



(51) International Patent Classification:

F16J 15/52 (2006.01) F16J 15/32 (2006.01)
F16J 15/50 (2006.01)

(21) International Application Number:

PCT/US2009/033749

(22) International Filing Date:

11 February 2009 (11.02.2009)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/028,275 13 February 2008 (13.02.2008) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: LIP SEAL REPLACEMENT SEAL DEVICE

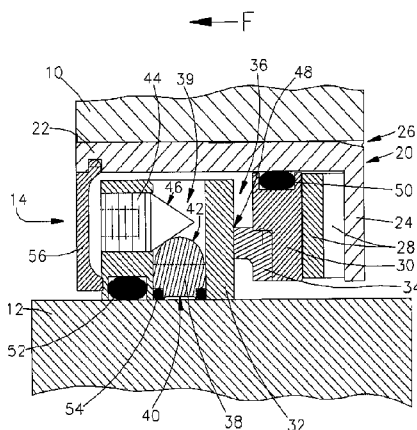


FIGURE 1

(57) Abstract: A face-type seal is adapted to be disposed between a stationary element and a rotatable element. The face-type seal arrangement includes an annular cassette adapted to be coupled to the stationary element and a carrier disposed within the cassette and adapted to be coupled to the rotatable element so as to rotate together therewith and relative to the cassette. The face-type seal further includes a drive face coupled to the carrier so as to rotate together therewith, and a seal element operatively coupled to the cassette and resiliency biased into sealing engagement with the drive face. In one example, the carrier is adapted to be coupled to the rotatable element by at least one lock-pin. In another example, one of the seal element and the drive face includes a material having a hardness generally equal to or greater than approximately 8.5 on the Moh's hardness scale.

LIP SEAL REPLACEMENT SEAL DEVICE

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/028,275, filed February 13, 2008, the entire disclosure of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to sealing systems for rotating machines and, more specifically, to an improved sealing assembly used therein.

BACKGROUND OF THE INVENTION

[0003] Sealing systems are often used in machine applications to provide a seal between a rotating shaft and a machine housing, wall or other stationary element of a machine. These machines generally include a stationary element (such as a housing) and a drive element (such as a shaft), and may further include a driven element (such as an impeller or the like) that is coupled directly or indirectly to the drive element.

[0004] Conventionally, a flexible lip seal is used to provide the seal between the rotating shaft and the stationary element of the machine. However, lip seals often fail and/or cause damage to the rotating shaft. Moreover, lip seals generally cannot maintain a seal in a pressurized environment. Accordingly, there is a need for an improved sealing system.

BRIEF SUMMARY OF THE INVENTION

[0005] The following presents a simplified summary of the invention in order to provide a basic understanding of some example aspects of the invention. This summary is not an extensive overview of the invention. Moreover, this summary is not intended to identify critical elements of the invention nor delineate the scope of the invention. The sole purpose of the summary is to present some concepts of the invention in simplified form as a prelude to the more detailed description that is presented later.

[0006] In accordance with one aspect of the present invention, a face-type seal is adapted to be disposed between a stationary element and a rotatable element. The face-type seal includes an annular cassette adapted to be coupled to the stationary element and a carrier disposed within the cassette and adapted to be coupled to the rotatable element so as to rotate together therewith and relative to the cassette. The face-type seal further includes a drive face coupled to the carrier so as to rotate therewith, and a seal element operatively coupled to the cassette and resiliently biased into sealing engagement with the drive face such that the drive face rotates against the seal element.

[0007] In accordance with another aspect of the present invention, a face-type seal is adapted to be disposed between a stationary element and a rotatable element. The face-type seal includes an annular cassette adapted to be coupled to the stationary element and a carrier disposed within the cassette and adapted to be coupled to the rotatable element by at least one lock-pin so as to rotate together therewith and relative to the cassette. The face-type seal further includes a drive face coupled to the carrier so as to rotate together therewith and a seal element operatively coupled to the cassette, wherein the seal element includes a material that is relatively softer than a material of the drive face. The face-type seal further includes a resilient element operatively coupled to the cassette and disposed between the drive face and the seal

element. The resilient element is adapted to resiliently bias the seal element into sealing engagement with the drive face.

[0008] In accordance with another aspect of the present invention, a face-type seal is adapted to be disposed between a stationary element and a rotatable element. The face-type seal includes an annular static seal element including a first material and operatively coupled to the stationary element, and an annular rotatable seal element including a second material and being adapted to rotate together with the rotatable element and relative to the static seal. One of the first and second materials has a hardness generally equal to or greater than approximately 8.5 on the Moh's hardness scale. The face-type seal further includes a resilient element disposed between the static seal element and the rotatable seal element. The resilient element is adapted to resiliently bias the static seal element into sealing engagement with the rotatable seal element while the rotatable seal element rotates relative to the static seal element.

[0009] It is to be understood that both the foregoing general description and the following detailed description present example and explanatory embodiments of the invention, and are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed. The accompanying drawings are included to provide a further understanding of the invention and are incorporated into and constitute a part of this specification. The drawings illustrate various example embodiments of the invention, and together with the description, serve to explain the principles and operations of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing and other aspects of the present invention will become apparent to those skilled in the art to which the present invention relates upon reading the following description with reference to the accompanying drawings, in which:

[0011] Figure 1 is a partial sectional view of an example lip seal replacement system in accordance with an aspect of the present invention;

[0012] Figure 2 is similar to Figure 1, but shows an additional example lip seal replacement system in accordance with another aspect of the present invention;

[0013] Figure 3 is similar to Figure 1, but shows an additional example lip seal replacement system utilizing a bellows in accordance with another aspect of the present invention.

[0014] Figure 4 is a sectional view of the example lip seal replacement system of Figure 1 assembled on an example drive shaft and bearing housing;

[0015] Figure 5 is similar to Figure 3, but shows a modified bellows in accordance with another aspect of the present invention;

[0016] Figure 6 is similar to Figure 3, but shows another modified bellows in accordance with yet another aspect of the present invention;

[0017] Figure 7 is similar to Figure 5, but shows an additional example lip seal replacement system utilizing a compressed elastomer in accordance with another aspect of the present invention; and

[0018] Figure 8 is similar to Figure 7, but shows a modified composite face configuration in accordance with yet another aspect of the present invention.

DESCRIPTION OF EXAMPLE EMBODIMENTS

[0019] Example embodiments that incorporate one or more aspects of the present invention are described and illustrated in the drawings. These illustrated examples are not intended to be a limitation on the present invention. For example, one or more aspects of the present invention can be utilized in other embodiments and even other types of devices. Moreover, certain terminology is used herein for convenience only and is not to be taken as a

limitation on the present invention. Still further, in the drawings, the same reference numerals are employed for designating the same elements.

[0020] The present application describes a face-type sealing device, referred to herein as a lip seal replacement (hereinafter “LSR”) seal, that is a face-type mechanical seal in which the sealing mechanism is generally self-contained, such as in a single shell or cassette. One purpose of this sealing mechanism is to replace conventional lip type rotary seals with a positive sealing device that can withstand pressures exceeding atmospheric pressure, such as by one or more times. In one example, the LSR seal can permit a positive pressure to be contained inside a machine, such as greater than about 5 to 8 psi, or even more, above atmospheric pressure. That is, the LSR seal can contain the pressure exerted from within a rotary machine that is the result of various operating conditions, such as heat build-up or an induced pressure atmosphere, etc. For example, the seal is designed to include pressure as well as exclude pressure. The design may also permit high-pressure wash-down by virtue of the dust / liquid shield inhibiting the high-pressure water from directly entering the cassette cavity.

[0021] Turning to the shown example of Figure 1, a rotating machine includes a stationary element 10 and a rotatable element, such as a drive shaft 12 or the like that is adapted to rotate relative to the stationary element 10. The lip seal replacement system (LSR) 14 is interposed between the stationary element 10 and the rotatable drive shaft 12 so as to provide a sealed connection therebetween. Turning briefly to Figure 4, the LSR 14 is illustrated assembled upon a drive shaft 12 of a rotatable machine, such as a gear reducer housing, though various other rotatable machines are also contemplated. Thus, the LSR 14 is configured to inhibit or prevent dirt, debris, liquids, etc. from entering the machine from an exterior side 16, while also inhibiting or preventing dirt, debris, liquids, lubrication, etc., including pressurized and/or unpressurized materials, from leaking out of the machine from an interior side 18. Moreover, the LSR 14 can be a positive sealing device that can withstand pressures exceeding atmospheric pressure by one or more times.

That is, the LSR 14 can be adapted to contain the pressure exerted from within a rotary machine that results from heat build-up or an induced pressure atmosphere. Further, the LSR 14 can also be adapted to exclude an exteriorly-applied pressure.

[0022] As shown, the LSR 14 is adapted to have a generally annular geometry so as to be coupled to and surround the drive shaft 12, though it is to be appreciated that the LSR 14 can also be coupled to only a portion of the drive shaft 12. Moreover, the LSR 14 can be configured to be self-contained within a cassette or similar structure, so as to be easily inserted or removed. Similarly, the LSR 14 can include an annular geometry that can extend at least partially, or completely, about a periphery of the drive shaft 12, and/or can be formed of a single element or even multiple elements that extend at least partially about a periphery of the drive shaft 12.

[0023] Turning now back to Figure 1, the LSR 14 will now be described in more detail. The LSR 14 can be self-contained within a cassette shell 20. Moreover, the cassette shell 20 can have a generally “L” shaped geometry including a top wall 22 that is in abutment with the stationary element 10, and a rear wall 24, though various other geometries are also contemplated. As shown, the low-profile design of the LSR 14 enables the cassette 20 to be approximately equal in length to the stationary element 10 so as to not extend a distance beyond the stationary element 10. Still, the LSR 14 can also be configured to extend to various distances. For example, as shown in Figure 6, the LSR 14''' can be configured to extend a distance out from the stationary machine element. Additionally, where the LSR 14 is adapted to completely surround the drive shaft 12, the cassette shell 20 can have a corresponding annular geometry. A portion of the cassette shell 20 can include a tapered structure 26, keyed structure, or the like for alignment of the cassette shell 20 relative to the stationary element 10 and/or drive shaft 12.

[0024] The engagement between a stationary or static seal element, such as a stationary composite face 34, and a rotatable seal element, such as a drive face 32, constitutes a primary sealing surface for the LSR 14. As

shown, the stationary composite face 34 can be interposed between a stationary carrier 30 and the drive face 32. Additionally, within the interior of the cassette housing 20, a resilient element 28 is provided in abutment with the rear wall 24 for providing a force F for biasing the stationary carrier 30 towards the drive face 32. Various resilient elements can be used, such as a stamped star spring, wave spring, individual coil spring, torsion spring, leaf spring, welded bellows, rolled or hydroformed bellows, etc. attached to or formed with the cassette housing 20. Thus the spring 28 acts to resiliently bias the stationary composite face 34 into engagement with the drive face 32. Moreover, either or both of the static and rotatable seal elements can include an annular geometry that can extend at least partially, or completely, about a periphery of an associated component. In addition or alternatively, either or both of the static and rotatable seal elements can be formed of a single element or even multiple elements.

[0025] Generally, the rotatable seal element is disposed at least partially within the cassette 20. As shown, the rotatable seal element can be disposed substantially entirely within the cassette 20. The drive face 32 is formed with or constitutes a portion of a drive face carrier 36 that is coupled to the drive shaft 12 so as to rotate therewith by at least one lock-pin 38, or even a plurality of lock-pins 38 that can each adapted to slide vertically within a shaft 39. In the shown example, three lock-pins 38 (only one is visible) are utilized and are spaced generally equidistant about the outer perimeter of the drive shaft 12. However, it is to be appreciated that various other numbers of lock-pins 38 can also be used and arranged variously about the drive shaft 12 so as to provide a desired amount of engagement. Moreover, the various lock-pins 38 can each be of varying length according to any or all of the relative sizes or diameters of the driveshaft 12, drive face carrier 36, cassette 20, stationary element 10, etc. In one example, the lock-pins 38 can be designed to perform as a combination dog-point and cup-point setscrew on the drive shaft side 12, and include a pin end 40 for direct or indirect contact with the outer peripheral surface of the drive shaft 12. Still, the lock-pins 38 can also have various other geometries, setscrew styles, etc.

[0026] The lock-pins 38 and associated structure can be configured to enable the rotatable seal element to be disposed at least partially, such as entirely, within the cassette 20. For example, as shown, the lock-pins 38 and associated structure can be disposed entirely within the cassette 20. The lock-pins 38 each also include a rounded end 42 that is contacted and driven downward (i.e., towards the drive shaft 12) by at least one fastener, such as a screw 44 or the like so as to drive the pin end 40 into engagement with the drive shaft 12. The setscrew can be arranged at an angle relative to a longitudinal axis of the lock-pin 38. In one example, the screw 44 can be arranged generally perpendicular to the lock-pin 38, though various other angles are also contemplated. For example, the rounded end 42 is engaged by a generally cone-shaped end 46 of the socket-head screw 44 (or the like) that is threadingly engaged with the drive face carrier 36. Thus, because of the compact nature of the perpendicular arrangement, the screw 44 can be retained entirely within the bounds of the cassette 20, thereby enabling the cassette 20 to be relatively more compact in size.

[0027] In one example, the included angle of the cone-shaped end 46 is approximately 60 degrees (i.e., providing a 30 degree taper), though various other angles are also contemplated for providing various performance levels at various force vectors. Moreover, the end 46 of the socket-head screw 44 can also have various other geometries. Thus, the cone-shaped end 46 of the screw 44 engages the rounded end 42 of the lock-pin 38 as the screw is tightened 44, thereby forcing the lock-pin 38 downwards and into direct or indirect engagement with the driveshaft 12. Upon engagement thereof, the drive face carrier 36 is secured to the driveshaft so as to rotate together therewith. Additionally, the drive face carrier 36, lock-pins 38, and/or the screws 44 can include structure to inhibit inadvertent loosening thereof.

[0028] During operation of the rotational machine, the drive face carrier 36 rotates with the drive shaft 12 and relative to the stationary cassette 20 such that the drive face 32 rotates relative to the stationary composite face 34. The engagement point 48 between the stationary composite face 34 and the

drive face 32 constitutes a primary sealing surface for the LSR 14. It is to be understood that the term "primary" is only used for convenience to indicate one relatively important seal. Depending on the instant force of friction between the bearing surfaces of the drive face 32 and the stationary composite face 34, as provided by the force F of the spring 28 acting against the clamping force of the lock-pins 38, a dynamic seal will be created at the engagement point 48.

[0029] The drive face 32 can be formed of various generally rigid materials. For example, the drive face 32 can be formed of various steels, carbon steels, and/or stainless steels, such as various 400-series stainless steels. For example, 413, 440C, 17-4PH, or 17-7PH stainless steels can be used, though other steels can also be used. Other materials may include silicon carbides, carbon, or other composite metals having relatively high graphite contents. Such other materials may be bonded or otherwise coupled to a metal carrier or the like to facilitate installation, and may be replaceable as they wear over time. Various material enhancements and/or various coatings, etc. can be performed upon or applied to the drive face 32 to provide a desired performance level. In one example, a "boronizing" treatment can be applied to the drive face 32, such as to increase the relative hardness thereof, reduce the coefficient of friction, and/or permit the face surface to be machined, face lapped, etc. The "boronizing" treatment can be applied in various manners, such as by way of various chemical vapor deposition (CVD) techniques to diffuse boron atoms into the surface of the drive face to form complex borides or the like with the base metal at various material depths. In one example, the "boronizing" treatment can alloy the surface of the drive face 32 to a hardness generally equal to or greater than approximately 8.5 on the Moh's hardness scale, such as approximately 9.35 on the Moh's hardness scale, though other hardness amounts are also contemplated. Various other treatments can also be applied. Moreover, various surface treatments, coatings, or the like can also be applied. For example, the surface can be lapped on either or both sides, such as to achieve 2-3 light bands of flatness or other desired finish. It is also to be appreciated that any or all of

the elements discussed herein can similarly have a "boronizing" treatment, other treatments, and/or other coatings, etc.

[0030] The stationary composite face 34 can also be formed of various materials that are generally softer than that of the drive face 32. In one example, the stationary composite face 34 can be formed of a relatively hard carbon having a relatively high graphite content. In other examples, the stationary composite face 34 can be formed of a glass-filled Teflon having a relatively high graphite content, or a relatively hard plastic, such as Polyetheretherketone (PEEK) or other polyketone, also having a relatively high graphite content. In other examples, the stationary composite face 34 can be formed of silicon carbides or composite metals having relatively high graphite contents.

[0031] Accordingly, relative rotation of the drive face 32 and the stationary composite face 34 can cause the graphite in either or both of the drive face 32 and the stationary composite face 34 to form a lubricating graphite film at the engagement point 48. For example, the stationary composite face 34 can include a material that is relatively softer than a material of the drive face 32. Still, either component can include a relatively softer or harder material, or both components can include materials having a generally equal hardness. In this way, a dynamic seal can be provided between the drive face 32 and the stationary composite face 34.

[0032] Additional seals can also be provided with the LSR 14. For example, as shown in FIGS. 1-2, a dynamic o-ring seal 50 can be provide on the stationary carrier 30 for engagement with an interior surface of the top wall 22 of the cassette 20. The dynamic o-ring seal 50 can permit sealing despite longitudinal movement of the stationary carrier 30 via the spring 28. In another example, the drive face carrier 36 can include a static o-ring 52 for engagement with the drive shaft 12. In yet another example, the lock-pins 38 can be adapted to accept a micro-o-ring 54 to inhibit or prevent leakage after the lock-pins 38 are secured. In addition or alternatively, a dust/liquid shield 56 can be provided and adapted to be coupled to the cassette 20, and disposed generally about the drive

face carrier 36 to inhibit contaminants from entering the cassette 20. In one example, the dust/liquid shield 56 can protect against dirt, debris, etc. from the exterior side 16. The dust/liquid shield 56 can be adapted to stay closed and inhibit or prevent liquid entry, even when high-pressure fluid or the like is directed toward the seal from an external source, such as during a high pressure machine wash-down procedure, and to inhibit or prevent dust and/or moisture from entering the cassette 20 during static or operational conditions. Moreover, the dust/liquid shield 56 can also have a portion that sealingly engages the drive face carrier 36 to act as a face-type excluder or the like. It is to be appreciated that the dust/liquid shield 56 can be adapted to inhibit various contaminants from entering the interior of the cassette 20, including various solids, liquids, and/or gasses.

[0033] Assembly of the LSR 14 within an example rotating machine will now be discussed. Prior to installation with the intended machinery, the LSR 14 can be fully assembled as described herein, but can further include a retainer ring 80 (see Figure 6) instead of the dust/liquid shield 56. The retainer ring is used to restrain movement of the drive face carrier 36 against the force of the spring 28. The retainer ring 80 can be coupled to the cassette 20 in the same way as the dust/liquid shield 56 (e.g., by way of the same mounting groove or the like), though other methods can also be used. Next, the cassette 20 is installed into the machinery and onto the drive shaft. In one example, the cassette 20 can be force-fitted or the like into an equipment housing of the machinery. Next, each of the socket-head screws 44 are tightened to engage the lock-pins 38 with the drive shaft 12. The retainer ring 80 can include holes, grooves, or the like to provide access to the screws 44. Once the lock-pins 38 are engaged with the drive shaft 12 so as to secure the drive face carrier 36 against the force of the spring 28, the retainer ring 80 is removed, and either re-used or discarded. Finally, the dust/liquid shield 56 is removably or non-removably coupled to the cassette 20, and the LSR 14 is ready to be used. For example, the dust / liquid shield 56 is pushed into the retaining ring groove which locks it in place and

provides a light contact seal with the outer portion of the drive mechanism, such as a face-type excluder or the like.

[0034] Various other example embodiments are illustrated in the various Figures. It is to be appreciated that, for brevity, similar or identical elements are referenced by use of a single or multiple prime (e.g., “ ’ ”) designation, and that the various lip seal arrangement examples can include more or less elements than those previously described herein. Single or multiple prime designations can be used.

[0035] Turning now to the example of Figure 2, which is similar to that of Figure 1, except that the static o-ring 52' has been incorporated into the drive face 32' on the opposite side of the lock-pins 38. Thus, the micro-o-rings 54 can be removed from the lock-pins 38 so as to eliminate a potential leak path, or can alternatively be kept to provide a double-seal.

[0036] Turning now to the example of Figure 3, which is also similar to that of Figure 1, except that the resilient element 28, stationary carrier 30, and dynamic o-ring 48 have been replaced by a resilient bellows 62. The movement of a dynamic o-ring (i.e., o-ring 48) may cause damage to the surface that it seals against, such as by repetitively abrading the sealing surface, which may cause sealing degradation and/or failure. Thus, as shown in FIGS. 3, 5 and 6, the number of dynamic o-rings can be reduced, such as eliminated. For example, only one or more static o-rings (i.e., 52 and/or 54) can be utilized to reduce, such as eliminate, the potential for dynamic o-ring failure.

[0037] The bellows 62, as the term is used herein, is a resilient tube which behaves like a compression spring. Corrugations or ribs 66 are provided to the bellows 62 to provide a longitudinal biasing force similar to that of the spring 28 of Figures 1 and 2. The bellows 62 can be formed of thin wall metal or plastic tubing, which can be seamless or welded. The corrugations 66 are formed in the tubing by a known hydraulic or rolling process. For example, the bellows can be a rolled, such as a hydro-formed, bellow(s). Alternatively, the bellows 62 can be formed by injection molding, by the lamination of a tube to a coil spring, or by various other suitable processes.

[0038] As shown, the bellows 62 can be removably or non-removably coupled 64 to the top wall 22'' of the cassette 20'' in various manners, including bonding, welding, brazing, adhesives, mechanical fasteners, etc. The bellows 62 can similarly be coupled to the stationary composite face 34''. Thus, the resilient biasing force F biases the stationary composite face 34'' against the drive face 32'' to provide the dynamic seal as discussed previously herein. Moreover, the connection 64 between the bellows 62 and the cassette 20'' can provide an additional seal for the LSR 14''. Furthermore, any or all of the connections with the bellows 62 can include gaskets, such as elastomeric rings or the like, and/or sealants, such as epoxy, silicone, etc.

[0039] Turning now to the example of Figure 5, which is also similar to that of Figure 3, except that the bellows 62 is replaced by an edge-welded bellows 68. The edge-welded bellows 68 can be similarly removably or non-removably coupled to either of the top or rear walls 22''', 24''' the cassette 20''' and/or stationary composite face 34''' by bonding, welding, brazing, adhesives, mechanical fasteners, etc. The edge-welded bellows 68 can also provide a similar biasing force F , and/or can also provide an additional seal.

[0040] Turning now to the example of Figure 6, which is also similar to that of Figure 3, except that the bellows 62 is replaced by a three-element, carbon to carbon face system (CCFS) 69. The CCFS 69 includes a bellows 70 similar to that described herein, though connected at each end to a separate stationary composite face 34''', 72. The first stationary composite face 34''' is in engagement with the first drive face 32''', as described herein. However, the second stationary composite face 72 (i.e., a second seal element) is in engagement with a second drive face 74 that is coupled to the cassette 20''' near the rear wall 24'''. Thus, the bellows 70 exerts the biasing force in opposite directions (i.e., force F and force F_2) to simultaneously engage the first and second stationary composite faces 34''', 72 with the drive faces 32''', 74 to provide two separate, dynamic seals. Additional structure (not shown) can be provided to retain, locate, and/or inhibit unwanted movement of the bellows 70.

[0041] Turning now to the example of Figure 7, which is similar to that of Figure 5, except that the resilient element 68 is replaced by a compressed elastomer 82. It is to be appreciated that, for brevity, similar or identical elements are referenced by use of a one hundred series (e.g., 110) designation, and that the lip seal arrangement 114 can include more or less elements than those previously described herein. The compressed elastomer 182 is a resilient element which behaves like a compression spring to provide a longitudinal biasing force similar to that of the spring 28 of Figures 1 and 2. However, because of the inherent properties of elastomers, the compressed elastomer 182 can act as both a resilient element and a seal, thereby eliminating an O-ring (e.g., such as the dynamic O-ring 50 of Figure 1).

[0042] The compressed elastomer 182 can include various elastomers, including both natural and synthetic, such as silicon rubber, nitrile rubbers, etc. The compressed elastomer 182 can be molded, extruded, or otherwise formed, and/or can be die-cut to a specific shape and/or size. Still, various other manufacturing processes can be used to obtain the appropriate end result. Moreover, the compressed elastomer 182 can be cut, formed, etc. to accommodate various addition seals or gaskets, such as elastomeric rings or the like, and/or sealants, such as epoxy, silicone, etc. In addition or alternatively, the compressed elastomer 182 can include structure to inhibit rotation relative to the equipment housing 110. In one example, the compressed elastomer 182 can include dimples 184 on the non-sealing face for engagement with the rear wall 124, which may or may not also include corresponding dimples. Thus, as shown, the compressed elastomer 182 provides a resilient biasing force against the stationary carrier 130 that biases the stationary composite face 134 against the drive face 132 to provide the dynamic seal as discussed previously herein.

[0043] Turning now to the example of Figure 8, which is similar to that of Figure 7, except that the previously separate stationary carrier 130 and stationary composite face 132 have been combined into a one-piece composite configuration 186. That is, the one-piece composite configuration 186 can be formed entirely from a relatively hard carbon having a relatively high graphite

content or the like. It is to be appreciated that the one-piece composite configuration 186 can be formed from a single, monolithic piece of hard carbon, or alternatively, can be an assembly of two or more hard carbon elements fastened together. As before, the compressed elastomer 182' can act as both a resilient element and a seal, thereby eliminating an O-ring or the like. Additionally, it is to be appreciated that the compressed elastomer 182 and/or the one-piece composite configuration 186 of Figures 7 and 8 can be used in any of the previously described LSR's 14.

[0044] It is to be appreciated that because the LSR 14 is adapted to be used with rotating machinery, and because many of the elements include wear surfaces, any or all of the aforescribed elements can be removed and replaced.

[0045] The invention has been described with reference to the example embodiments described above. Modifications and alterations will occur to others upon a reading and understanding of this specification. Examples embodiments incorporating one or more aspects of the invention are intended to include all such modifications and alterations insofar as they come within the scope of the appended claims.

What is claimed is:

1. A face-type seal adapted to be disposed between a stationary element and a rotatable element, including:
 - an annular cassette adapted to be coupled to the stationary element;
 - a carrier disposed within the cassette and adapted to be coupled to the rotatable element so as to rotate together therewith and relative to the cassette;
 - a drive face coupled to the carrier so as to rotate together therewith; and
 - a seal element operatively coupled to the cassette and resiliently biased into sealing engagement with the drive face such that the drive face rotates against the seal element.
2. The face-type seal of claim 1, wherein the seal element includes a material that is relatively softer than a material of the drive face.
3. The face-type seal of claim 2, wherein the material of the seal element at least partially includes graphite.
4. The face-type seal of claim 1, wherein the seal element is operatively coupled to the cassette via a stationary carrier that further includes a dynamic seal.
5. The face-type seal of claim 1, wherein the seal element is resiliently biased into sealing engagement with the drive face by a spring.
6. The face-type seal of claim 1, wherein the seal element is resiliently biased into sealing engagement with the drive face by a resilient bellows.
7. The face-type seal of claim 1, wherein the seal element is resiliently biased into sealing engagement with the drive face by a compressed elastomer.

8. The face-type seal of claim 1, wherein the carrier further includes a static seal.
9. The face-type seal of claim 1, wherein the carrier is coupled to the rotatable element by at least one lock-pin.
10. The face-type seal of claim 9, wherein the at least one lock-pin is driven into engagement with the rotatable element by a setscrew arranged at an angle relative to a longitudinal axis of the lock-pin.
11. The face-type seal of claim 1, further including a dust/liquid shield adapted to be coupled to the cassette and disposed generally about the carrier to inhibit contaminants from entering the cassette.
12. The face-type seal of claim 1, further including a retainer coupled to the cassette adapted to inhibit movement of the seal element relative to the drive face.
13. The face-type seal of claim 1, further including a second drive face coupled to the cassette and a second seal element resiliently biased into sealing engagement with the second drive face.
14. A face-type seal adapted to be disposed between a stationary element and a rotatable element, including:
 - an annular cassette adapted to be coupled to the stationary element;
 - a carrier disposed within the cassette and adapted to be coupled to the rotatable element by at least one lock-pin so as to rotate together therewith and relative to the cassette;
 - a drive face coupled to the carrier so as to rotate together therewith;

a seal element operatively coupled to the cassette, wherein the seal element includes a material that is relatively softer than a material of the drive face; and

a resilient element operatively coupled to the cassette and disposed between the drive face and the seal element, the resilient element adapted to resiliently bias the seal element into sealing engagement with the drive face.

15. The face-type seal of claim 14, wherein the at least one lock-pin is driven into engagement with the rotatable element by a setscrew arranged at an angle relative to a longitudinal axis of the lock-pin.

16. The face-type seal of claim 14, wherein the resilient element includes a bellows.

17. The face-type seal of claim 16, further including a second drive face coupled to the cassette and a second seal element, the bellows being adapted to resiliently bias the second seal element into sealing engagement with the second drive face.

18. A face-type seal adapted to be disposed between a stationary element and a rotatable element, including:

an annular static seal element including a first material and operatively coupled to the stationary element;

an annular rotatable seal element including a second material and being adapted to rotate together with the rotatable element and relative to the static seal, wherein one of the first and second materials has a hardness generally equal to or greater than approximately 8.5 on the Moh's hardness scale; and

a resilient element disposed between the static seal element and the rotatable seal element, the resilient element adapted to resiliently bias the static seal element into sealing engagement with the rotatable seal element while the rotatable seal element rotates relative to the static seal element.

19. The face-type seal of claim 18, further including a cassette operatively coupled to the stationary element and the static seal, and a carrier coupled to the rotatable element and the rotatable seal, the carrier being adapted to rotate relative to the cassette such that the rotatable seal rotates relative to the static seal.

20. The face-type seal of claim 19, wherein the carrier is coupled to the rotatable element by at least one lock-pin, and wherein the at least one lock-pin is driven into engagement with the rotatable element by a fastener arranged at an angle relative to a longitudinal axis of the lock-pin.

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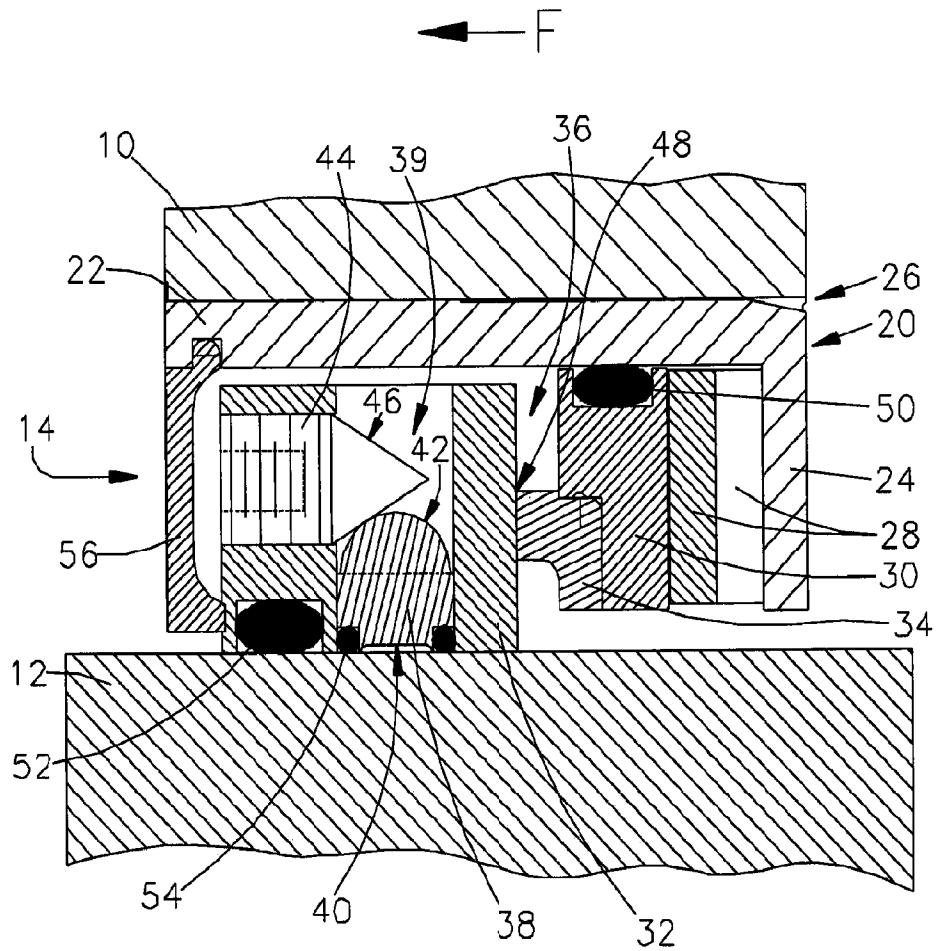


FIGURE 1

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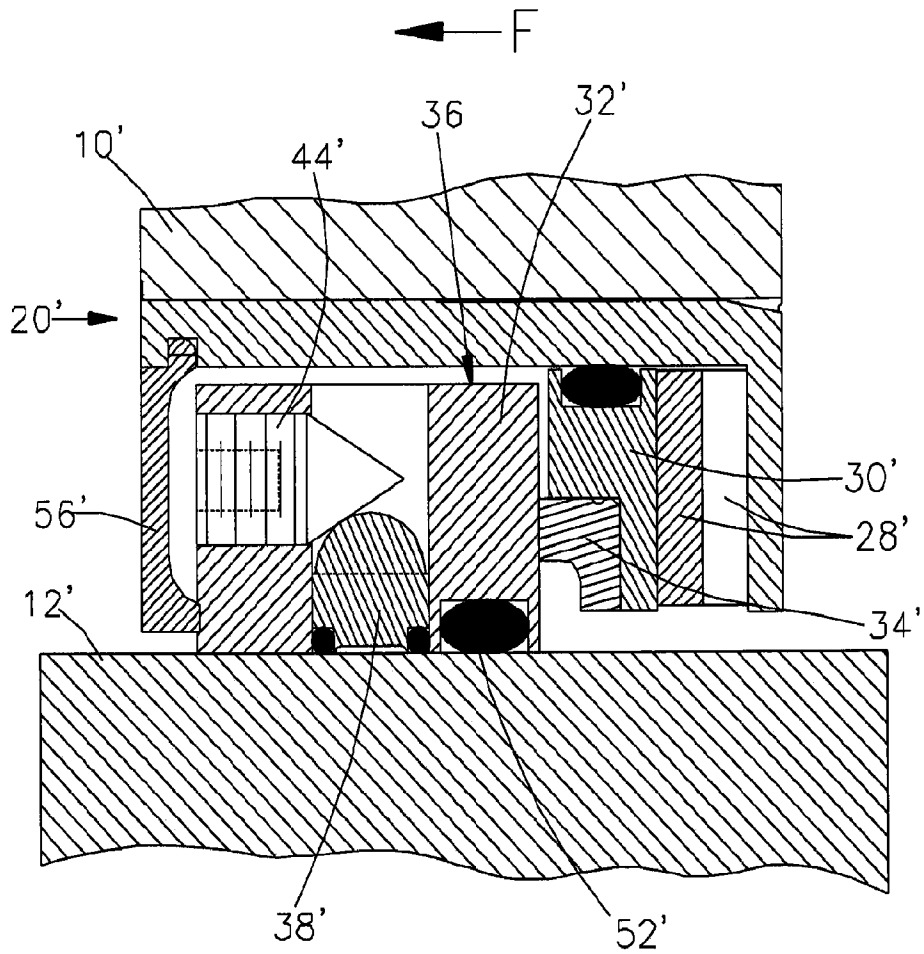


FIGURE 2

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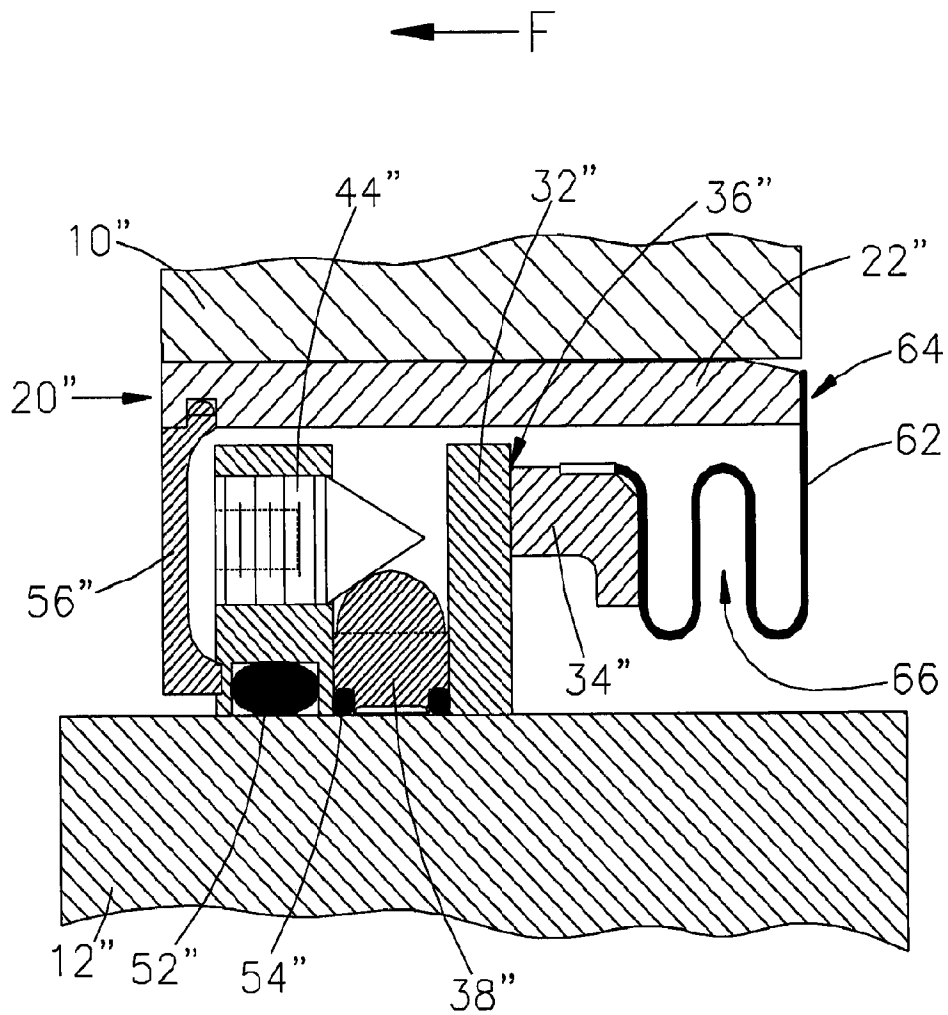


FIGURE 3

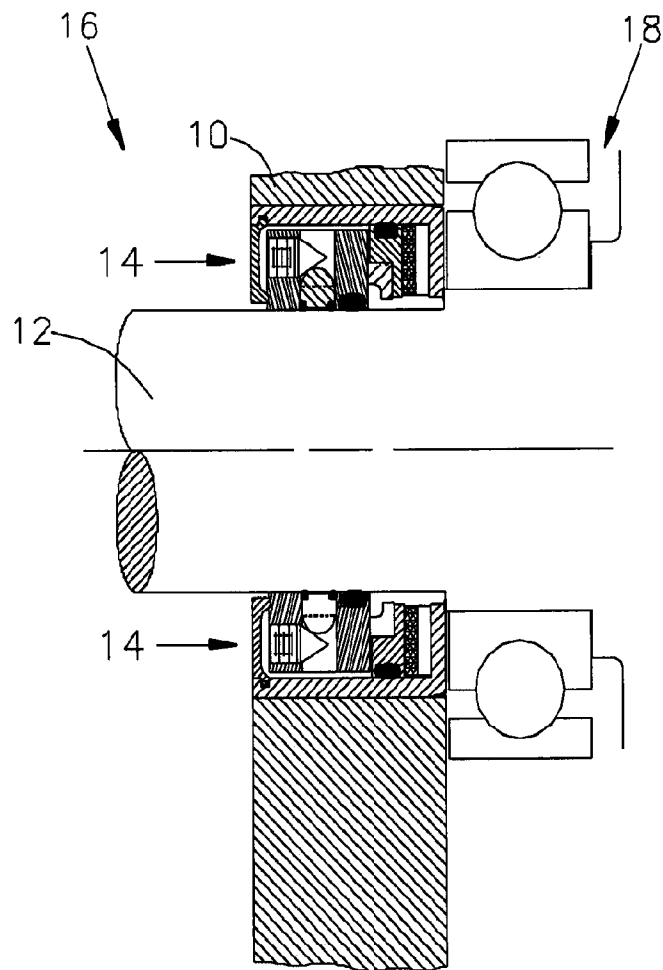


FIGURE 4

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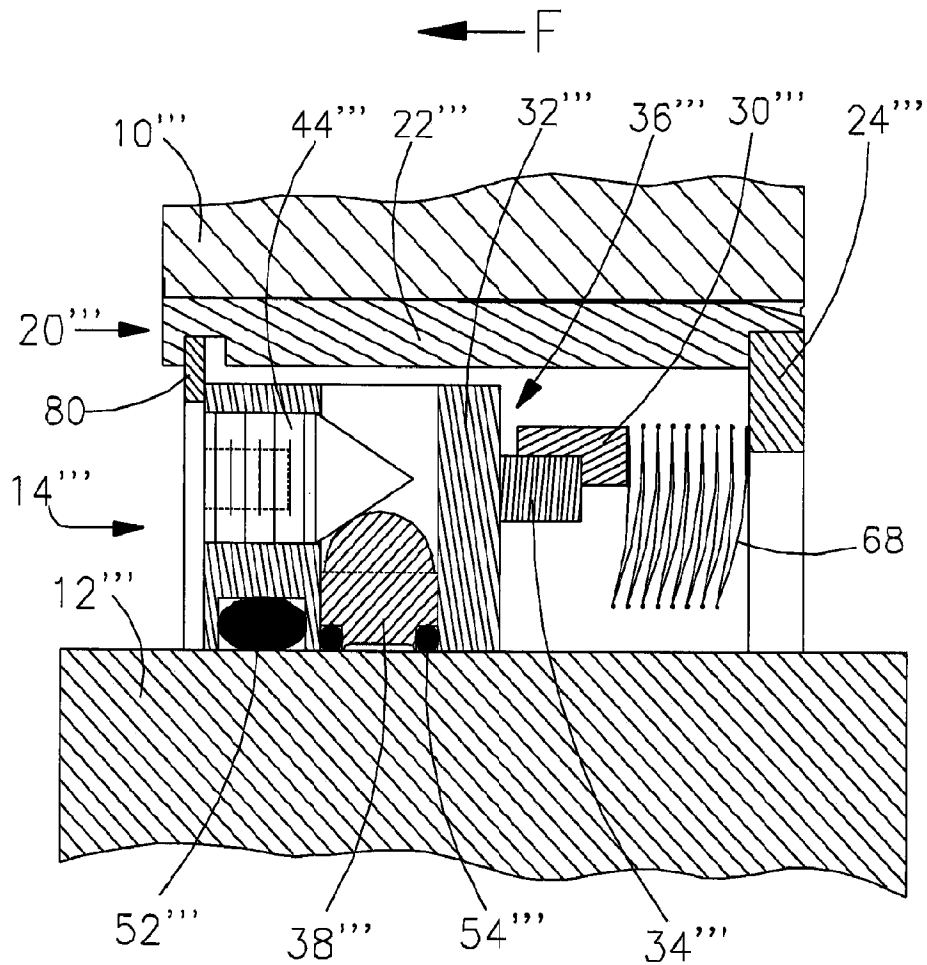


FIGURE 5

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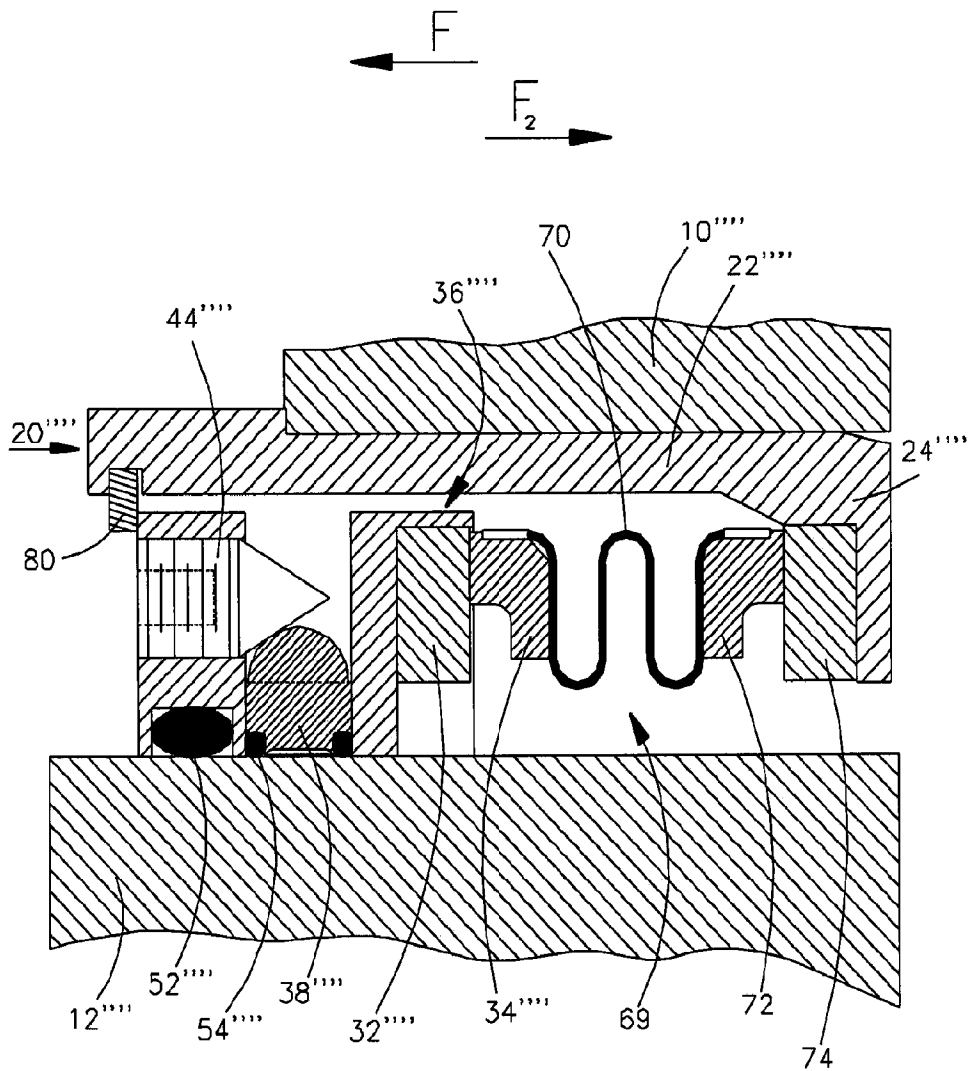


FIGURE 6

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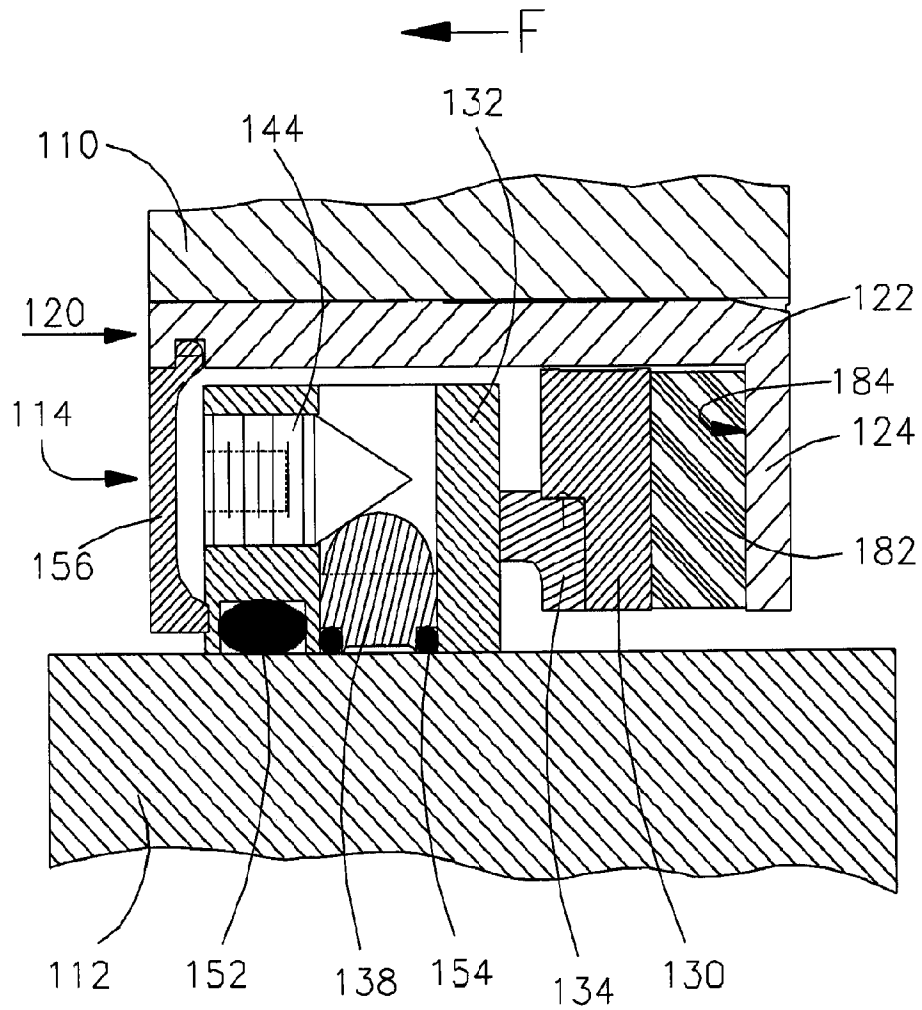


FIGURE 7

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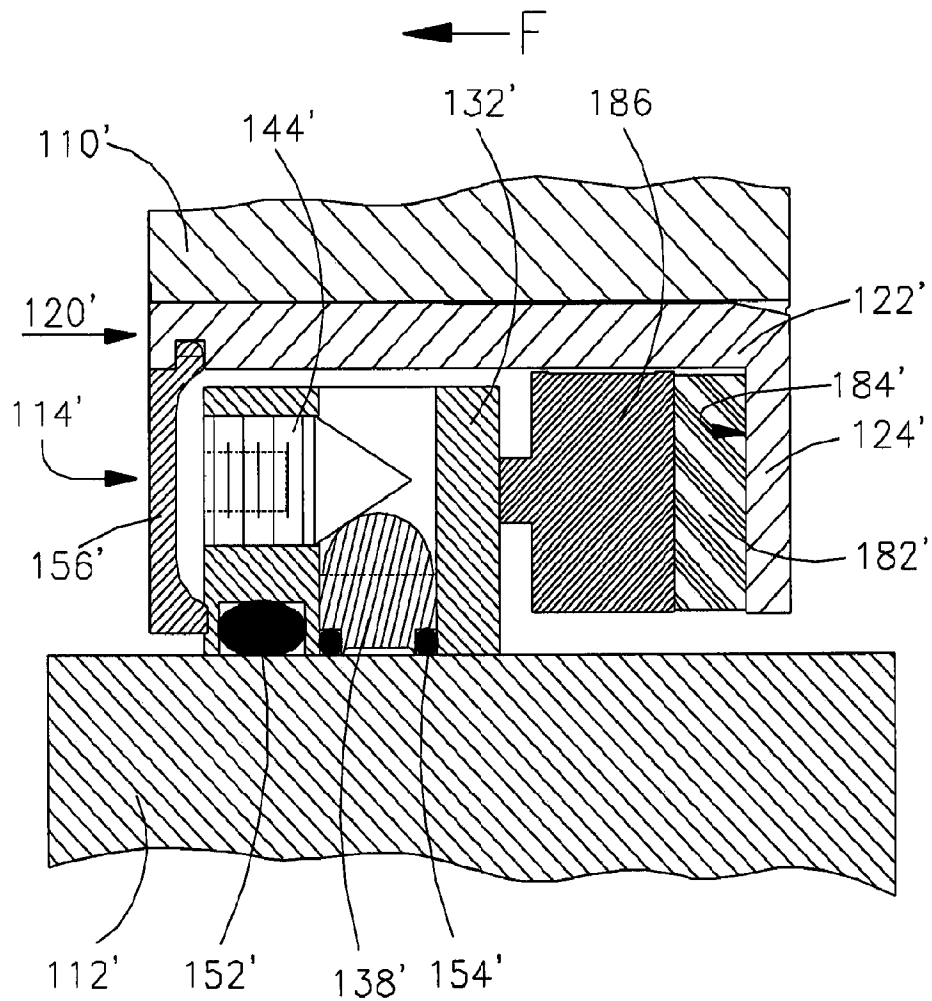


FIGURE 8