PCB array 520 is received by an appropriately formed recess in the plastic locator 540. This arrangement allows for selective soldering to be used to couple the leads from the Hall devices 530 and the PCB leads 525 to the PCB array 520.

The sensor assembly 120 is assembled prior to its placement into the endshield assembly
10 110 of the rotating machine 100. According to one preferred assembly method, the lead wires 525 are first mechanically connected to the PCB array 520 via openings 610 therein, as shown in Figure 6. The PCB array 520 is then snapped into engagement with the arms 542 on the underside of the locator body 540. The Hall effect devices 530 are then inserted into the pockets of the locator body 540, such that movement of the Hall effect devices is restricted or prohibited
15 and the lead wires 532 of the Hall effect devices extend through the openings 600 in the PCB array 520. The lead wires 525 are then electrically connected to the Hall effect leads 532 by application of a solder to the surface of the PCB array 520.

Because the sensor assembly will later be inserted into a rotating machine that is designed to be immersed in operating fluid, it is important that the soldering process does not result in
20 flaking or balling of solder particles during use in the harsh environment. Therefore, selective soldering is preferably used to electrically connect the lead wires to the Hall effect leads. As shown in Figure 13, the selective soldering process is carried out by using a cookie-cutter like pattern 1300 sealed against the surface of the PCB array 520 to control the application of solder, thus preventing solder from coming into contact with other parts of the sensor assembly 120 such
25 as the locator body 540. The cookie cutter pattern 1300 is placed above a solder bath 1310, and the PCB array 520 is placed over the top of the cookie cutter pattern 1300 and sealed against the upper edge 1320 thereof. The solder bath 1310 is then pressurized 1320, causing a wave of solder to rise from the solder bath within the cookie cutter pattern 1300 and into contact with the surface of the PCB array 520 and the protruding ends of the lead wires 525 and Hall effect device
30 leads 532 thereby electrically and mechanically connecting lead wires 525 to openings 610 and Hall effect leads 532 to openings 600. The PCB array 520 includes the required connections between the lead wires 525 and the Hall effect leads 532.

After the sensor assembly **120** has been assembled, it is positioned within the endshield **110** by placing the mounting holes **500, 510** of the plastic locator about the positioning posts **250, 260** of the endshield **110**. The locator body is then secured to the positioning posts **250, 260**. Preferably, the posts **250, 260** are deformed by spin riveting to secure the sensor assembly **120** to the endshield **110**. Deformation of the posts is preferred since the number of parts used in the assembly is reduced, thereby alleviating concerns of parts coming loose in the rotating machine during operation. Alternatively, separate fasteners, such as locking washers or screws may be used to secure the locator body to the positioning posts. The manner in which the sensor assembly **120** is positioned within the endshield **110** is reflected Figure 7.

As shown in Figure 7, a channel **270** is formed along the interior wall of the endshield **110** to allow the PCB leads **525** to exit the rotating machine **100** for connection to a controller. A slotted grommet **700** is inserted into the channel **270** and surrounds the lead wires in the channel. The grommet **700** may be formed of any material that meets chemical compatibility and temperature conditions for submersible use in an electro-hydraulic motor. The preferred material for the grommet **700** is glass filled nylon. The PCB leads **525** can be inserted into the grommet **700** through the slot therein, and the grommet **700** inserted into the channel **270** through the opening therein. This assembly obviates threading of the PCB leads through a hole in the endshield or other portion of the rotating machine, thus simplifying assembly of the rotating machine. The grommet **700** also inhibits chaffing of the PCB leads **525** and pinching of the wires **525** between the endshield **110** and the stator assembly **140**.

Referring to Figure 8, a cut-out view of the rotor assembly **130** is shown. The rotor assembly **130** includes a substantially cylindrical rotor member **800** having an outer surface **810** and an interior surface **820**. The rotor member **800** may be formed of a metallic material having good magnetic properties, such as powdered metal. One such preferred material is Z29 magnetic iron grade, 7.2 g/cc min. or an engineering approved equivalent. Although the rotor member **800** shown in Figure 8 comprises a solid metallic member, the rotor member may also comprise a laminated construction wherein a plurality of metallic discs are arranged in a stacked configuration and separated by alternating insulation discs. The interior surface **820** includes a stepped portion **830** at one end thereof, the inner surface of which frictionally engages the outer surface **840** of the rotor shaft **160**.

The shaft **160** has a first end **880** with a tapered or beveled edge, and a second end **890** which includes a tang **895** that may be configured to engage the shaft of a load (i.e. pump) to transmit the required torque and speed to the load. The shaft **160** is formed from heat treated

metal, and preferably case hardened steel, that is hardened and ground to act as a suitable bearing journal. The shaft **160** is heat treated to provide a hard outer surface and a softer core. According to one embodiment, the shaft may be case hardened to about HRC 55 with a case depth of between about .50mm and .63mm, with a core hardness of between about HRC 30 and HRC 38. The hard outer surface of the shaft **160** forms a hydrodynamic bearing with the aluminum inner surface of the endshield protrusion **150**. The interaction between the hard outer surface of the shaft **160** and the softer aluminum surface of the endshield protrusion **150** is necessary to prevent galling or surface destruction during use of the rotating machine **100**, and particularly during start-up or shut-down of the machine. The softer core of the shaft **160** is useful in situations where the rotating machine **100** may be exposed to low temperature environments because the softer core is less brittle than the hard outer surface and therefore less prone to fracture. A spiral groove **850** is formed in the outer surface of the shaft **160**. The spiral groove **850** acts to circulate fluid within the bearing assembly, making the shaft **160** an integral part of the bearing system.

As best shown in Figures 9A and 9B, the outer surface **810** of the rotor member **800** includes a plurality of projecting ribs **900** that define a corresponding plurality of recesses **910** for receiving a corresponding plurality of magnets **860**. Preferably, the rotor member **800** includes eight ribs **900** defining eight recesses for receiving eight magnets **860** of alternating polarity. Any type of commercially available permanent magnet may be utilized, and preferably a neodymium magnet is used. The rotor magnets **860** act to transmit magnetic signals to the sensor assembly **120**, which in turn transmits electrical signals to a controller to control the speed of the rotating machine. The magnets **860** may be further secured in the recesses by application of a layer of adhesive material between the magnet and the outer surface **810** of the rotor member **800**.

The shear strength of the adhesive material holding the permanent magnet members **860** to the rotor member **800** depends, to a great extent, on the thickness of the layer of adhesive or glue between the magnets **860** and the outer surface **810** of the rotor member **800**. To ensure that this glue thickness is within an acceptable range, a secondary recess or "glue trough" **920** is formed within each main recess **910** defined by the outer surface **810** of the rotor member **800**. The depth of the glue trough depends upon the type of adhesive used. According to one embodiment, the adhesive used is a single-part, heat cured epoxy, and the optimal depth of the glue trough is between about 0.05 mm and 0.15mm.

The ribs **900** help properly position the permanent magnets **860** within the recesses **910** and also help resist the effects of torque on the magnets **860** in the event that the attachment means (e.g. glue) affixing the magnets **860** to the rotor member **800** fails.

During fabrication of the rotor assembly **130**, the magnets **860** are first secured in the recesses **910**. A layer of adhesive material is applied to the surface of the rotor member **800** in the main recess **910**, filling the glue trough **920**. The permanent magnets **860** are then placed within the main recesses **910**, and the magnets **860** are compressed against the rotor member **800**. Some of the glue will collect in the glue trough **920**, and the remainder will be extruded out of the main recess **910**. Thus, after this compression, the thickness of the glue layer between the permanent magnets **860** and the rotor member **800** will depend, to a great extent, on the depth of the glue trough **920**.

Before the magnets **860** are secured to the rotor member **800**, the rotor member and shaft **160** are assembled, preferably by inserting a beveled first end **880** of the shaft into the opening in an end of the rotor member. The shaft **160** may be coated with a light oil prior to press fitting into the rotor member **800** to ease the assembly. Care must be taken to ensure that the shaft outer surface and the inner surface of the stepped portion **830** of the rotor member **800** are free of burrs and foreign material, since the assembly is very susceptible to contamination after magnetization.

Finally, according to the embodiment shown in Figure 8, an encapsulation layer or insert molding **870** may be provided surrounding the rotor member **800** with attached permanent magnets **860**, to serve as a further backup retention means should the adhesive fail. Alternatively, the encapsulating layer or insert molding **870** may serve as the primary magnet **860** retainer, where glue is not used to adhere the magnet **860** to the rotor member **800**. The encapsulation layer **870** may be formed by placing the assembled rotor member **800** into a plastic injection tool and molding a plastic about the outer surfaces thereof. Preferably, the encapsulation layer or insert molding **870** comprises glass-filled nylon.

The size of the air gap between the stator assembly **140** and the magnets **860** of the rotor assembly **130** is important in determining the efficiency of the rotating machine **100**. At full load a smaller air gap results in a more efficient machine. At full load, the viscous drag between the rotor assembly **130** and the stator assembly **140** is not a major contributor to the load on the machine **100**. However, under no load or low load conditions, the viscous drag component is a major contributor to the load on the machine **100**. As the size of the air gap decreases, the viscous drag increases. In cases where the machine **100** is used intermittently, such as in a power steering pump application, the machine is frequently operated with little or no load. Therefore, it

is important to balance the improved efficiency at full load with the increased viscous drag caused by the smaller air gap and its effect under no or low load conditions. In the illustrated embodiment, the air gap is between about 0.008 and 0.012 inches.

Figure 12 illustrates an alternate rotor member **800** embodiment which cooperates with the encapsulation layer **870** to mechanically secure the encapsulation layer to the rotor. The ribs **900** define longitudinal bores **1200** extending substantially the entire length of the ribs **900**. Also, undercuts **1210**, consisting of a notch in the rib **900** are defined in each rib. When the encapsulation layer **870** is formed around the rotor member **800** after the magnets **860** have been attached, the encapsulation layer **870** substantially fills the undercuts **1210** and bores **1200**, thus mechanically locking the encapsulation layer **870** to the rotor member **800**.

As the motor is assembled, the shaft **160** of the rotor assembly **130** is positioned within the endshield protrusion **150** as shown in Figure 1. A clip **170** is then used to secure the shaft **160** against axial movement in relation to the endshield **110**. A washer is placed between the clip **170** and the endshield **110** to form a thrust bearing as is known in the art. A washer may also be placed about the shaft **160** between the rotor member **800** and the free end of the endshield protrusion **150**. No other endshield is required. Moreover, no ball bearing assemblies are used in the rotating machine **100**. Instead, the spiral-grooved shaft **160** and the endshield protrusion **150** form a hydro-dynamic unit bearing that utilizes the hydraulic fluid in which the motor **100** is submerged for lubrication and cooling. Thrust bearing surfaces are formed between the clip **170** and washer and the endshield **110** and also between the top of the endshield protrusion **150** and the overhanging surface **835** of the step portion **830** which is proximate the endshield protrusion **150** after assembly.

Referring to Figures 5 and 8, the sensor assembly **120** orients the Hall devices **530** in the cavity defined between the interior surface **820** of the rotor member **800** and the outer surface of the rotor shaft **160**, such that the sensing surface **550** of the Hall devices **530** is proximate the inner surface **865** of the portions of the magnets **860** that protrude beyond the end of the rotor member **800**. The cooperation of the rotor tab **300**, the endshield assembly locating notch **230**, the locating posts **250**, **260**, and the sensor assembly mounting holes **500**, **510** ensure that the Hall devices **530** are oriented in a known position with respect to the stator assembly **140**. Fixing the location of the Hall devices **530** with respect to the stator assembly **140** simplifies the assembly process. The output of the Hall effect devices **530** is used by a controller attached to the rotating machine **100** to control the timing of the phase winding switching. Due to the fixed orientations, the Hall devices **530** do not have to be adjusted to determine their positions relative

to the stator assembly **140** for proper control of the rotating machine **100**. The proper alignment is ensured during the manufacturing process due to the locating features.

As shown in Figure 14, the rotating machine **100** may be used in connection with a hydraulic power steering pump **1440** that is driven by the rotating machine **100** instead of a belt drive from the engine of a vehicle. The rotating machine **100** and pump **1440** are submerged in hydraulic fluid within a system housing **1400**. The system housing **1400** includes a fluid inlet **1420** and a fluid outlet **1410** that corresponds to a fluid outlet **1450** of the pump **1440**. The fluid outlet **1410** is sealed against the pump outlet **1450** by a seal **1430**. In operation, the shaft **160** of the rotating machine **100** is connected to an impeller of the power steering pump **1440** and is fully submerged with the pump in power steering fluid. The unit bearing formed by the rotor assembly **130** and the endshield protrusion **150** relies upon the power steering fluid, rather than on ball bearings, to lubricate the shaft. The controller **1460** may also be located within the system housing **1400**.

During operation of the rotating machine **100**, rotation of the spiral-grooved shaft **160** draws hydraulic fluid through the holes **245** in the endshield **110** into the cavity defined between the outer surface **840** of the rotor shaft **160** and the endshield protrusion **150**. The pressure and flow of hydraulic fluid between the outer surface **840** of the shaft **160** and the inner surface of the endshield protrusion **150** creates a lubricating layer between the endshield protrusion, the shaft and the rotor member **800**.

In typical power steering pump designs, the motor drive has two endshields and uses ball bearings to lubricate the shaft. The motor is generally separated from the fluid by a seal on the shaft. The use of a ball bearing motor in the presence of hydraulic fluid limits the life expectancy of the ball bearings. The rotating machine **100** of the invention uses a single endshield and a unit bearing and is not susceptible to degradation from the power steering fluid as is the case with a ball bearing design. The unit bearing has improved reliability over ball bearing systems, in that it has improved resistance to shock and contamination, and thus has a longer expected life. The single endshield design also reduces the size and complexity of the completed assembly, simplifies the assembly of a magnetized rotor, and is ideally suited for automated assembly.

Those skilled in the art will now see that certain modifications can be made to the apparatus and methods herein disclosed with respect to the illustrated embodiments, without departing from the spirit of the instant invention. And while the invention has been described above with respect to the preferred embodiments, it will be understood that the invention is

adapted to numerous rearrangements, modifications, and alterations, and all such arrangements, modifications, and alterations are intended to be within the scope of the appended claims.

CLAIMS

WHAT IS CLAIMED IS:

1. A rotor assembly for a rotating machine, comprising:
 - a substantially cylindrical main rotor body having an outer surface;
 - 5 a plurality of longitudinal ribs projecting from the outer surface of the main rotor body;
 - a plurality of primary recesses defined by adjacent ribs;
 - a secondary recess defined in the outer surface within at least one primary recess;
 - a magnet positioned within at least one primary recess; and
 - 10 a layer of adhesive between the magnet and the secondary recess.
2. The rotor assembly according to claim 1, wherein the adhesive substantially fills the secondary recess and the thickness of the adhesive depends on the depth of the secondary recess.
3. The rotor assembly according to claim 1, wherein a secondary recess is defined within
15 each primary recess and a magnet is positioned within each primary recess.
4. The rotor assembly according to claim 1, wherein the rotor assembly further includes an encapsulation layer positioned about the main rotor body and the magnet.
5. The rotor assembly according to claim 4, wherein the encapsulation layer is formed from glass-filled nylon.
- 20 6. The rotor assembly according to claim 4, wherein the rotor assembly includes an undercut formed in each rib near a longitudinal midpoint thereof, and a longitudinal bore through each rib; the encapsulation layer substantially filling at least one of the undercuts and longitudinal bores.
7. The rotator assembly according to claim 1, wherein the main rotor body comprises
25 powdered metal.
8. The rotor assembly according to claim 1, wherein the main rotor body comprises a laminated body.
9. The rotor assembly according to claim 1, wherein the rotor assembly further comprises a magnet retainer member connected to the main rotor body and engaging surfaces of the
30 magnet.
10. The rotor assembly according to claim 1, wherein the adhesive is a single-part, heat cured epoxy, and the secondary recess exhibits a depth of between 0.05mm and 0.15mm.

11. A rotor assembly for a rotating machine, comprising:
- a substantially cylindrical main rotor body having an outer surface;
 - a plurality of longitudinal ribs projecting from the outer surface of the main rotor body;
 - 5 a plurality of primary recesses defined by adjacent ribs;
 - a magnet positioned within at least one primary recess; and
 - a layer of encapsulation material positioned about the main rotor body and the at least one magnet.
- 10 12. The rotor assembly according to claim 11, wherein each rib includes a longitudinal bore and an undercut formed near a longitudinal midpoint thereof, and the encapsulation material substantially fills at least one of the undercuts and the longitudinal bores.
13. A method of assembling a rotor assembly for a rotating machine, the rotor assembly
- 15 comprising a main rotor body having an outer surface; a plurality of longitudinal ribs defined in the outer surface; a plurality of primary recesses defined by adjacent ribs; and a secondary recess defined in the outer surface within at least one of the plurality of primary recesses, the method comprising:
- providing an adhesive layer within at least one primary recess and substantially
 - 20 filling the secondary recess with adhesive;
 - positioning a magnet within the primary recess; and
 - compressing the magnet against the main rotor body such that the adhesive is extruded from the primary recess.
- 25 14. The method of assembling a rotor assembly according to claim 13, further including molding an encapsulation layer about the main rotor body and the magnet.
15. The method of assembling a rotor assembly according to claim 14, wherein the main rotor body includes an undercut formed in each rib near a longitudinal midpoint thereof,
- 30 and a longitudinal bore through each rib; and the act of molding the encapsulation layer about the main rotor body and magnet includes substantially filling at least one of the undercuts and longitudinal bores with the encapsulation material.

16. A method of assembling a rotor assembly for a rotating machine, the rotor assembly comprising a main rotor body having an outer surface; a plurality of longitudinal ribs defined in the outer surface; and a plurality of magnet recesses defined by adjacent ribs, the method comprising:

5 positioning a magnet within at least one of the magnet recesses; and

 molding an encapsulation layer about the main rotor body and the magnet.

17. The method of assembling a rotor assembly according to claim 16, wherein the main rotor body includes an undercut formed in each rib near a longitudinal midpoint thereof, and a longitudinal bore through each rib; and the act of molding the encapsulation layer about the main rotor body and magnet includes substantially filling at least one of the undercuts and longitudinal bores with the encapsulation material.

18. A rotating machine comprising:

 an endshield assembly including an endwall and a cylindrical endshield protrusion projecting therefrom;

15 a stator assembly connected to the endshield assembly and having a main body extending from the endwall substantially parallel to the endshield protrusion; and
 a rotor assembly positioned within a central cavity of the stator assembly and arranged for rotation relative to the stator assembly; the rotor assembly including a shaft extending therefrom and passing through the cylindrical endshield protrusion.

19. The rotating machine according to claim 18, wherein an outer surface of the shaft and an inner surface of the cylindrical endshield protrusion form a hydrodynamic bearing when the rotating machine is immersed in fluid.

20. The rotating machine according to claim 18, wherein the outer surface of the shaft has a spiral groove formed therein.

21. The rotating machine according to claim 18, wherein the shaft is press fitted through an opening in the rotor such that a first end of the shaft is secured to the rotor assembly.

22. The rotating machine according to claim 18, wherein one of the endshield assembly and stator assembly includes a positioning notch while the other of the endshield assembly and stator assembly includes a corresponding positioning projection.

23. The rotating machine according to claim 22, wherein the endshield assembly includes a cylindrical sidewall extending substantially perpendicular from an outer edge of the planar surface, the notch being formed in an outer endface thereof, and the projection extending radially outward from an outer surface of the stator assembly.
- 5 24. The rotating machine according to claim 18, wherein the endshield assembly includes a plurality of openings in the endwall thereof for allowing fluid to circulate between the rotating machine and a load to which the rotating machine is attached.
25. The rotating machine according to claim 18, further including a sensor assembly mounted to the endshield assembly proximate to the rotor assembly.
- 10 26. The rotating machine according to claim 25, further including means for locating and aligning the sensor assembly within the endshield assembly and in relation to the stator assembly.
27. The rotating machine according to claim 26, wherein the locating and aligning means includes one or more posts for positioning and aligning a locator body of the sensor assembly, and the locator body includes one or more openings therein, the openings
15 corresponding to the one or more posts.
28. The rotating machine according to claim 25, wherein the sensor assembly includes: a locator body having a plurality of pockets formed in a surface thereof; and a sensor positioned in each of the plurality of pockets.
- 20 29. The rotating machine according to claim 28, wherein the sensor assembly further includes:
a printed circuit board array electrically connected to the sensors; and
lead wires for connecting the printed circuit board to a controller.
30. The rotating machine according to claim 29, further including:
25 a channel located in a wall of the endshield assembly and having a longitudinal opening therein for receiving a length of the lead wires; and
a grommet having a longitudinal opening therein to permit radial insertion of the lead wires, the grommet being positioned in the longitudinal opening of the channel such that the grommet surrounds the lead wires and spans the longitudinal
30 opening of the channel.
31. The rotating machine according to claim 28, wherein the sensor is a hall effect device.
32. The rotating machine according to claim 28, wherein the plurality of pockets includes three pockets and three corresponding sensors are provided.

33. The rotating machine according to claim 18, wherein the rotor assembly comprises:

a substantially cylindrical main rotor member having an outer surface;

a plurality of longitudinal ribs projecting from the outer surface of the main rotor member;

a plurality of primary recesses defined in the outer surface between adjacent ribs;

a secondary recess being defined in the outer surface within each primary recess;

a permanent magnet positioned within each primary recess; and

a layer of adhesive between each magnet and the outer surface of the main rotor member, wherein the adhesive fills the secondary recess and the thickness of the adhesive depends on the depth of the secondary recess.

34. A rotating machine, comprising:

an endshield assembly having an internal surface, a first locating feature located on the internal surface, and a second locating feature;

a sensor assembly mounted to the endshield assembly, the sensor assembly cooperating with the first locating feature to locate the sensor assembly in a known position on the endshield assembly adjacent the internal surface;

a stator assembly having a third locating feature, the second and third locating features cooperating to locate the stator in a known position with respect to the endshield assembly; and

a rotor assembly positioned within a cavity of the stator assembly proximate to the sensor assembly, and arranged for rotation relative to the stator assembly.

35. The rotating machine as in claim 34, wherein the second locating feature comprises a notch defined in the endshield assembly and the third locating feature comprises a corresponding projection defined in the stator assembly, where the notch interfaces with the projection to positively locate the stator assembly with respect to the endshield assembly.

36. The rotating machine as in claim 34, wherein the first locating feature comprises one or more locating posts defined in the endshield assembly.

37. The rotating machine as in claim 36, wherein the sensor assembly includes a locator body, the locator body having one or more openings therein corresponding to the one or more posts defined in the endshield assembly.

38. A rotating machine comprising:
- an endshield assembly having an internal surface;
 - a stator assembly having a main body connected to the endshield assembly;
 - a rotor assembly positioned within a central cavity of the stator and arranged for rotation relative to the stator;
 - 5 a sensor assembly connected to the endshield assembly proximate to the rotor assembly; and
 - a sensor assembly locator extending from the internal surface of the endshield assembly for locating and aligning the sensor assembly in a known position relative to the stator assembly.
- 10 39. The rotating machine according to claim 38, wherein the sensor assembly locator comprises one or more posts for positioning and locating a locator body of the sensor assembly.
40. The rotating machine according to claim 39, wherein the locator body includes one or more openings therein, the openings corresponding to the one or more posts.
- 15 41. The rotating machine according to claim 38, wherein the sensor assembly includes:
- a locator body having a plurality of pockets formed in a surface thereof; and
 - a sensor positioned in each of the plurality of pockets.
42. The rotating machine according to claim 41, wherein the sensor assembly further includes:
- 20 a cavity formed in the locator body for receiving a printed circuit board array;
 - lead wires connecting the sensors to the printed circuit board; and
 - lead wires for connecting the printed circuit board to a controller.
43. The rotating machine according to claim 41, wherein the sensor is a hall effect device.
- 25 44. The rotating machine according to claim 41, wherein the plurality of pockets includes three pockets and three corresponding sensors are provided.
45. The rotating machine according to claim 41, wherein the locator body is a plastic locator body.
46. A method of locating a sensor assembly within a rotating machine comprising:
- 30 positioning and aligning a sensor locator body of the sensor assembly on a sensor assembly locator; the sensor assembly locator being positioned on an internal surface of an endshield assembly of the rotating machine; and
 - securing the sensor locator body to the sensor assembly locator.

47. The method of positioning a sensor assembly according to claim 46, wherein positioning the sensor locator body includes:

aligning one or more openings in the sensor locator body with one or more corresponding projecting pins of the sensor assembly locator; and

attaching the locator body to the sensor assembly locator by inserting a portion of the projecting pins through the corresponding openings in the sensor locator body.

48. The method of positioning a sensor assembly according to claim 47, wherein the step of securing the sensor locator body includes the step of deforming the ends of the projecting pins to secure the locator body to the sensor assembly locator.

49. The method of positioning a sensor assembly according to claim 46, further comprising:

positioning and securing one or more sensors in one or more corresponding pockets formed in a surface of the locator body;

positioning a printed circuit board within a slot formed in another surface of the locator body;

electrically connecting the sensors to the printed circuit board; and

electrically connecting the printed circuit board to a controller.

50. A method of assembling a stator assembly and an endshield assembly of a rotating machine comprising:

aligning a locating feature of the stator assembly with a locating feature of the endshield assembly, the locating feature of the endshield assembly being located on an internal surface thereof;

moving the stator assembly and endshield assembly into engagement such that the locating feature of the stator assembly cooperatively engages the locating feature of the endshield assembly; and

securing the stator assembly and endshield assembly together.

51. The method of assembling a stator assembly and an endshield assembly according to claim 50, wherein aligning the locating feature on the stator with the locating feature on the endshield assembly includes aligning a radial projection on the stator assembly with a notch in the endshield assembly.

52. A pressurized fluid system comprising:

a system housing substantially filled with an operating fluid and having a fluid inlet and a fluid outlet;

a fluid pump substantially submerged in the operating fluid within the housing and having a fluid outlet corresponding to the fluid outlet of the housing; and

a rotating machine substantially submerged in the operating fluid within the housing and operatively connected to the fluid pump.

53. The pressurized fluid system according to claim 52, wherein a shaft of the rotating machine is operative connected to an impeller of the fluid pump.

54. The pressurized fluid system according to claim 52, wherein the rotating machine comprises:

an endshield assembly including an endwall and a cylindrical endshield protrusion projecting therefrom;

a stator assembly connected to the endshield assembly and having a main body extending from the endwall substantially parallel to the endshield protrusion; and

a rotor assembly positioned within a central cavity of the stator assembly and arranged for rotation relative to the stator assembly; the rotor assembly including

a shaft extending therefrom and passing through the cylindrical endshield protrusion.

55. The pressurized fluid system according to claim 54, wherein an outer surface of the shaft and an inner surface of the cylindrical endshield protrusion form a hydrodynamic bearing with the operating fluid.

56. The pressurized fluid system according to claim 52, wherein the operating fluid is hydraulic fluid.

57. The pressurized fluid system according to claim 56, wherein the fluid system is an electro-hydraulic power steering system and the hydraulic fluid is power steering fluid.

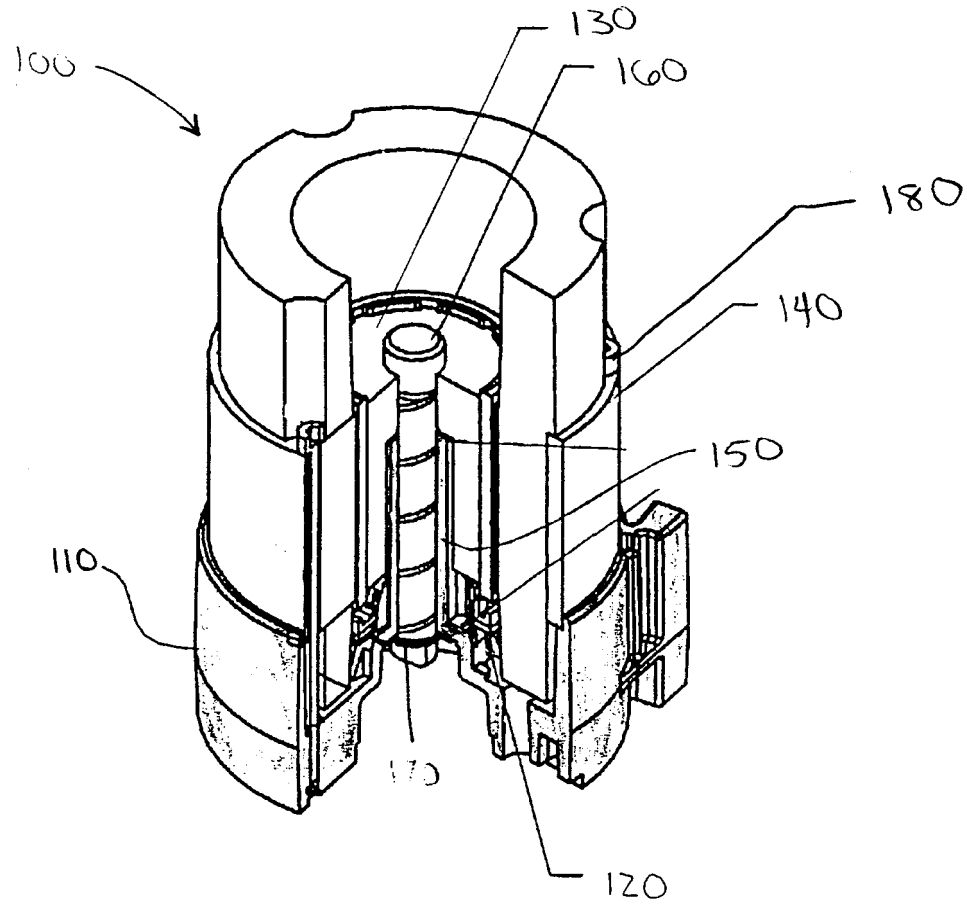


Figure 1

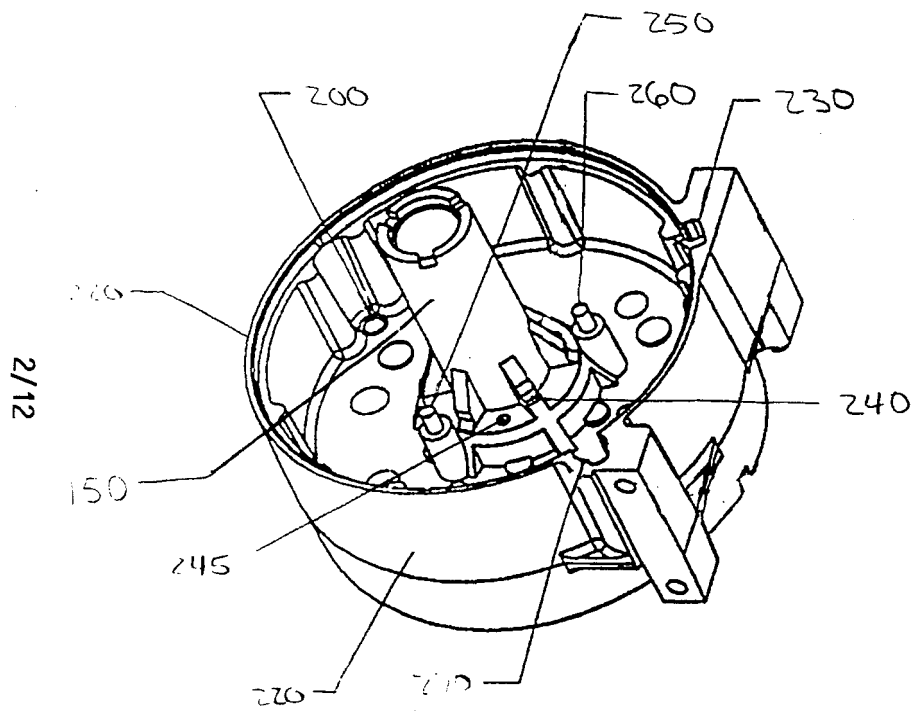


Figure 2a

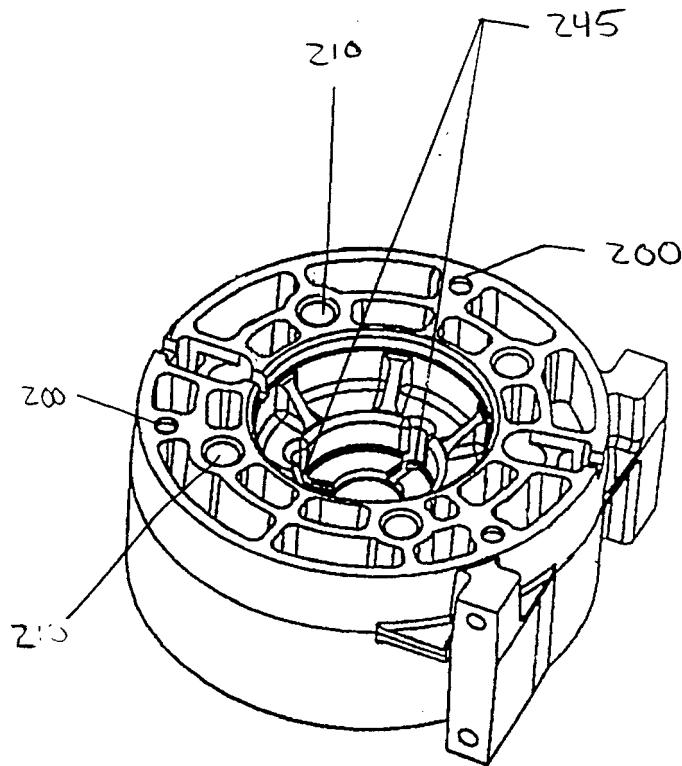


Figure 2b

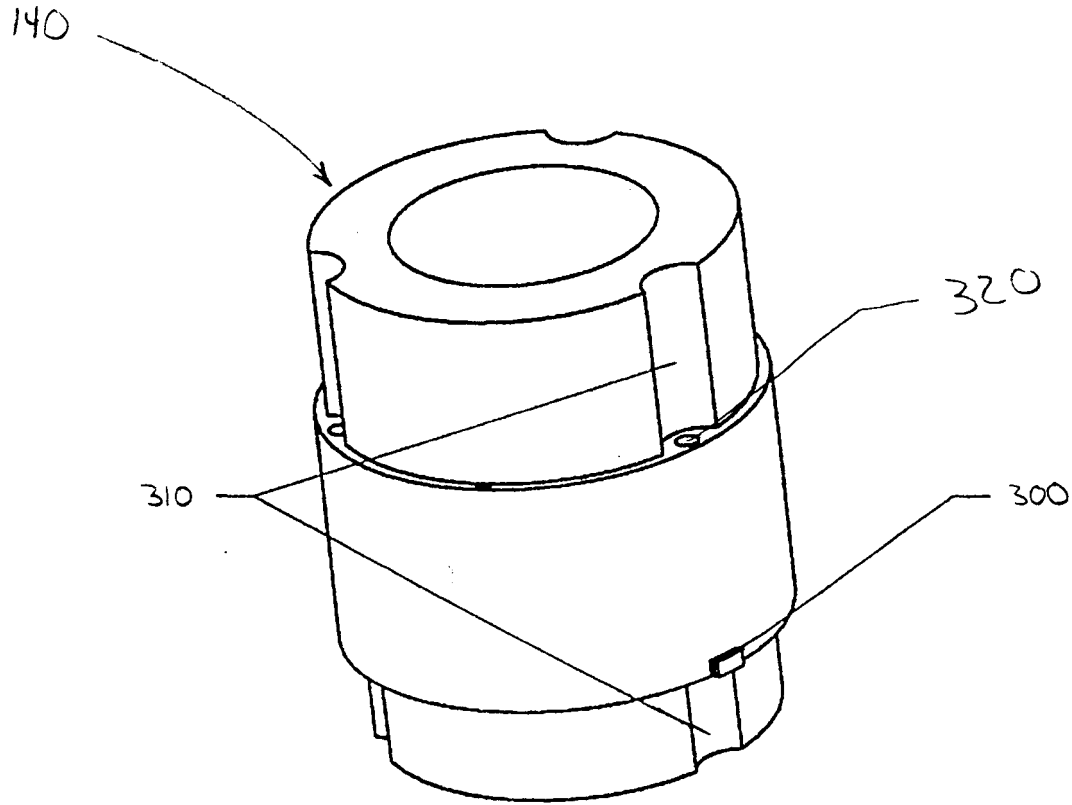


Figure 3

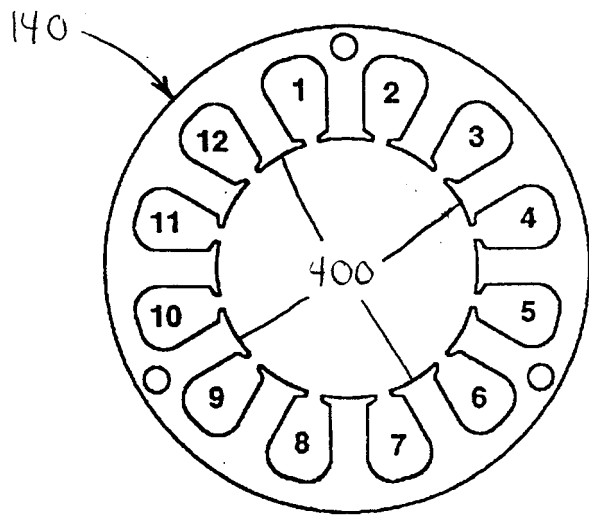


Figure 4a

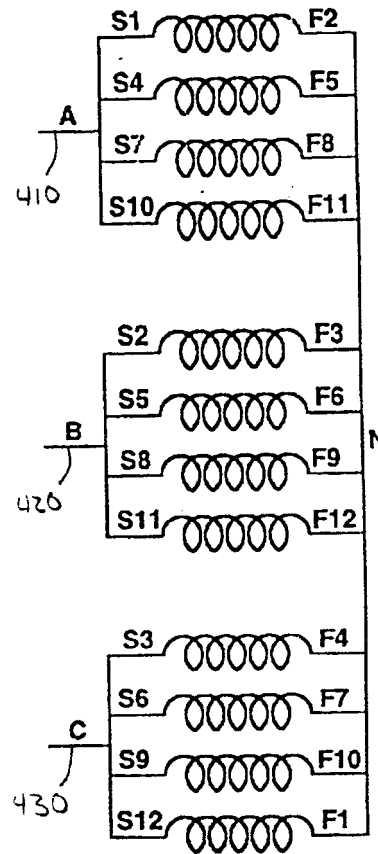


Figure 4b

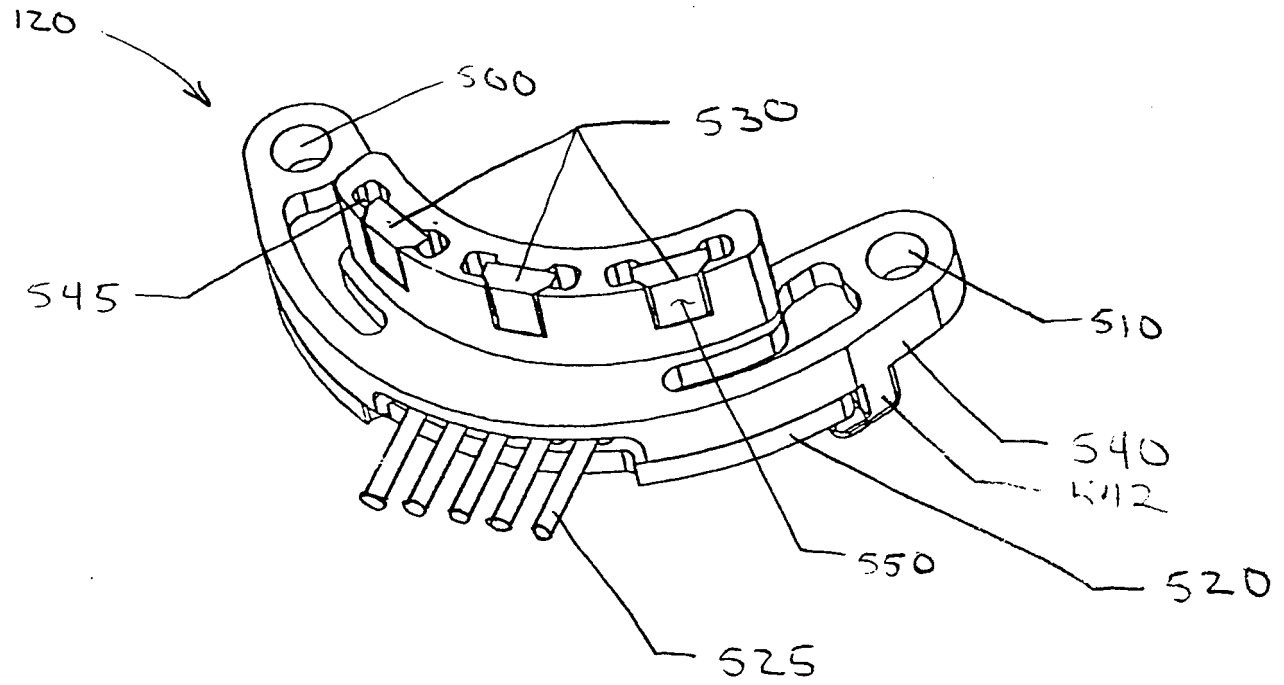


Figure 5

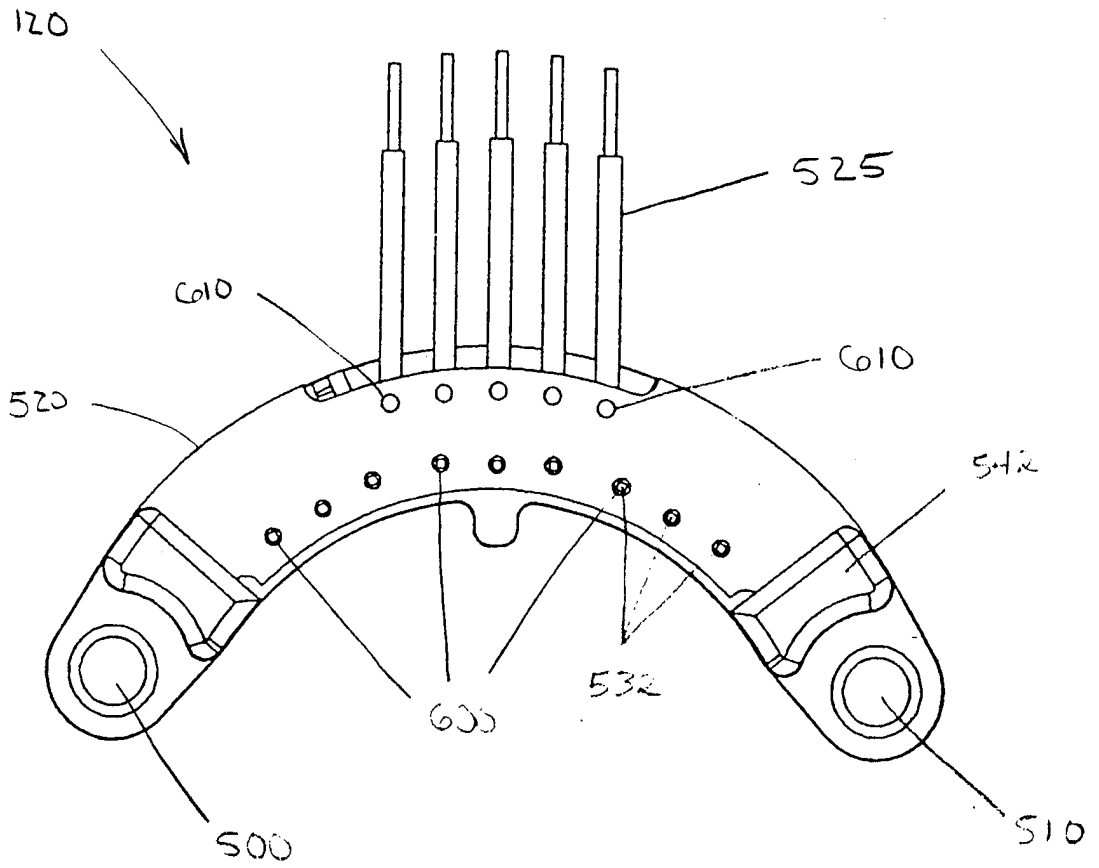


Figure 6

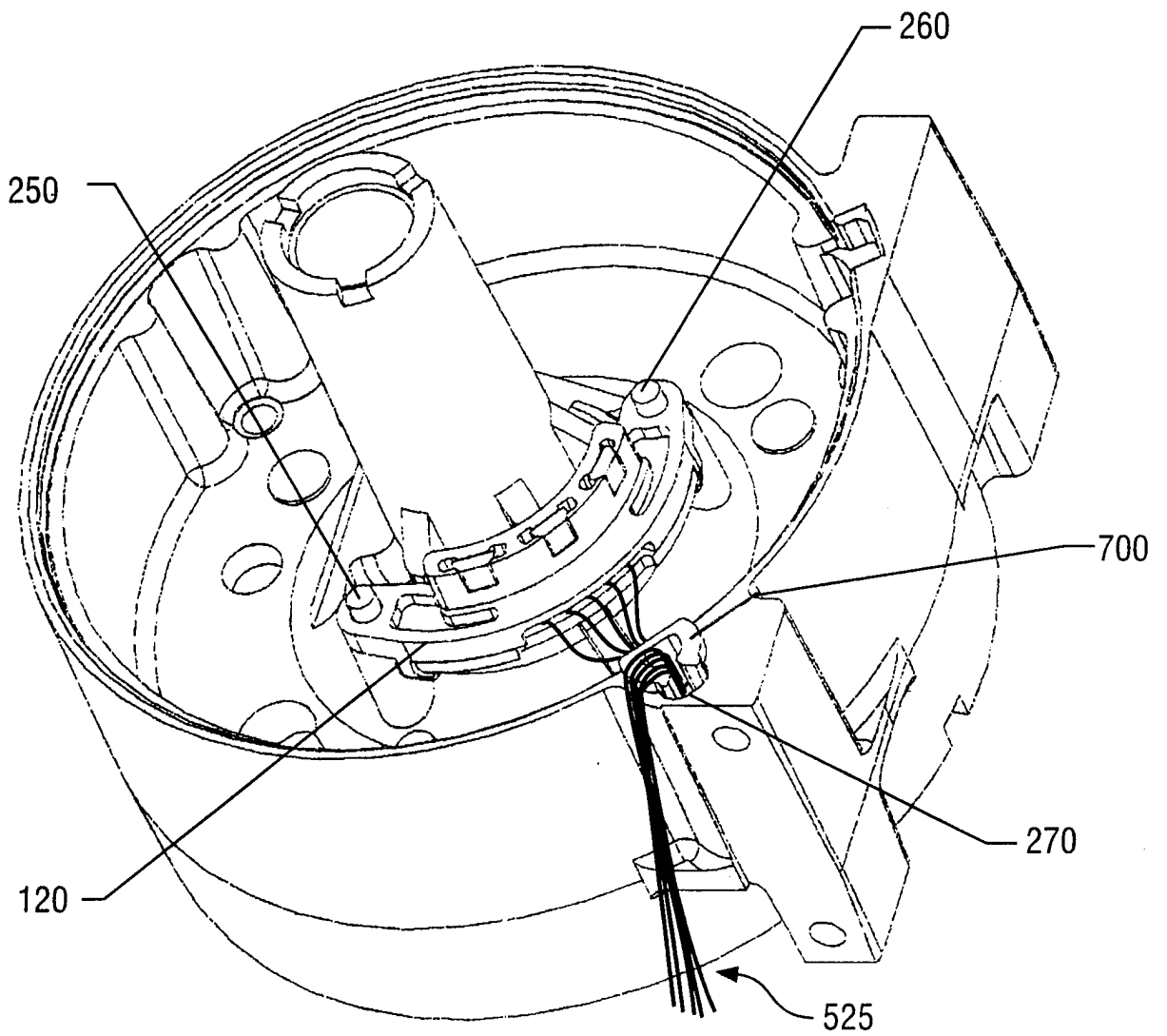


FIG. 7

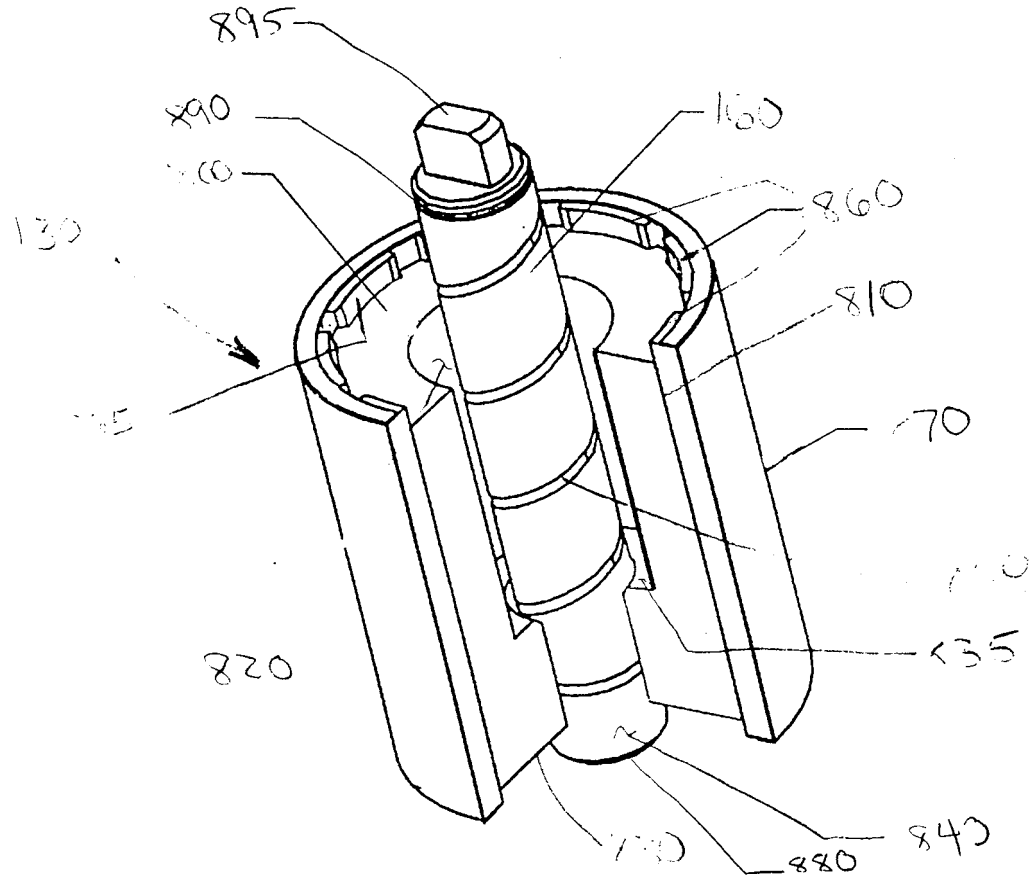


Figure 8

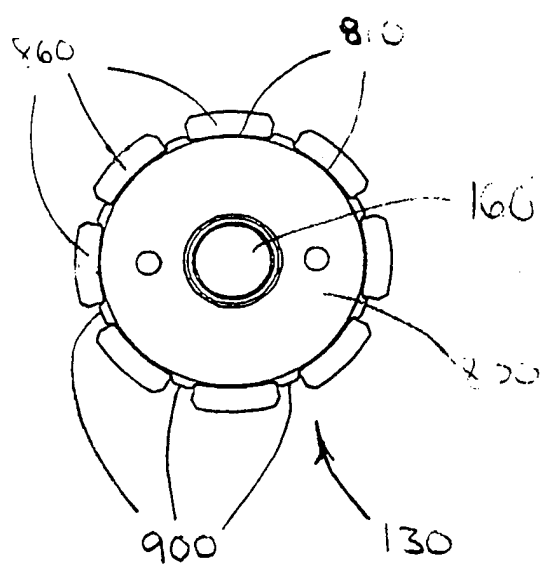


Figure 9a

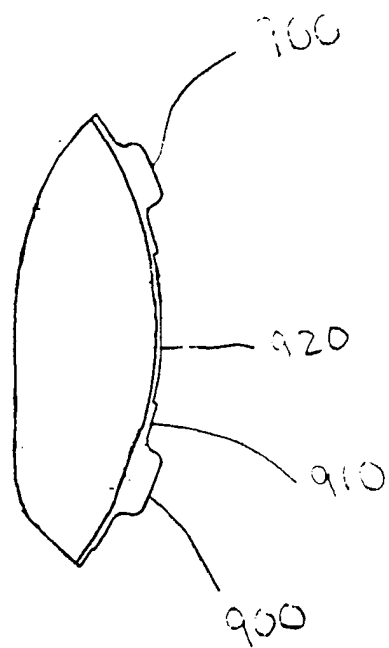


Figure 9b

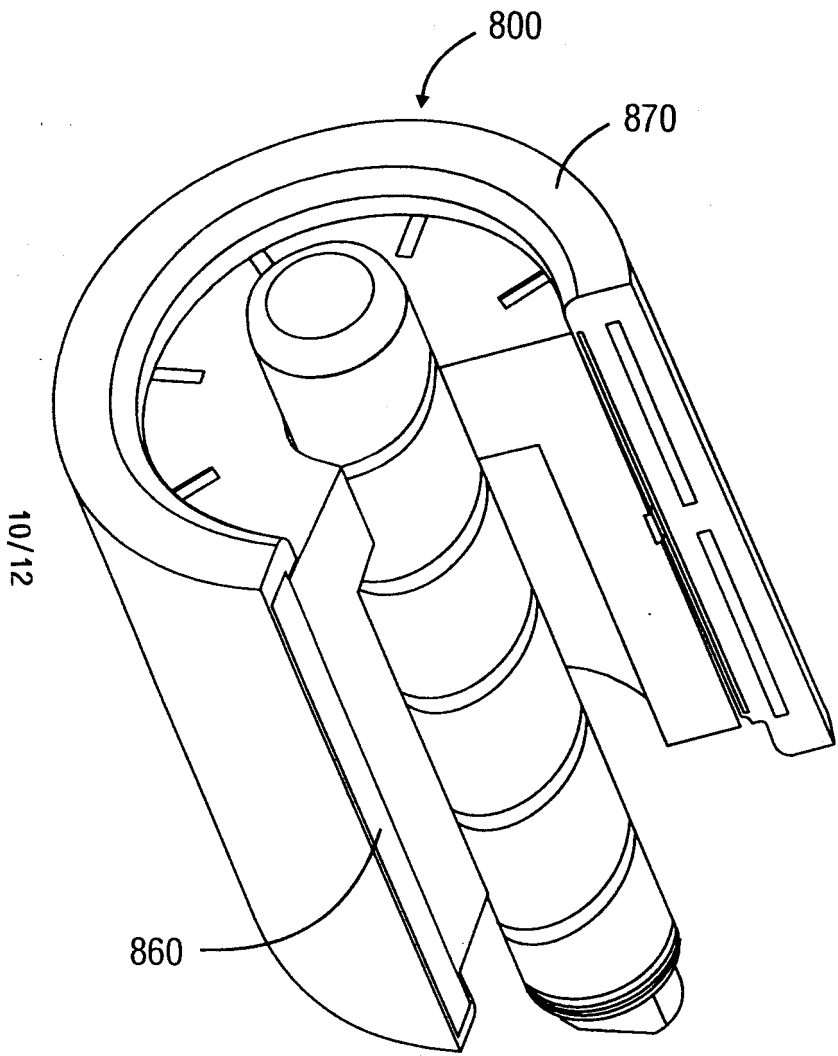


FIG. 12A

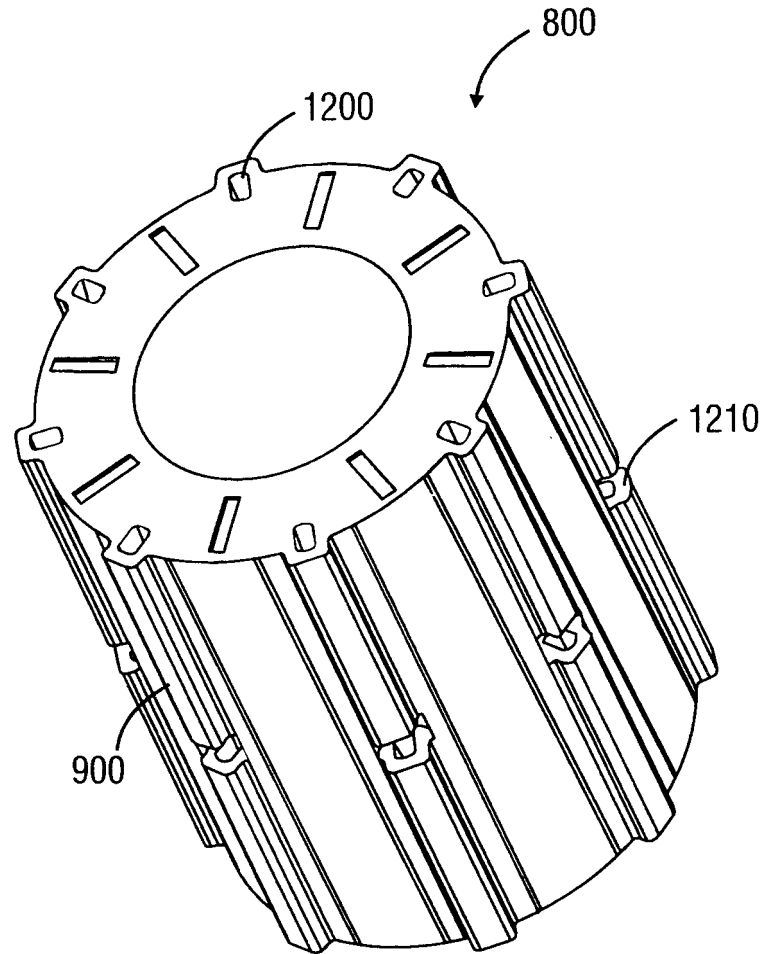


FIG. 12B

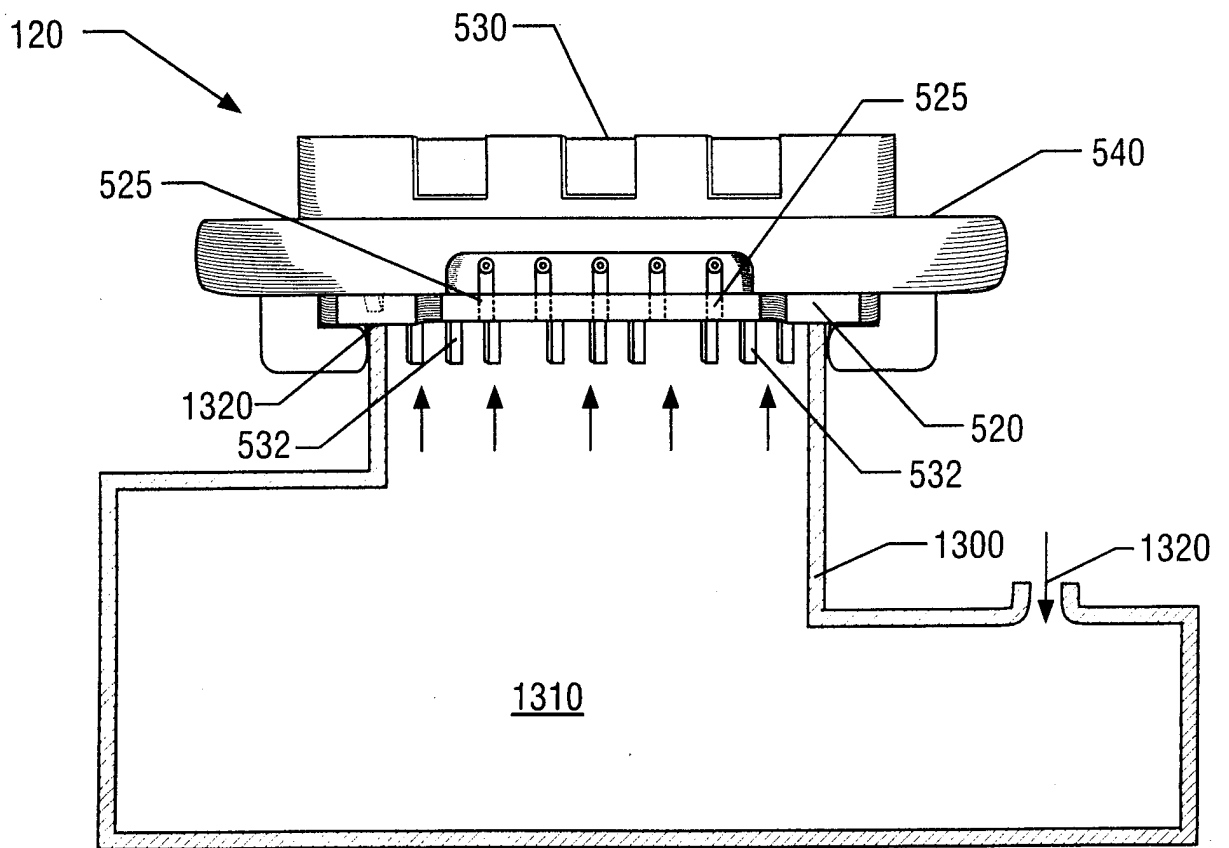


FIG. 13

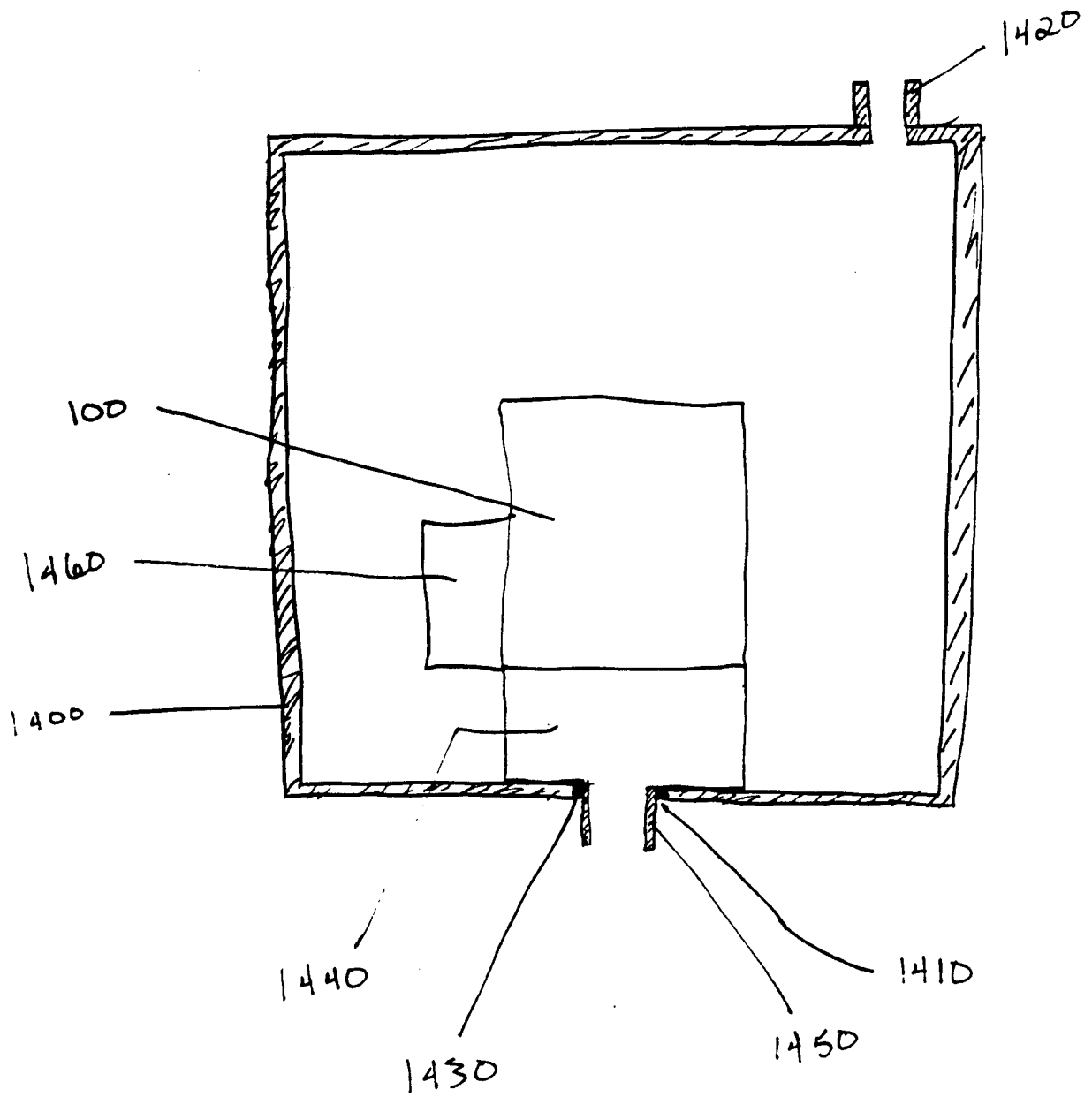


FIGURE 14