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(54) **SELF-CENTERING FOR ENCODER DEVICE**

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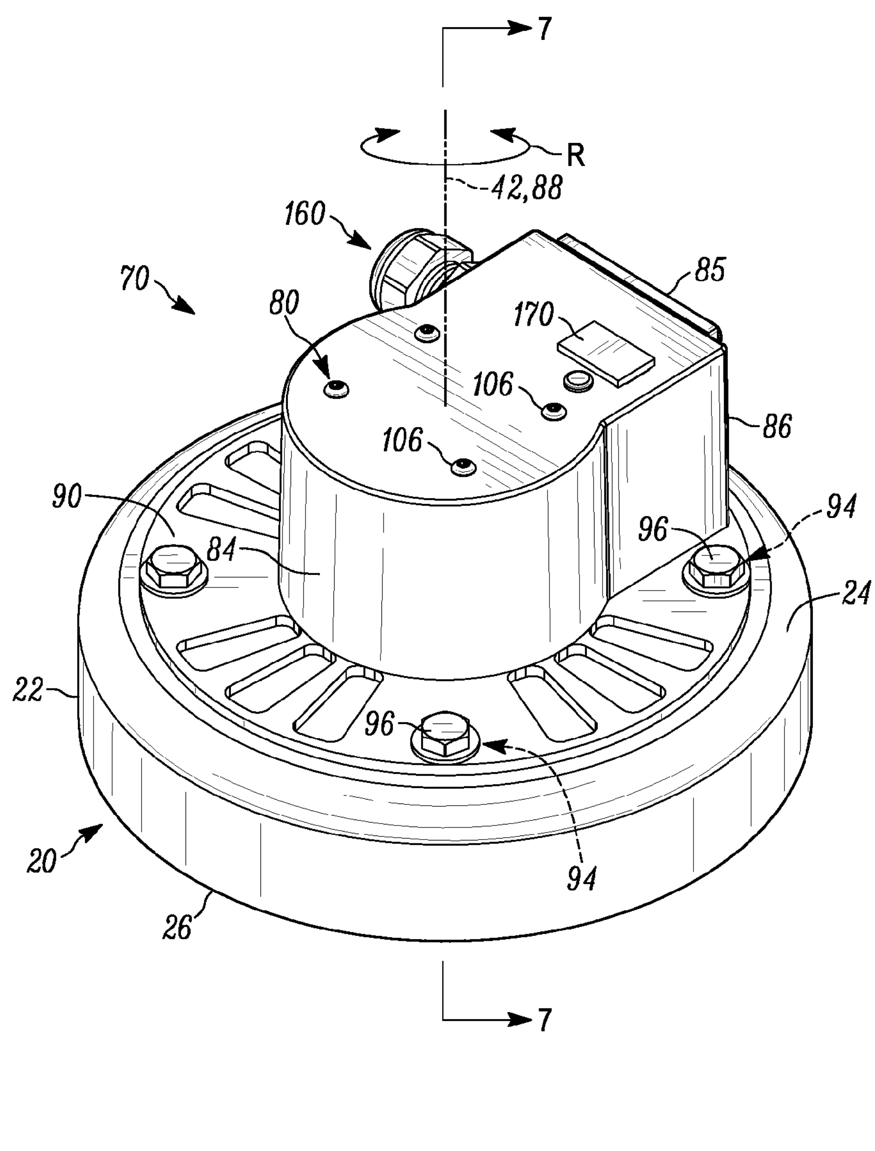
(57) **ABSTRACT**

A self-centering device for a motor having a base and a shaft extending through the base and rotatable relative to the base along an axis includes a housing having a flange for securing the housing to the motor base. A bushing is connected to the housing and has a passage for receiving the motor shaft. A rotary encoder is secured to the housing and configured to measure at least one of position or rotation of the motor shaft. Positioning the motor shaft in the passage in the bushing centers the housing on the motor shaft to place the encoder in a desired position for measuring the at least one of position or rotation of the motor shaft.



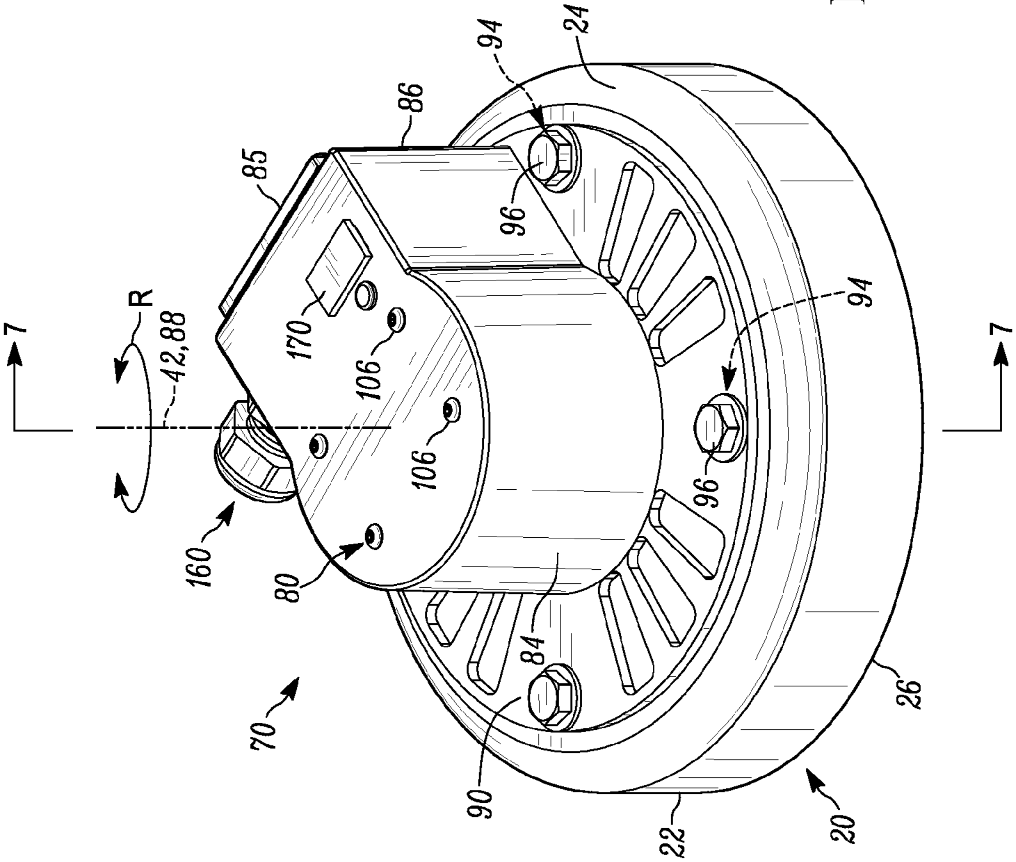
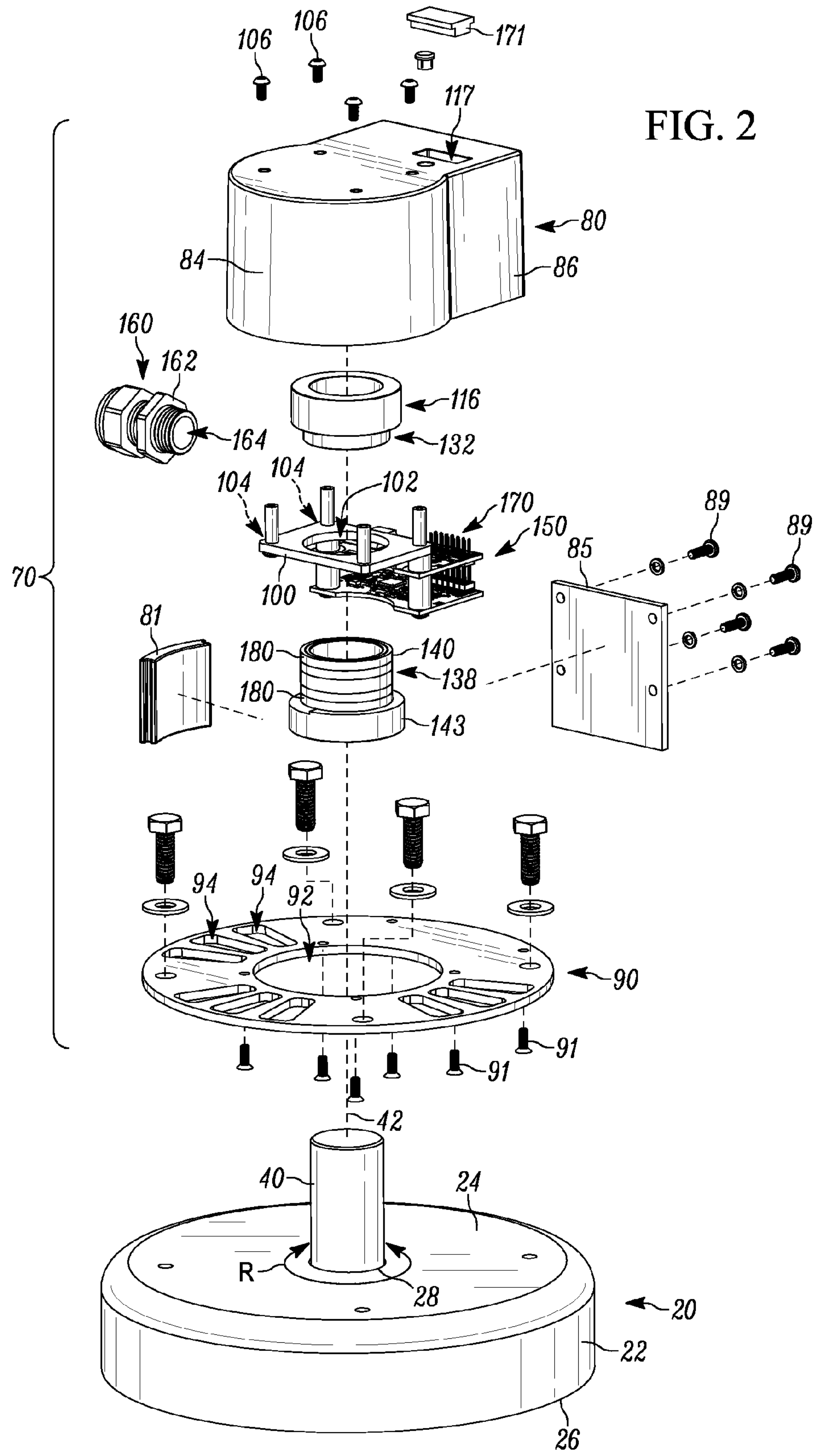


FIG. 1



106
106
171
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162
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164
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102
170
150
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89
85
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70
81
180
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138
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143
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90
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91
42
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24
R
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22
26

FIG. 2

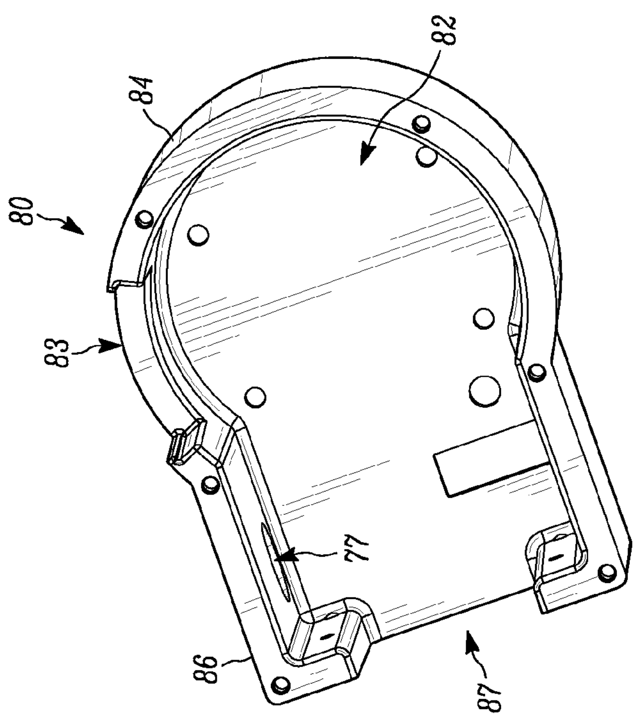


FIG. 3B

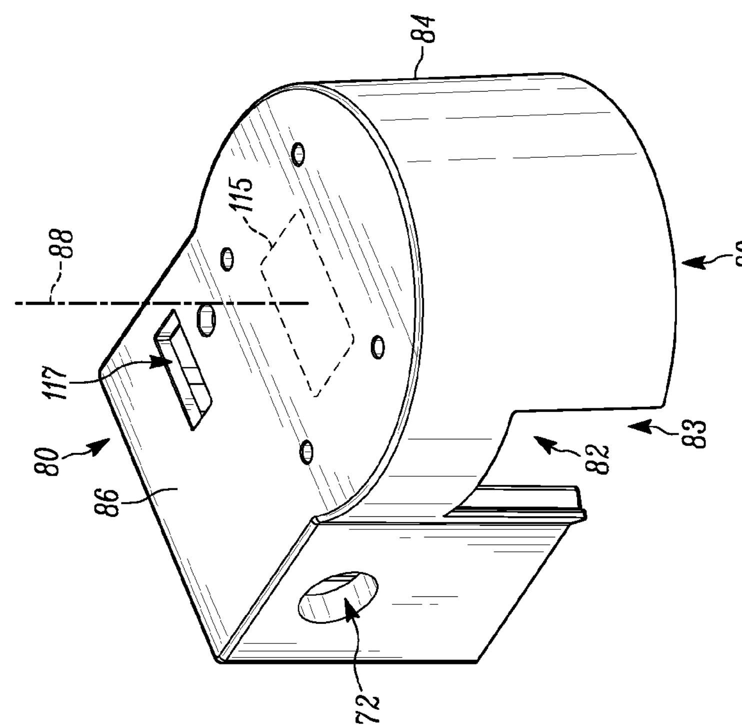


FIG. 3A

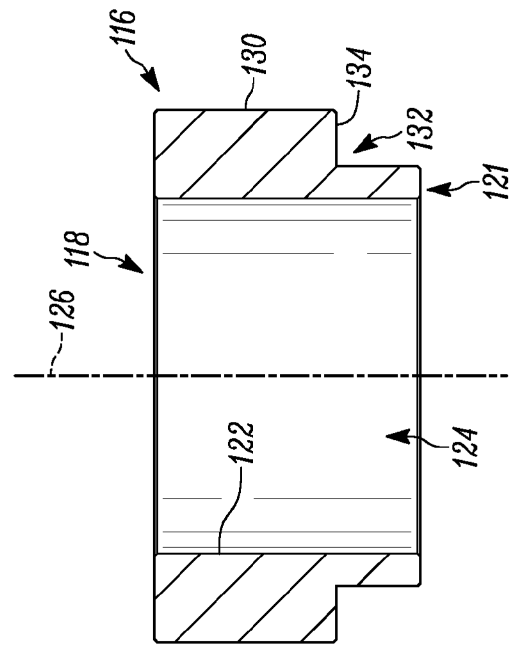
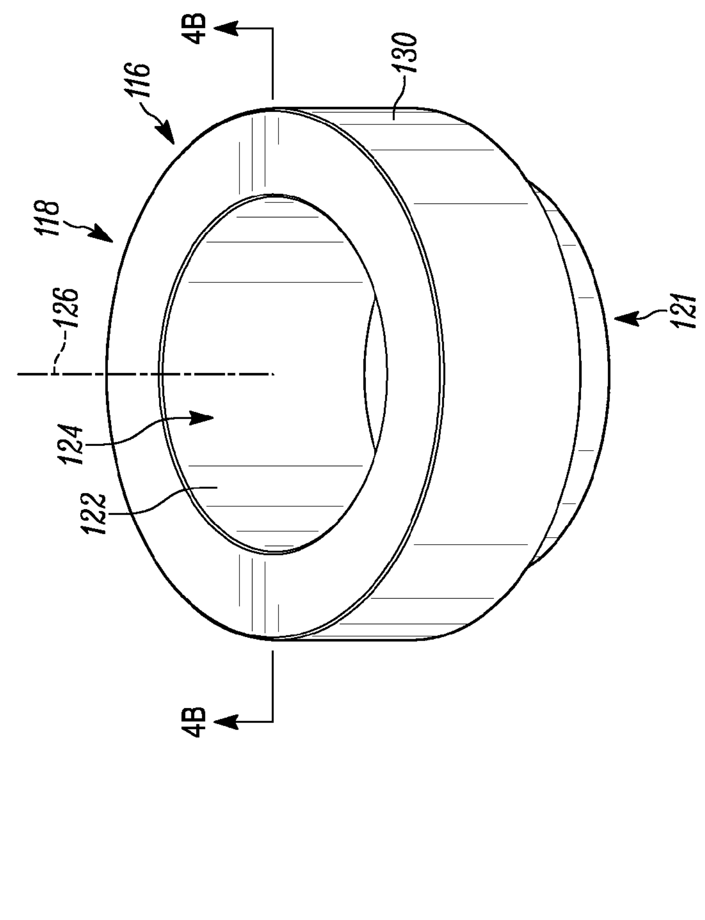

116
130
134
132
121
118
126
122
124

FIG. 4B


4B
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130
118
126
121
124
122
4B

FIG. 4A

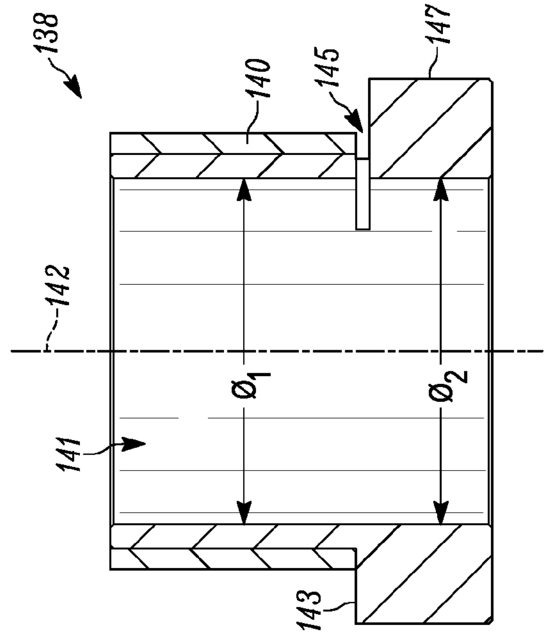
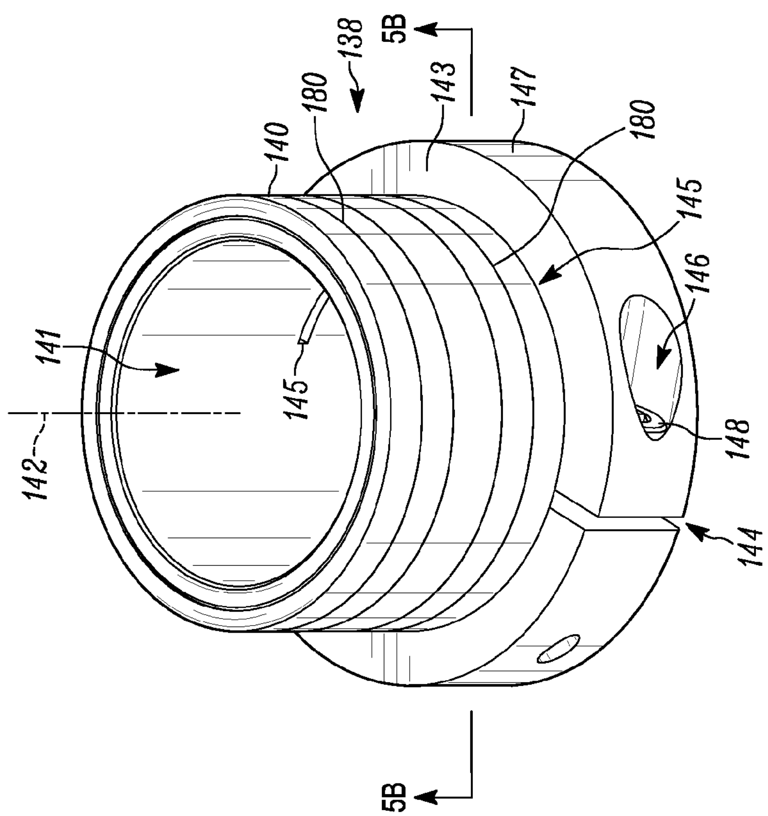

138
140
145
147
142
141
Ø1
Ø2
143

FIG. 5B


5B
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180
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146
141
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142
148
144
5B

FIG. 5A

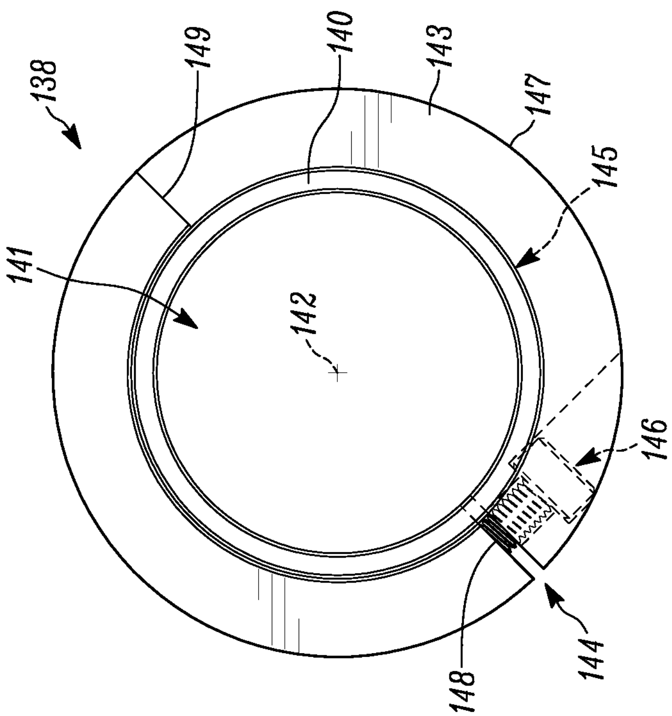


FIG. 5C

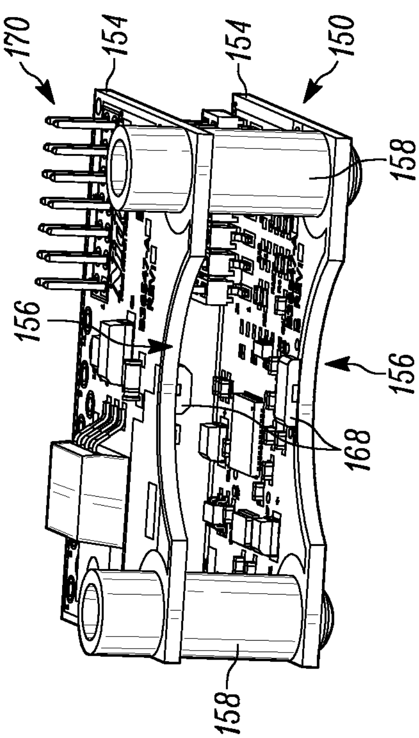
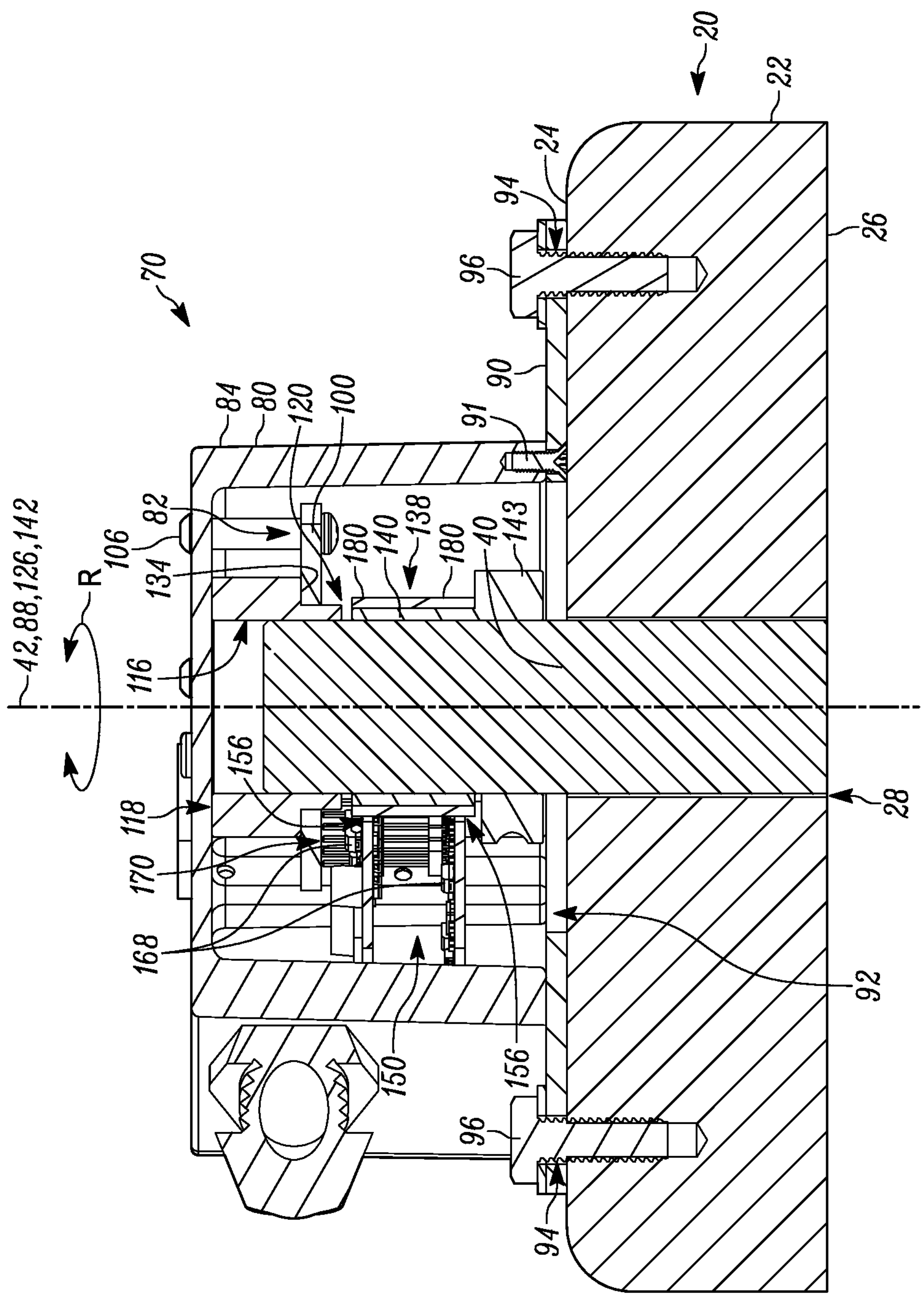


FIG. 6



20
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84
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120
100
82
106
42,88,126,142
R
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180
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143
116
156
118
170
168
150
156
96
94
92
28

FIG. 7

SELF-CENTERING FOR ENCODER DEVICE

TECHNICAL FIELD

[0001] This disclosure relates generally to motors and, more specifically, relates to a self-centering device for an encoder.

BACKGROUND

[0002] Encoders are used in motor applications to monitor the rotation of a shaft transmitting power through the system. Modular encoders in use today currently use either pre-existing pilot holes on a motor (or generator) face to center the encoder on the motor shaft or hollow clamping shafts with internal bearings and tethering devices. Pre-existing pilot holes, however, may be absent and/or not in their intended position, which can compromise installation accuracy and reliability. Hollow clamping shafts are expensive to manufacture and are prone to installation errors and bearing failure.

SUMMARY

[0003] One example provides a self-centering device for a motor having a base and a shaft extending through the base and rotatable relative to the base along an axis includes a housing having a flange for securing the housing to the motor base. A bushing is connected to the housing and has a passage for receiving the motor shaft. A rotary encoder is secured to the housing and configured to measure at least one of position or rotation of the motor shaft. Positioning the motor shaft in the passage in the bushing centers the housing on the motor shaft to place the encoder in a desired position for measuring the at least one of position or rotation of the motor shaft.

[0004] Another example provides a system that includes a housing having an interior space and a flange for securing the housing to a base of an apparatus from which a rotatable shaft extends. A retaining plate can be secured to the housing within the interior space and include an opening. A bushing is positioned between the housing and the retaining plate such that a distal end portion of the bushing extends through the opening in the retaining plate. The bushing also includes a passage at its distal end portion for slidably receiving the shaft therein. An encoder is configured to measure at least one of angular position or rotation of the shaft. The encoder includes at least one sensor connected to the housing for measuring the at least one of angular position or rotation of the shaft. In response to the shaft being received in the passage of the bushing, the housing aligns with respect to the shaft to place the at least one sensor within a predetermined radial distance from a longitudinal axis of the shaft.

[0005] A self-centering device for a motor having a base and a shaft extending through the base and being rotatable relative to the base along an axis includes a housing having an interior space and a flange for securing the housing to the motor base. A retaining plate having an opening is secured to the housing within the interior space. A bushing extends through the opening in the retaining plate and is positioned between the housing and the retaining plate. The bushing has a passage for slidably receiving the motor shaft. An encoder for measuring motor shaft rotation has a shaft component fixed to the motor shaft and at least one sensor connected to the housing for measuring rotation of the shaft component. Positioning the motor shaft in the passage in the bushing centers the housing on the motor shaft to place the at least one sensor in communication with the shaft component for measuring rotation of the motor shaft.

[0006] Yet another example provides a method that includes providing a device housing that includes an interior space. The housing includes a bushing and encoder electronics mounted within the interior space of the housing. The bushing includes a passage configured to receive a rotating shaft that extends axially from a base of a rotary apparatus. The encoder electronics are spaced apart from bushing. The housing also includes a flange extending outwardly from an end of the housing. The method also includes receiving the motor shaft in the passage of the bushing to position the encoder electronics within a predetermined distance with respect to the axis of the shaft to enable the encoder electronics to measure at least one of motion or position of the rotatable shaft. The flange of the housing can be secured to the base of the rotary apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a schematic illustration of an example of a self-centering device secured to a motor.

[0008] FIG. **2** is an exploded assembly view of FIG. **1**.

[0009] FIG. **3**A is an isometric view of a housing of the self-centering device of FIG. **1**.

[0010] FIG. **3**B is a bottom view of the housing of FIG. **3**A.

[0011] FIG. **4**A is an isometric view of a centering bearing of the self-centering device of FIG. **1**.

[0012] FIG. **4**B is a sectional view of the centering bearing of FIG. **4**A taken along line **4**B-**4**B.

[0013] FIG. **5**A is an isometric view of a hollow shaft component of the self-centering device of FIG. **1**.

[0014] FIG. **5**B is a sectional view of the hollow shaft component of FIG. **5**A taken along line **5**B-**5**B.

[0015] FIG. **5**C is a top view of the hollow shaft component of FIG. **5**A.

[0016] FIG. **6** is a schematic illustration of an encoder of the self-centering device of FIG. **1**.

[0017] FIG. **7** is a sectional view of the self-centering device and motor of FIG. **1** taken along line **7**-**7**.

DETAILED DESCRIPTION

[0018] This disclosure relates generally to encoders and, more specifically, relates to a self-centering device for measuring angular position and/or rotation of a rotating shaft. The device includes a housing (e.g., a stator housing) that includes a bushing and an encoder. The bushing can be mounted in a predetermined position and include a passage configured to receive a rotatable shaft (e.g., of a motor or generator) therein. The passage of the bushing has a central axis that has a predetermined spatial relationship with a sensor of the encoder. The encoder can be implemented as an absolute or incremental rotary encoder. When the shaft is received within the bushing **116** of the housing, the bushing operates as a mechanical template to align the housing with respect to the shaft such that the encoder is positioned at a desired position and orientation to measure the position and/or rotation of the shaft. For example, the encoder can include a sensor configured to sense indicia on a rotor that is secured to the shaft and received within the housing for sensing by the sensor. The bushing thus operates to self-align a central axis (e.g., centerline) of the rotor with a corresponding axis (e.g., centerline) of the encoder sensor to enable the sensor to measure position and/or motion of the rotor affixed to the shaft. Accordingly, once the shaft is received in the bushing, the housing can be fixed to a surface from which the shaft extends (e.g., by bolts or other fastener means). Once the housing is fixed to the surface, the bushing permits the substantially free rotation of the shaft in a non-interfering manner such that it could be removed without affecting operation of the encoder.

[0019] FIGS. **1** and **2** illustrate examples of a self-centering device **70**. The device **70** can used to precisely position an encoder apparatus with respect to a rotating shaft, such as a rotor shaft of a motor or generator, to help accurately track angular position and/or rotation of the shaft. In one example, the device **70** includes a housing **80**, a bushing **116** positioned in the housing and configured to provide for self-centering the device with respect to a shaft **40** of an apparatus **20**, such as for a motor, generator or other rotating shaft carrying apparatus. The device can also include an encoder **150** mounted in the housing and configured to measure angular position and/or rotation of the shaft.

[0020] As one example, the apparatus **20** constitutes a typical electric motor for generating and transmitting torque in a system. The apparatus **20** includes a base **22** having a generally cylindrical shape that defines a pair of opposing end faces or surfaces **24**, **26**. A cylindrical passage **28** extends though the base **22** between the end surfaces **24**, **26**. A cylindrical rotor shaft **40** extends along an axis **42** through the passage **28**. The shaft **40** is rotatable about the axis **42** relative to the base **22** in the direction indicated generally by the arrow R. The passage **28** can contain motive generating structures, which can vary depending on the type and configuration of the apparatus **20**.

[0021] Referring to FIGS. **3**A-**3**B, the housing **80** includes a first portion **84** and a second portion **86** that cooperate to define an interior space **82**. The first portion **84** can have a generally circular shape centered on an axis **88**. The second portion **86** extends from the first portion **84** in a direction extending radially outward from the axis **88**. The second portion **86** may have a square or rectangular shape, for example. A lateral opening **83** extends through the first portion **84** to the interior space **82**. The lateral opening **83** can be closed by a removable door or plate **81** (see FIG. **1**) secured to the first portion **84**. An additional opening, shown in phantom at **115**, may extend through the top of the first portion **84** into the interior space **82**. An opening **117** extends through the top of the second portion **86** into the interior space **82**. A pair of lateral openings **77**, **87** extends through the side of the second portion **86** to the interior space **82**. The lateral opening **87** is closed by a removable door or plate **85** secured to the second portion **86** via fasteners **89** (see FIG. **1**). The housing **80** can be made of a substantially rigid material, such as a metal (e.g., stainless steel, aluminum or the like) or it can be made from a non-metal material such as a polymer or plastic.

[0022] Referring to FIGS. **2** and **7**, the housing includes a flange **90** that can be connected to the first portion **84** and the second portion **86** to partially close the interior space **82** of the device **70**. The flange **90** may be a separate component secured to the housing **80** via fasteners **91** (as shown) or, in other examples, may be integrally formed with the housing. The flange **90** may therefore be made from the same material as the housing **80** or from a different material than the housing, e.g., metal or plastic. In any case, the flange **90** extends radially outward from the first portion **84** of the housing **80**. As illustrated, the flange **90** can be a continuous annular flange and can be generally concentric with the first portion. In other examples, the flange can be configured as one or more radially outwardly extending features that is configured to secure the housing to a surface of the apparatus **20** as the bushing **116** within the housing aligns sensing circuitry with respect to the shaft. In the example of FIGS. **2** and **7**, a central opening **92** extends through the flange **90** and is centered about the axis **88** of the first portion **84** to provide access to the interior contents of the device **70** (e.g., containing the bushing and encoder sensing circuitry). Optionally, one or more outer openings **94** extend through the flange **90** and are positioned circumferentially about the central opening **92**. The openings **94** can be pre-configured or be customized for a particular installation, such as to align axially with threaded boreholes in the apparatus **20** for securing the flange to the apparatus via threading fasteners **96** in such boreholes. In some examples, the threaded boreholes can be formed in the surface of the apparatus **20** during installation of the device **70** to the apparatus **20**.

[0023] Referring to FIG. **2**, a retaining plate **100** is provided to be connected to the first portion **84** of the housing **80** within the interior space **82**. The retaining plate **100** can be rectangular or another shape and includes a central opening **102** and a plurality of outer openings **104** positioned radially outward from the central opening. The openings **104** are dimensioned and configured to receive fasteners **106** for securing the retaining plate **100** to the first portion **84** of the housing **80**. The retaining plate **100** may be formed from metal or plastic. The central opening is dimensioned and configured to provide for passage of a distal end of the bushing **116** therethrough while the retaining plate clamps the bushing at a predetermined position between the retaining plate and the first portion of the housing **84**. By clamping the bushing **116** between the retaining plate and the housing in this manner, the bushing can be considered held by a weak friction fit sufficient to perform its self-alignment function while also being free or floatable within the housing.

[0024] Referring to the example of FIGS. **4**A and **4**B, the centering bushing **116** is ring-shaped and extends along an axis **126** from a first end **118** to a second end **121**. The bushing **116** includes an inner surface **122** defining a cylindrical passage **124** extending along the axis **126** entirely through the bushing **116**. The inner diameter of the passage **124** is sized to be slightly smaller (e.g., 1-10 microns larger) than the diameter of the shaft **40** to ensure a precise fit between the bushing **116** and shaft. In one example, the passage **124** and shaft **40** form a tight, sliding fit with one another to enable rotation of the shaft relative to the bushing (e.g., due to wearability and/or lubricant impregnated with the material forming the sidewall of the passage).

[0025] The bushing **116** includes a peripheral surface **130** extending circumferentially about the axis **126**. A recess **132** is formed in the peripheral surface **130** and extends from the second end **121** towards the first end **118**, terminating at an end surface **134** between the first and second ends. The recess **132** is concentric with the inner surface **122**. The recess **132** can provide a shoulder that is engaged by (e.g., provide an abutment with) an adjacent surface of the retaining plate **100** for clamping the bushing with respect to the housing while the end **121** protrudes through the opening in the retaining plate for receiving the shaft **40**.

[0026] The bushing **116** can be made from a wearable material, such as a metal, plastic or polymer, which may be lubricated or unlubricated. In one example, the bushing **116** is made from bronze, e.g., SAE **841** oil-impregnated, sintered bronze. In another example, the bushing **116** may be made from a plastic or polymer impregnated with oil or another lubricant. The bushing **116** may be molded and/or machined to accommodate a variety of different shaft diameters.

[0027] Referring back to FIG. **2**, the encoder **150** constitutes an encoder **150** that cooperates with a hollow shaft component (e.g., a rotor) **138** to measure angular position and/or rotation of the shaft **40**. It will be understood that the shaft component **138** may alternatively constitute part of the encoder **150**. In any case, the encoder **150** may constitute any one of a number of known encoder types. For example, the encoder **150** may be mechanical, optical, magnetic, inductive or capacitive.

[0028] Referring to example demonstrated in FIGS. **5A-5C**, the shaft component **138** is provided as a rotor that is to be secured to the shaft **40** of the apparatus **20** and, in turn, rotate with the shaft. The shaft component **138** includes a ring-shaped base **140** and a clamping member **143** extending radially outward from the base. Indicia **180** can be disposed about the base for sensing by the encoder **150**. In this example, the indicia **180** are demonstrated as including one or more bands that extend around the outer periphery of the base **140**. The indicia **180** may be formed from a series of discrete markings or other detectable objects, which can vary depending on the type of encoder technology being implemented (e.g., magnetic, optical, inductive, capacitive, etc.). The indicia **180** can vary along the circumference to encode angular position and/or rotation information for the shaft **40**. In some examples, the indicia **180** may be formed from one or more strips of material different from the rest of the base **140**.

[0029] By way of further example, a passage **141** extends entirely through the shaft component **138** along an axis **142**. The passage **141** has a circular cross-section sized to slidably receive the shaft **40** of the apparatus **20**. The passage **141** has a first diameter Φ_1 within the base **140** and a second diameter Φ_2 within the clamping member **143**. The clamping member **143** includes an outer peripheral surface **147**. A slot or passage **144** extends from the outer surface **147**, through the clamping member **143**, and into the passage **141**. As a result, the clamping member **143** has a C-shaped axial cross-section. An annular slot or passage **145** extends from the passage **144** and circumferentially about the axis **142**. The annular passage **145** extends entirely through the clamping member **143** such that the clamping member and base **140** are spaced apart from one another along the annular passage **145**. Due to the passages **144**, **145**, a portion of the clamping member **143** is movable relative to the base **140** and movable relative to the remainder of the clamping member. In other words, the portion of the clamping member **143** along the annular passage **145**—and spaced from the base **140**—is movable relative to the base as well as the portion of the clamping member secured directly to the base.

[0030] A lateral passage **146** extends through the outer surface **147** of the clamping member **143** to the annular passage **145**. A fastener **148** extends through the lateral passage **146** and the annular passage **145**. The fastener **148** threads into the clamping member **143** such that the degree of threaded engagement between the fastener and clamping member adjusts the circumferential width of the annular passage **144**. In other words, rotating the fastener **148** moves the portion of the clamping member **143** along the annular passage **145** relative to the portion of the clamping member secured directly to the base **140** as well as the base. As a result, the diameter Φ_2 of the passage **141** within the clamping member **143** may be reduced to a size that is equal to or smaller than the diameter Φ_1 to secure the shaft component **138** to the shaft **40** of the apparatus **20**.

[0031] As shown in FIG. **6**, the encoder **150** includes one or more circuit boards **154** secured together by fasteners **158**. Each circuit board **154** includes electronic components for detecting, measuring, and transmitting information related to rotation of the shaft **40**. Each circuit board **156** can include an arcuate recess **156** that mimics the outer contour of the base **140** of the shaft component **138**. One or more sensors **168** can be provided on each circuit board **156** for detecting rotational movement of the bands **180** on the shaft component **138**. The sensor **168** may be an optical sensor, magnetic sensor, etc., which can depend on the type of encoder technology being implemented. A programming port **170** can be electrically connected to the circuit boards **154**, which allows the user to program, calibrate, test or otherwise adjust sensing variables programmed into the circuit boards and/or sensors **168**. In other examples, the data can be transmitted wirelessly (e.g., via Bluetooth, WiFi or another short range wireless technology). A door or panel **171** is releasably secured to the first portion **84** of the housing **80** and extends through the opening **117** in the housing (see FIG. 3A) and provides access to the programming port **170** when the device **70** is installed.

[0032] Referring to FIGS. **1** and **2**, an adapter **160** is configured to be secured to the second portion **86** of the housing **80** and extend through the lateral opening **77** in the second portion into the interior space **82**. The adaptor **160** includes a fastener **162** and a passage **164** extending through the fastener to receive wires (not shown) for the transmission of data from the encoder **150** to a controller (not shown). The adaptor **160** can be electrically connected to the controller (not shown) and relays data related to the shaft **40** rotation to the controller.

[0033] Referring to FIGS. **2** and **7**, when the device **70** is assembled, the second end **121** of the bushing **116** extends through the central opening **102** in the retaining plate **100**. This places the end surface **134** in abutment with the retaining plate **100**. Although the retaining plate **100** and bushing **116** are shown as separate components it will be appreciated that the retaining ring and bushing could be formed as a single, integrated component (not shown). Regardless of the construction, in this configuration, the central opening **102** in the retaining plate **100** can center the axis **126** of the bushing **116** in predetermined orientation and position. The fasteners **106** extend through the outer openings **104** in the retaining plate **100** and secure the retaining plate to the first portion **84** of the housing **80** within the interior space **82**. This positions the bushing **116** within the interior space **82** between the first portion **84** of the housing **80** and the retaining plate **100**, with the axis of the bushing in a predetermined position. In one example, the bushing **116** is not fastened to either the retaining plate **100** or the housing **80**. Rather, the bushing **116** is clamped or held between the retaining plate **100** and the housing **80** to prevent relative axial movement between the bushing and the retaining plate or housing. Alternatively, the retaining plate **100** and housing **80** may be spaced from one another sufficient to allow some movement of the bushing **116** along the axis **126** between the retaining plate and housing (not shown), such as after the housing has been secured to the apparatus **20**. In other words, in another example, the bushing **116** may be axially moveable relative to the retaining plate **100** over a portion or all of the depth of the recess **132**.

[0034] In some examples, the first portion **84** of the housing **80** may be configured to prevent removal of the bushing **116**

from between the retaining plate **100** and housing once the fasteners **106** are secured. In other examples, the first portion **84** may include a removable door or other structure, e.g., the phantom door **115** in FIG. 3A, that allows the bushing **116** to be removed from between the retaining plate **100** and the housing **80** after the device has been secured to the apparatus **20** in a desired position and orientation.

[0035] The encoder **150** is secured via the fasteners **158** to the retaining plate **100** within the interior space **82** of the housing **80**. This suspends the encoder **150** from the retaining plate **100**. At this point, a chuck or other alignment tool (not shown) may be used before tightening the fasteners to ensure the bushing **116** is properly positioned relative to the housing **80** and sensors **168**, i.e., the axis of the bushing is properly aligned to provide the axis **88** of the housing **80**. The chuck may be cylindrical and may be positioned abutting the arcuate recesses **156** in the circuit boards while abutting the retaining plate **100** and encircling the bushing **116**. This centers the bushing **116** along the axis **88** of the housing **80** and precisely locates the bushing relative to the sensors **168** on the circuit boards **154**. The fasteners **106**, **158** are then tightly secured and the chuck removed.

[0036] The adaptor **160** can be inserted through the opening **77** in the second portion **86** of the housing **80** into the interior space **82**. This places the passage **164** of the fastener **162** in fluid communication with the interior space **82**. The fastener **162** secures the adaptor **160** to the second portion **86**. The door **171** is positioned in the opening **117** in the housing **80**. Wires can be electrically connected to the circuit boards **154** and fed through the passage **164** in the adaptor **160** to be electrically connected to the controller (not shown). Alternatively, the adaptor **160** may be omitted and data from the circuit boards **154** sent wirelessly to a controller or other remote circuitry (not shown).

[0037] The shaft component **138** is positioned over the shaft **40** of the apparatus **20** such that the shaft extends through the passage and the clamping member **143** is spaced axially from the end surface **24** of the motor. The shaft **40** extends first through the clamping member **143** then through the base **140**. The fastener **148** is tightened to draw the portions of the clamping member **143** together to reduce the diameter Φ_2 until the clamping member clamps around the shaft **40**, thereby fixing the shaft component **138** to the shaft. Subsequent rotation of the shaft **40** in the direction R therefore rotates the shaft component **138** in the direction R. Alternatively, the shaft component **138** may be omitted entirely and the indicia (e.g., bands) **180** formed or provided directly on the shaft **40** (not shown).

[0038] At this time, if a pre-existing pilot exists in the end surface **24** of the base **22** (e.g., an annular recess in the surface of the motor base), one or more ring-shaped covering members (not shown) resembling the flange **90** may be placed on the end surface to cover or fill the pilot. The shaft **40** and shaft component **138** pass through the covering and freely rotate relative thereto. The covering member thus can be positioned between the flange **90** and the surface **24** of the base of the apparatus **20** prior to attaching the housing to such surface. The covering member thus can be utilized to effectively eliminate the recessed portion corresponding to the pilot such that originally intended alignment function of the pilot is removed. In other examples, the flange itself can be configured to have an outer diameter dimensioned to fit within the pilot, such that the alignment or misalignment afforded by the existing pilot can be eliminated.

[0039] In any case, the assembled device **70** is then brought near the apparatus **20** and the device oriented such that the central opening **92** in the flange **90** faces the end surface **24** of the motor and, where present, the ring-shaped covering. The user then aligns the axes **42** of the shaft **40** with the axis **126** of the passage **124** in the bushing **116** and moves the bushing—with the housing **80** and encoder **150** secured thereto—onto the shaft. During this movement, the shaft **40** and shaft component **138** pass through the central opening **92** in the flange **90** and the central opening **102** in the retaining plate **100** until the shaft extends into the passage **124** in the bushing **116**. The shaft **40** can move into and through the passage **124** until the flange **90** abuts the end surface **24** of the base **22**. In this configuration, the device **70** is substantially free to rotate about the shaft **40** relative to the base **22** in the direction R, which allows the device **70** to be moved to a desirable circumferential position about the axis **42**, e.g., to align the passage **164** in the adaptor **160** of the encoder **150** with connecting wiring and/or position the second portion **86** of the housing **80** out of the way of other structures. Regardless of the orientation of the device **70**, the encoder **150** is positioned such that the arcuate recesses **156** in the circuit boards **154** are adjacent and substantially concentric to the periphery of the base **140** of the shaft component **138**. In this orientation, the sensors **168** are positioned adjacent to and radially aligned with the bands **180** on the shaft component **138**.

[0040] Since the retaining plate **100** is securely fastened to the housing **80**, the central opening **102** in the retaining plate helps maintain the passage **124** of the bushing **116** disposed therein coaxial with the axis **88** of the housing. Furthermore, the recess **132** in the bushing **116** cooperates with the retaining plate **100** to prevent the axes from **88**, **126** from misaligning. Consequently, when the shaft **40** is positioned within the passage **124** of the bushing **116**, the bushing precisely and repeatably aligns the axis **42** of the shaft with the axis **88** of the housing **80**. As a result, the sensors **168** on the circuit boards **154** of the encoder **150**, which are also securely fastened to the housing **80**, are precisely radially aligned with the indicia **180** on the shaft component **138** regardless of the rotational orientation of the device **70** relative to the apparatus **20**. This precise positioning of the circuit boards **154** relative to the shaft component **138** allows the sensors **168** to detect rotation of bands **180**, which corresponds with the rotation of the shaft **40** secured thereto. The bushing **116** can facilitate and enable precisely aligning the axis **88** of the housing **80** with the axis **42** of the shaft **40**, therefore positions and fixes sensing circuitry of the encoder **150** at a predetermined distance from the rotating shaft to ensure the encoder will accurately detect and measure rotation of the shaft.

[0041] Once the desired rotational position of the device **70** relative to the shaft **40** is achieved the user secures the flange **90** to the base **22**. More specifically, fasteners **96** may be inserted into the openings **94** and threaded into the base **22** to secure the device **70** to the apparatus **20**. To this end, the user may drill or otherwise form the openings in the base **22** for receiving the fasteners **96** once the flange **90** abuts the end surface **24**. In other words, the openings in the base **22** for receiving the fasteners **96** can be pre-existing openings in the base or can be newly formed during installation of the device **70**. The device **70** therefore does not rely on pre-existing openings or pilot holes in the apparatus **20** to be secured to the motor. More particularly, since the bushing is secured with respect to the housing in a predetermined position when it is attached to the shaft, the bushing performs self-alignment function for the housing with respect to the shaft. Accordingly, the modular encoder does not need to rely on the axial and radial position of any pre-formed pilot that may exist in the base **22**. Although the flange **90** is shown as including the openings **94** it will be appreciated that these openings may be initially omitted and subsequently formed in the flange once the device **70** is placed on the apparatus **20**.

[0042] Once the device **70** is secured to the apparatus **20** rotation of the shaft **40** in the direction R about the axis **42** likewise rotates the shaft component **138** in the direction R. As the shaft component **138** rotates the sensors **168** of the encoder **150** track movement of the bands **180** passing thereby and convert that movement into a digital signal to be transmitted through wires (not shown) passing through the adaptor **160** to the controller (not shown) to be processed. Since the device **70** is securely fastened to the apparatus **20** and properly aligned relative to the axis **42** of the shaft **40** by the bushing **116**, the encoder **150** may readily and repeatably track shaft rotation.

[0043] If the bushing **116** becomes worn over time due to wobbling or misalignment of the shaft **40**, the encoder **150** still will function properly despite any such wearing of the bushing. That is, the bushing **116** can be employed to provide for initial alignment and attachment to the base **22**, after which the function is minimal. For example, after the housing **80** has been secured to the base **22** according to the alignment afforded by the bushing **116**, in some examples, the bushing of the device **70** can be removed. The bushing **116** can be replaced if desired; however, it is not needed for continued operation of the device **70** after it has been attached to the apparatus **20**. This is because the functioning of the encoder **150** electronics in sensing the bands **180** does not depend on the bushing **116**. Therefore, so long as the encoder **150** is properly functioning, even if the bushing **116** has become worn, it may be moved to a different or event the same apparatus and still afford the self-alignment function to enable operation as an encoder. In any case, the device **70** is configured to ensure that wear of the bushing **116** does not compromise the encoding function after it has be used for the precision centering and securing of the device to the apparatus **20**.

[0044] As mentioned, the device **70** simplifies securing the housing **80** and apparatus **20** together in that the need to locate and/or rely on pilot holes on the motor or secure a tether between the device and motor are alleviated. Instead, once the flange **90** abuts the end surface **24** of the base **22**, the user may simply drill and tap holes anywhere on the flange into the end surface **24** to allow the fasteners **96** to secure the device to the motor. Accordingly, the bushing **116** itself—and not pilot holes or other pre-existing apparatus structure—is used to align the device **70** on the shaft **40** and thereby precisely position the encoder **150** relative to the shaft for sensing angular position and/or motion of the shaft.

[0045] The self-aligning construction of the bushing **116** also simplifies assembling of the device **70** on the apparatus **20** and positioning of the encoder **150** relative to the shaft component **138**. By merely inserting the motor shaft **40** into the self-aligning/self-centering bushing **116**, the sensors **168** of the encoder **150** are automatically aligned with the bands **180** on the shaft component **138** secured to the shaft **40**, which ensures accurate and repeatable measuring of the motor shaft rotation. The self-centering device of the disclosed herein therefore reduces costs, improves the accuracy and versatility in installation locations, and increases the overall life expectancy of the product by reducing wear on components that might otherwise be out of tolerance with one another.

[0046] What have been described above are examples. It is, of course, not possible to describe every conceivable combination of components or methodologies, but one of ordinary skill in the art will recognize that many further combinations and permutations are possible. Accordingly, the disclosure is intended to embrace all such alterations, modifications, and variations that fall within the scope of this application, including the appended claims. As used herein, the term "includes" means includes but not limited to, the term "including" means including but not limited to. The term "based on" means based at least in part on. Additionally, where the disclosure or claims recite "a," "an," "a first," or "another" element, or the equivalent thereof, it should be interpreted to include one or more than one such element, neither requiring nor excluding two or more such elements.

What is claimed is:

1. A self-centering device for securing to a base through which a rotatable shaft extends along an axis, the self-centering device comprising:

a housing including a flange to secure the housing to the base;

a bushing connected to the housing and having a passage for receiving the rotatable shaft; and

an encoder secured to the housing spaced apart from the bushing, the encoder being configured to measure at least one of position or rotation of the rotatable shaft;

wherein positioning the rotatable shaft in the passage of the bushing aligns the encoder with respect to the rotatable shaft to enable the encoder to measure the at least one of position or rotation of the rotatable shaft.

2. The self-centering device of claim **1**, wherein the encoder is one of a magnetic encoder, an optical encoder, an inductive encoder or a capacitive encoder.

3. The self-centering device of claim **2**, wherein the encoder further comprises a sensor secured within the housing and a shaft component separate from the housing and fixed to the rotatable shaft such that a portion of the rotatable shaft extends beyond the shaft component and is received in the passage of the bushing, the sensor configured to sense indicia on the shaft component to detect the at least one of position or rotation of the rotatable shaft.

4. The self-centering device of claim **1**, wherein the flange extends radially outward from the housing and receives at least one fastener to secure the housing to the base.

5. The self-centering device of claim **1**, wherein the bushing comprises a wearable substantially rigid material.

6. The self-centering device of claim **5**, wherein the bushing comprises a lubricant-impregnated material.

7. The self-centering device of claim **1**, further comprising a retaining plate connected to the housing to clamp the bushing between the retaining plate and the housing to hold the bushing and the passage in a predetermined position and orientation within the housing.

8. The self-centering device of claim **7**, wherein the retaining plate includes an opening through which an end of the bushing extends, the bushing having a shoulder spaced apart from the end and abutting the retaining plate adjacent the opening to prevent the bushing from passing entirely through the retaining plate while clamped between the retaining plate and the housing.

9. The self-centering device of claim **1**, wherein the passage of the bushing is configured to have an inner diameter that approximates an outer diameter of the rotatable shaft as to facilitate substantially free rotation of the rotatable shaft relative to the bushing.

10. The self-centering device of claim **1**, wherein the housing includes an opening for removing the bushing from the housing while the flange of the housing is secured to the base.

11. The self-centering device of claim **1**, further comprising a member configured to cover a pre-existing pilot in the base prior to securing the flange to the base.

12. The self-centering device of claim **1**, further comprising fasteners extending through the flange into the base to secure the self-centering device to the base.

13. A system, comprising:

a housing having an interior space and a flange to secure the housing to a base of an apparatus from which a rotatable shaft extends;

a retaining plate secured to the housing within the interior space, the retaining plate having an opening;

a bushing positioned between the housing and the retaining plate such that a distal end portion of the bushing extends through the opening in the retaining plate, the bushing including a passage at the distal end portion for slidably receiving the rotatable shaft therein; and

an encoder for measuring at least one of angular position or rotation of the rotatable shaft, the encoder including at least one sensor connected to the housing for measuring the at least one of angular position or rotation of the rotatable shaft;

wherein, in response to receiving the rotatable shaft in the passage of the bushing, the housing aligns with respect to the rotatable shaft to place the at least one sensor within a predetermined distance from a longitudinal axis of the rotatable shaft.

14. The system of claim **13**, wherein the apparatus is a motor or a generator having a pilot formed as a recessed portion in a surface of the base of the apparatus from which the rotatable shaft extends, the system further comprising a covering member positioned between the flange and the surface of the base of the apparatus, the covering member filling the recessed portion in the surface covering the pilot.

15. The system of claim **13**, further comprising fasteners extending through the flange and into boreholes in the base to secure the housing to the base of the apparatus while the rotatable shaft is positioned in the bushing.

16. The system of claim **13**, wherein the flange extends radially outward from the housing and receives at least one fastener to secure the housing to the base.

17. The system of claim **13**, wherein the bushing comprises a wearable substantially rigid material, the passage in the bushing is configured to have a diameter that approximates an outer diameter of the rotatable shaft to enable substantially free rotation of the rotatable shaft with respect to the bushing while the housing is secured to the base of the apparatus.

18. The system of claim **17**, wherein the substantially rigid material comprises a lubricant impregnated material to facilitate rotation of the rotatable shaft relative to the bushing.

19. The system of claim **13**, wherein an outer sidewall of the bushing has a shoulder spaced apart from a distal end of the bushing and abutting the retaining plate adjacent the opening of the retaining plate to prevent the bushing from passing entirely through the retaining plate while clamped between the retaining plate and the housing.

20. A method comprising:

providing a housing that includes an interior space, the housing comprising:

a bushing mounted within the housing, the bushing comprising a passage configured to receive a rotatable shaft that extends axially from a base of a rotary apparatus;

encoder electronics mounted within the interior space and spaced apart from the bushing; and

a flange extending outwardly from an end of the housing;

receiving the rotatable shaft in the passage of the bushing to position the encoder electronics within a predetermined distance with respect to an axis of the rotatable shaft to enable the encoder electronics to measure at least one of motion or position of the rotatable shaft; and

securing the flange of the housing to the base of the rotary apparatus.

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