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(54) Title: SEALED ROTATING SYSTEM FOR MANAGED PRESSURE DRILLING

(57) Abstract: A system includes a rotating control device housing including at least one passive sealing element, and a double cavity active housing disposed above the rotating control device housing. The double cavity active housing is configured to be activated by an external power source.

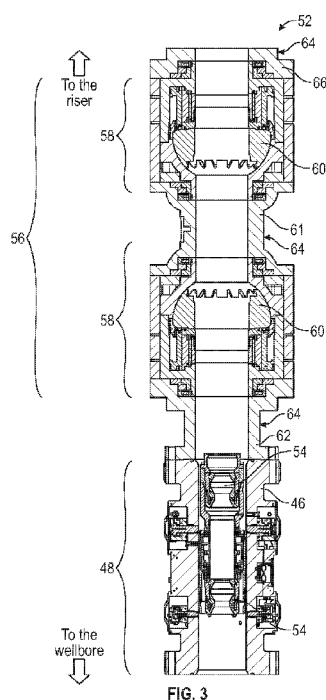


FIG. 3

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PATENT APPLICATION

SEALED ROTATING SYSTEM FOR MANAGED PRESSURE DRILLING**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] This application claims priority to Indian Provisional Patent Application No. 202221004543, which was filed on January 27, 2022 and is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Drilling systems are often employed to access natural resources below the surface of the earth. Such drilling systems may include a drilling fluid system configured to circulate drilling fluid into and out of a wellbore to facilitate drilling the wellbore. For example, the drilling fluid system may provide a flow of the drilling fluid through a drill string as the drill string rotates a drill bit that is positioned at a distal end portion of the drill string. The drilling fluid may exit through one or more openings at the distal end portion of the drill string and may return toward a platform of the drilling system via an annular space between the drill string and a casing that lines the wellbore, *i.e.*, a wellbore annulus. In some cases, the drilling system may use managed pressure drilling (“MPD”).

[0003] Specifically, MPD uses well pressure control systems that control return flow of drilling fluid in the wellbore annulus to maintain a selected pressure or pressure profile in the wellbore. MPD may require the well to be “capped” with a rotating control device (“RCD”). An RCD is a pressure control device used during drilling for the purpose of making a seal around the drill string while the drill string rotates. Typically, within an RCD there is a bearing assembly or sealing assembly, which contains between two and five sealing elements that seal around the drill string during operations and divert flow to a series of pressure manifolds with the aim of controlling the wellbore pressure.

[0004] These bearing or sealing assemblies must be changed out periodically depending on a number of variables. A seabed based system further complicates operations insofar as dedicated runs are needed to set and retrieve each bearing or sealing assembly, ultimately leading to lost service time. Accordingly, there is a need for new sealing assemblies for MPD operations to shift away from these dedicated runs, thereby reducing the impact of lost service time and other disadvantages associated with the state of the art.

SUMMARY

[0005] A system according to one or more embodiments of the present disclosure includes a rotating control device housing including at least one passive sealing element, and a double cavity active housing disposed above the rotating control device housing. According to one or more embodiments of the present disclosure, the double cavity active housing is configured to be activated by an external power source.

[0006] A system according to one or more embodiments of the present disclosure includes a rotating control device assembly including a first assembly; and at least one sensor that monitors wear of the first assembly, wherein the first assembly includes a latching profile. The system according to one or more embodiments of the present disclosure also includes a second assembly including a corresponding latching profile, the second assembly configured to be dropped from an above location to enable the corresponding latching profile to mate with the latching profile of the first assembly.

[0007] A method according to one or more embodiments of the present disclosure includes performing a drilling operation using a system including: a hybrid sealing assembly connected to a rotating control device assembly, wherein the hybrid sealing assembly includes an active sealing assembly stacked on top of a passive sealing assembly, monitoring wear of the passive sealing assembly of the hybrid sealing assembly, detecting an imminent failure of the passive sealing assembly, activating the active sealing assembly of the hybrid sealing assembly, and continuing the drilling operation.

[0008] A system according to one or more embodiments of the present disclosure includes a rotating control device assembly including at least one passive sealing element; and at least one wear sensor, a riser, a first assembly housing, and a second assembly housing, wherein the first and second assembly housings are stacked between the rotating control device assembly

and the riser, and wherein at least one of the first and second assembly housings includes an active sealing assembly housing.

[0009] A drilling system according to one or more embodiments of the present disclosure includes a rotating control device assembly, including: a rotating control device housing including a bore, and a seal element including an elastomeric material, positioned within the rotating control device housing and configured to seal the bore, the seal element further including an insert surrounding the elastomeric material, and a bearing assembly supported within the rotating control device housing and configured to enable the seal element to rotate relative to the rotating control device housing, and a wireless seal monitoring system including: at least one sensor embedded within or disposed on the seal element, and a control system that communicates with the at least one sensor, wherein the control system is configured to determine a presence of wear in the seal element based on information provided by the at least one sensor.

[0010] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0012] FIG. 1 shows a schematic diagram of a drilling system according to one or more embodiments of the present disclosure;

[0013] FIGS. 2A-2D show stackable sealing assemblies, which may be used in the drilling system of FIG. 1, according to one or more embodiments of the present disclosure;

[0014] FIG. 3 shows an active hybrid sealing assembly, which may be used in the drilling system of FIG. 1, according to one or more embodiments of the present disclosure;

[0015] FIG. 4 shows a zoomed in view of a double cavity active housing of the active hybrid sealing assembly shown in FIG. 3 according to one or more embodiments of the present disclosure;

[0016] FIG. 5A shows a zoomed in view of an RCD assembly of the active hybrid sealing assembly shown in FIG. 3 according to one or more embodiments of the present disclosure;

[0017] FIG. 5B shows a bearing assembly of the RCD assembly shown in FIG. 5A, according to one or more embodiments of the present disclosure;

[0018] FIG. 5C shows an RCD housing of the RCD assembly shown in FIG. 5A, according to one or more embodiments of the present disclosure;

[0019] FIGS. 6A and 6B show a cross-section of a passive sealing element according to one or more embodiments of the present disclosure;

[0020] FIGS. 7A and 7B show a cross-section of a passive sealing element having a different geometry according to one or more embodiments of the present disclosure;

[0021] FIGS. 8A and 8B show a cross-section of a passive sealing element having a different geometry according to one or more embodiments of the present disclosure;

[0022] FIGS. 9A – 9C show a cross-section of a passive sealing element having a different geometry according to one or more embodiments of the present disclosure; and

[0023] FIG. 10 shows an approximate positioning of sensors on or within a seal element, according to one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0024] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0025] In the specification and appended claims, the terms “connect,” “connection,” “connected,” “in connection with,” and “connecting,” are used to mean “in direct connection with,” in connection with via one or more elements.” The terms “couple,” “coupled,” “coupled with,” “coupled together,” and “coupling” are used to mean “directly coupled together,” or “coupled together via one or more elements.” The term “set” is used to mean setting “one element” or “more than one element.” As used herein, the terms “up” and “down,” “upper” and “lower,” “upwardly” and “downwardly,” “upstream” and “downstream,” “uphole” and “downhole,” “above” and “below,” “top” and “bottom,” and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly describe some embodiments of the disclosure. Commonly, these terms relate to a reference point at the surface from which drilling operations are initiated as being the top point and the total depth being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal, or slanted relative to the surface.

[0026] In general, embodiments of the present disclosure relate to MPD operations. More specifically, embodiments of the present disclosure relate to sealing assemblies for MPD operations.

[0027] The drilling system according to one or more embodiments of the present disclosure may use MPD, which regulates a pressure and a flow of the drilling fluid within the drill string so that the flow of the drilling fluid does not over-pressurize a well (*e.g.*, expand the well) and/or blocks the well from collapsing under its own weight. The ability to manage the pressure and the flow of the drilling fluid enables use of the drilling system to drill in various locations, such as locations with relatively softer seabeds.

[0028] The drilling system according to one or more embodiments of the present disclosure may include an RCD system. The RCD system may include a housing that defines a bore, and the drill string may extend through the bore during drilling operations. The RCD system may also include a seal element positioned within the housing, and the seal element may be configured to seal against the drill string to thereby block the drilling fluid, cuttings, and/or natural resources (*e.g.*, carbon dioxide, hydrogen sulfide) from passing across the seal element of the RCD system from the well toward the platform. Advantageously, the seal element may also be configured to seal against itself while the drill string is absent from the bore. In some embodiments, the fluid flow may be diverted toward another suitable location (*e.g.*, a collection tank) other than the platform.

[0029] As discussed in more detail below, the RCD system may include a bearing assembly (*e.g.*, annular bearing assembly) that is configured to enable the seal element to rotate relative to the housing, such as with the drill string when the seal element is sealed against the drill string. The RCD system may include a piston assembly (*e.g.*, annular piston assembly) that is configured to drive the seal element to seal against the drill string and/or itself to seal the bore.

[0030] FIG. 1 is a schematic diagram that illustrates an embodiment of a drilling system 10 that is configured to carry out drilling operations. The drilling system 10 may be a subsea system, although the disclosed embodiments may be used in a land-based (*e.g.*, surface) system. The drilling system 10 may use MPD techniques. As illustrated, the drilling system 10 includes a wellhead assembly 12 coupled to a mineral deposit 14 via a well 16 having a wellbore 18.

[0031] The wellhead assembly 12 may include or be coupled to multiple components that control and regulate activities and conditions associated with the well 16. For example, the wellhead assembly 12 generally includes or is coupled to pipes, bodies, valves, and seals that enable drilling of the well 16, route produced minerals from the mineral deposit 14, provide for regulating pressure in the well 16, and provide for the injection of drilling fluids into the wellbore 18. A conductor 22 may provide structure for the wellbore 18 and may block collapse of the sides of the well 16 into the wellbore 18. A casing 24 may be disposed within the conductor 22. The casing 24 may provide structure for the wellbore 18 and may facilitate control of fluid and pressure during drilling of the well 16. The wellhead assembly 12 may include a tubing spool, a casing spool, and a hanger (e.g., a tubing hanger or a casing hanger) to enable installation of the casing 24. As shown, the wellhead assembly 12 may include or may be coupled to a blowout preventer (BOP) assembly 26, which may include one or more ram BOPs. For example, the BOP assembly 26 shown in FIG. 1 includes a ram BOP having moveable rams 28 configured to seal the wellbore 18.

[0032] A drilling riser 30 may extend between the BOP assembly 26 and a platform 32. The platform 32 may include various components that facilitate operation of the drilling system 10, such as pumps, tanks, and power equipment. The platform 32 may also include a derrick 34 that supports a tubular 36 (e.g., drill string), which may extend through the drilling riser 30. A drilling fluid system 38 may direct the drilling fluid into the tubular 36, and the drilling fluid may exit through one or more openings at a distal end portion 40 of the tubular 36 and may return (along with cuttings and/or other substances from the well 16) toward the platform 32 via an annular space (e.g., between the tubular 36 and the casing 24 that lines the wellbore 18; between the tubular 36 and the drilling riser 30). A drill bit 42 may be positioned at the distal end portion 40 of the tubular 36. The tubular 36 may rotate within the drilling riser 30 to rotate the drill bit 42, thereby enabling the drill bit 42 to drill and form the well 16.

[0033] As shown, the drilling system 10 may include an RCD system 44 that is configured to form a seal across and/or to block fluid flow through the annular space that surrounds the tubular 36. For example, the RCD system 44 may be configured to block the drilling fluid, cuttings, and/or other substances from the well 16 from passing across a seal element of the RCD system 44 toward the platform 32. The RCD system 44 may be positioned at any suitable location within the drilling system 10, such as any suitable location between the wellbore 18

and the platform 32. For example, as shown, the RCD system 44 may be positioned between the BOP assembly 26 and the platform 32.

[0034] In operation, the tubular 36 may be rotated and/or moved along an axial axis 2 to enable the drill bit 42 to drill the well 16. As discussed in more detail below, the RCD system 44 may be controlled to provide a seal against the tubular 36 even as the tubular 36 is rotated and/or to seal against itself while the tubular 36 is absent. The drilling system 10 and its components may be described with reference to the axial axis 2 (or axial direction), a radial axis 4 (or radial direction), and a circumferential axis 6 (or direction) to facilitate discussion.

[0035] Referring now to FIGS. 2A-2D, stackable sealing assemblies according to one or more embodiments of the present disclosure, which may be used in the drilling system of FIG. 1, are shown. Referring specifically to FIG. 2A, the RCD system 44 of FIG. 1 may include one or more RCD housings 46 disposed in an RCD assembly 48. According to one or more embodiments of the present disclosure, the RCD assembly 48 may be tall enough to accommodate multiple RCD housings 46 or a single RCD housing 46 containing multiple sets of pistons (not shown). The RCD assembly 48 may be coupled within a riser 30 as shown in FIG. 2A, for example. As also shown in FIG. 2A, the RCD housing 46 may include a first passive assembly 50a having at least one passive sealing element, according to one or more embodiments of the present disclosure. For example, the RCD housing 46 according to one or more embodiments of the present disclosure may include a bearing assembly or a sealing assembly containing a plurality passive sealing elements, which seal around the drill pipe during operations and divert flow to a series of pressure manifolds with the aim of controlling the wellbore pressure. According to one or more embodiments of the present disclosure, the at least one passive sealing element of the first passive assembly 50a uses an interference fit and wellbore pressures to be forced against the drill pipe, thereby forming a seal. In one or more embodiments of the present disclosure, a sensor (not shown) may be disposed on or within the at least one passive sealing element of the first passive assembly 50a to monitor the wear of the at least one passive sealing element. When failure of the at least one passive sealing element of the first passive assembly 50a is imminent, as detected by the sensor, a second passive assembly 50b may be dropped from an above location into the RCD assembly 48 to mate with the first passive assembly 50a, as shown in FIG. 2A, for example. According to one or more embodiments of the present disclosure, the second passive assembly 50b may be

dropped on top of the spent first passive assembly 50a with the use of drill pipe or drill ahead type tools. For example, at least FIGS. 6A, 8A, and 9A show passive sealing elements 54 having a profiled elastomer 76 for both tool joint and drill pipe diameters. The second passive assembly 50b, *i.e.*, stackable bearing assembly or seal, would be landed into the RCD assembly 48 by either using additional sets of pistons within the RCD assembly 48 or locking either the bearing assembly or seal of the second passive assembly 50b on to the previously deployed bearing assembly or seal latching profile of the first passive assembly 50a by a collet or another type of locking device. That is, the second passive assembly 50b may mate with the first passive assembly 50a via corresponding latching profiles, for example, according to one or more embodiments of the present disclosure. As shown in FIG. 2A, subsequent passive assemblies 50c, 50d may be dropped into the RCD assembly 48 to mate with previously spent passive assemblies to extend the life of a drilling operation well beyond what was previously possible, according to one or more embodiments of the present disclosure.

[0036] Referring now to FIG. 2B, the RCD system 44 of FIG. 1 may include a hybrid sealing assembly 52a disposed in an RCD assembly 48, and the RCD assembly 48 may be coupled within a riser 30 that is tall enough to accommodate multiple stackable hybrid sealing assemblies 52b, 52c. As also shown in FIG. 2B, the hybrid sealing assembly 52a within the RCD assembly 48 may include an active sealing assembly 51a stacked on top of a passive sealing assembly 50a containing at least one passive sealing element according to one or more embodiments of the present disclosure. In one or more embodiments of the present disclosure, a sensor (not shown) may be disposed on or within the at least one passive sealing element of the passive sealing assembly 50a to monitor the wear of the at least one passive sealing element. When failure of the at least one passive sealing element of the passive sealing assembly 50a is imminent, as detected by the sensor, the active sealing assembly 51a of the hybrid sealing assembly 52a may be activated in order to re-seal the wellbore. According to one or more embodiments of the present disclosure, the active sealing assembly 51a may include an active sealing element that uses an external power source, such as electrical, mechanical, or hydraulic power, for example, to create the seal against the drill pipe. According to one or more embodiments of the present disclosure, the active sealing element of the active sealing assembly 51a may be activated and deactivated as needed. In view of FIG. 2B, the hybrid sealing assembly 52a may include a latching profile on top of the active

sealing assembly 51a, which would be the receptacle for a collet to lock the dropped the hybrid sealing assembly 52b in position within the riser 30. As shown in FIG. 2B, subsequent hybrid sealing assemblies 52b, 52c may be dropped into the riser 30 to mate with previously spent hybrid sealing assemblies to extend the life of a drilling operation well beyond what was previously possible, according to one or more embodiments of the present disclosure.

[0037] Referring now to FIG. 2C, one or more active 51a and passive 50a sealing assembly housings may be stacked in a hybrid configuration between the RCD assembly 48 and the riser 30, according to one or more embodiments of the present disclosure. The RCD assembly 48 shown in FIG. 2C may include at least one passive sealing element, according to one or more embodiments of the present disclosure, as previously described. The active sealing assembly housing 51a of the hybrid configuration may be activated individually as a redundancy, according to one or more embodiments of the present disclosure. For example, in a hydraulic activation method, hoses may be attached to the active sealing assembly housing 51a deployed on top of the RCD assembly 48. In a similar fashion to a blowout preventer annular, some pistons activated from surface by a hydraulic power unit or rig controls may compress the elastomer sealing element of the active sealing assembly housing 51a. The pistons would have sufficient travel to continue compressing the elastomer sealing element of the active sealing assembly housing 51a as sections of the hybrid sealing assembly configuration wear. As another example, in an electric activation method, instead of pistons, one or more electric actuators powered by a battery and activated by a surface control unit may be employed to energize the elastomer sealing element of the active sealing assembly housing 51a as sections of the sealing assembly wear. That is, as wear or failure is noted from a sensor on or within the bearing or sealing assemblies in the RCD assembly 48, for example, the active sealing assembly housing 51a may be energized, either hydraulically or electrically, to provide sealing capabilities for the hybrid sealing assembly configuration so that drilling operations may continue. Advantageously, stacking either housings or sections on top of the RCD assembly 48 as shown in FIG. 2C offers the ability to tailor each drilling operation job.

[0038] Referring now to FIG. 2D, one or more active sealing assembly housings 51a, 51b may be stacked between the RCD assembly 48 and the riser 30, according to one or more embodiments of the present disclosure. The RCD assembly 48 shown in FIG. 2D may include at least one passive sealing element, according to one or more embodiments of the present

disclosure, as previously described. The active sealing assembly housings 51a, 51b shown in FIG. 2D may be activated individually as a redundancy, according to one or more embodiments of the present disclosure. For example, in a hydraulic activation method, hoses may be attached to the active sealing assembly housings 51a, 51b deployed on top of the RCD assembly 48. In a similar fashion to a blowout preventer annular, some pistons activated from surface by a hydraulic power unit or rig controls may compress the elastomer sealing elements of the active sealing assembly housings 51a, 51b. The pistons would have sufficient travel to continue compressing the elastomer sealing element of the active sealing assembly housings 51a, 51b as sections of the sealing assembly wear. As another example, in an electric activation method, instead of pistons, one or more electric actuators powered by a battery and activated by a surface control unit may be employed to energize the elastomer sealing element of the active sealing assembly housings 51a, 51b as sections of the sealing assembly wear. That is, as wear or failure is noted from a sensor on or within the bearing or sealing assemblies in the RCD assembly 48, for example, the active assembly housings 51a, 51b may be individually energized, either hydraulically or electrically, to provide sealing capabilities for the sealing assembly so that drilling operations may continue. Advantageously, stacking either housings or sections on top of the RCD assembly 48 as shown in FIG. 2D offers the ability to tailor each drilling operation job.

[0039] Referring now to FIG. 3, an active hybrid sealing assembly 52, which may be used in the drilling system of FIG. 1, is shown, according to one or more embodiments of the present disclosure. The active hybrid sealing assembly 52 is intended to be deployed for use on a seabed for drilling operations, according to one or more embodiments of the present disclosure. As shown in FIG. 3, the active hybrid sealing assembly 52 includes an RCD assembly 48 including at least one passive sealing element 54, and a double cavity active housing 56 disposed above the RCD assembly 48. As further shown in FIG. 3, the double cavity active housing 56 may include two rotating active sealing assemblies 58, each rotating active sealing assembly 58 having an active sealing element 60 disposed therein. According to one or more embodiments of the present disclosure, an active housing connection 61 may be disposed between the two rotating active sealing assemblies 58. According to one or more embodiments of the present disclosure, the active housing connection 61 includes a pressure transducer 64 disposed therein for monitoring leaks between the two rotating active sealing assemblies 58.

According to one or more embodiments of the present disclosure, a passive/active housing connection 62 may be disposed between the RCD assembly 48 and the double cavity active housing 56, as shown in FIG. 3, for example. According to one or more embodiments of the present disclosure, the passive/active housing connection 62 may include a pressure transducer 64 disposed therein for monitoring leaks between the RCD assembly 48 and the double cavity annular housing 56.

[0040] Still referring to FIG. 3, a riser connection 66 may be disposed above the double cavity active housing 56, the riser connection 66 facilitating connection of the double cavity active housing 56 to a riser. According to one or more embodiments of the present disclosure, the riser connection 66 may include a pressure transducer 64 disposed therein for monitoring leaks between the riser and the double cavity active housing 56. Moreover, the RCD assembly 48 of the active hybrid sealing assembly 52 may be configured for connection to a wellbore for drilling operations, according to one or more embodiments of the present disclosure. According to one or more embodiments of the present disclosure, the pressure transducers 64 disposed within the housing connections of the active hybrid sealing assembly 52 are able to notify a surface hydraulic power unit or rig controls of the drilling system that one or more passive or active sealing elements of the active hybrid sealing assembly 52 have failed. In such cases, the pressure transducers 64 are configured to facilitate automatic activation of active sealing elements of the active hybrid sealing assembly 52 or await input from the operator as to how to proceed.

[0041] Still referring to FIG. 3, the active hybrid sealing assembly 52 according to one or more embodiments of the present disclosure essentially includes a passive section (*i.e.*, the RCD assembly 48 having at least one passive sealing element 54 disposed in the RCD housing 46), and an active section (*i.e.*, the active sealing elements 60 of the two rotating active sealing assemblies 58 of the double cavity active housing 56). According to one or more embodiments of the present disclosure, the active section, which is disposed above the passive section of the active hybrid sealing assembly 52, may be activated by an external hydraulic power source to compress the active sealing elements 60, as previously described, while the passive section relies on no external power source to activate the at least one passive sealing element 54. Instead, the at least one passive sealing element 54 of the passive section seals the bore using an interference fit and wellbore pressure. Due to this configuration, if the at least one passive

sealing element 54 within the passive section fails, the double cavity active housing 56 of the active section may be hydraulically activated as a redundancy to provide the sealing necessary for drilling operations to continue. Advantageously, the double cavity active housing 56 of the active section may be activated or deactivated according to the needs of the active hybrid sealing assembly 52 and associated drilling operations.

[0042] Referring now to FIG. 4, a zoomed in view of the double cavity active housing 56 of the active hybrid sealing assembly 52 shown in FIG. 3 is shown according to one or more embodiments of the present disclosure. Specifically, FIG. 4 shows additional details of the double cavity active housing 56, as previously described. For example, FIG. 4 shows that rotation of the two rotating active sealing assemblies 58 of the double cavity active housing 56 may be facilitated by bearings 68. That is, as shown in FIG. 4, the active sealing elements 60 may be mounted on bearings 68 to facilitate performance of the active hybrid sealing assembly 52 with rotation.

[0043] FIG. 4 also shows that the double cavity active housing 56 also includes means for monitoring wear 63 of the active sealing element 60. According to one or more embodiments of the present disclosure, the means for monitoring wear 63 of the active sealing element 60 may include a wireless seal monitoring system including one or more sensors (*e.g.*, RFID tags) disposed on and/or within each active sealing element 60, and one or more associated communication devices that communicate with and collect data from the sensors, as described in U.S. Provisional Patent Application No. 63/236,352, entitled “WIRELESS WEAR DETECTION FOR SEALING ELEMENTS,” filed August 24, 2021, which is incorporated by reference herein in its entirety. In other embodiments of the present disclosure, the means for monitoring wear 63 of the active sealing element 60 may include a wireless seal monitoring system including other types of sensors, such as nano-sensors, for example, which are further described below. Advantageously, the one or more sensors may facilitate understanding of the root causes of failure of the sealing elements, and may provide an early warning system and data at surface that one or more sealing elements are about to fail.

[0044] Referring now to FIG. 5A, a zoomed in view of the RCD assembly 48 of the active hybrid sealing assembly 52 shown in FIG. 3 is shown according to one or more embodiments of the present disclosure. Specifically, FIG. 5A shows additional details of the RCD assembly 48, as previously described. For example, FIG. 5A shows that a bearing assembly 70 facilitates

rotation of the at least one passive sealing element 54 relative to the RCD housing 46. For clarity, FIG. 5B shows the bearing assembly 70 of FIG. 5A without the RCD housing 46, and FIG. 5C shows the RCD housing 46 of FIG. 5A without the bearing assembly 70. In view of FIGS. 5A and 5B, the passive sealing elements 54 may be mounted within the bearing assembly 70 to facilitate performance of the active hybrid sealing assembly 52 with rotation. According to one or more embodiments of the present disclosure, the at least one passive sealing element 54 is configured to seal from above and below the at least one passive sealing element 54. FIG. 5A also shows that the RCD assembly 48 may include a plurality of pistons 72 supported within the RCD housing 46, according to one or more embodiments of the present disclosure. The plurality of pistons 72 is configured to drive the at least one passive sealing element 54 to seal the bore, according to one or more embodiments of the present disclosure. FIG. 5A also shows that the RCD assembly 48 may also include a shock and vibration sensor 74. According to one or more embodiments of the present disclosure, the shock and vibration sensor 74 may be associated with a recording device that records shocks and vibrations of the RCD assembly 48 during drilling operations.

[0045] Still referring to FIG. 5A, the at least one passive sealing element 54 of the RCD assembly 48 may have a sensor, such as an RFID tag, a nano-sensor or another type of sensor, disposed thereon or embedded therein for monitoring wear of the at least one passive sealing element 54, according to one or more embodiments of the present disclosure. Moreover, the at least one passive sealing element 54 shown in FIG. 5A may assume the geometry shown in FIGS. 6A and 6B, for example, according to one or more embodiments of the present disclosure. Specifically, FIG. 6A shows that the at least one passive sealing element 54 includes an elastomer 76, which may be profiled to accommodate tool joint and drill pipe diameters, according to one or more embodiments of the present disclosure. As further shown in FIG. 6A, the elastomer 76 is surrounded by a metallic insert 78, which is also more clearly shown in FIG. 6B. According to one or more embodiments of the present disclosure, the metallic insert 78 of the at least one passive sealing element 54 may include a plurality of collet fingers 80 to allow flex and movement of the molded elastomer portion of the passive sealing element 54. Referring back to FIG. 6A, the elastomer 76 may include one or more voids 82 to allow the elastomer 76 to flow under stresses during drilling operations, for example.

[0046] Referring now to FIGS. 7A and 7B, a cross-section of a passive sealing element 54 having a different geometry according to one or more embodiments of the present disclosure is shown. Specifically, FIG. 7A shows that the at least one passive sealing element 54 includes an elastomer 76, which may include one or more voids 82 to allow the elastomer 76 to flow under stresses during drilling operations, for example. As further shown in FIG. 7A, the elastomer 76 is surrounded by a metallic insert 78, which is also more clearly shown in FIG. 7B. According to one or more embodiments of the present disclosure, the passive sealing element 54 shown in FIG. 7A may include a sensor, such as an RFID tag, a nano-sensor, or another type of sensor disposed thereon or embedded therein for monitoring wear of the at least one passive sealing element 54.

[0047] Referring now to FIGS. 8A and 8B, a cross-section of a passive sealing element 54 having a different geometry according to one or more embodiments of the present disclosure is shown. Specifically, FIG. 8A shows that the at least one passive sealing element 54 includes an elastomer 76, which may include a necked profile to allow flow and spring in the elastomer 76, according to one or more embodiments of the present disclosure. As further shown in FIG. 8A, the elastomer 76 is surrounded by a metallic insert 78, which is also more clearly shown in FIG. 8B. According to one or more embodiments of the present disclosure, the metallic insert 78 of the at least one passive sealing element 54 may include a plurality of collet fingers 80 to allow flex and movement of the at least one passive sealing element 54. According to one or more embodiments of the present disclosure, the passive sealing element 54 shown in FIG. 8A may include a sensor, such as an RFID tag, a nano-sensor, or another type of sensor disposed thereon or embedded therein for monitoring wear of the at least one passive sealing element.

[0048] Referring now to FIGS. 9A, 9B, and 9C, a cross-section of a passive sealing element 54 having a different geometry according to one or more embodiments of the present disclosure is shown. Specifically, FIG. 9A shows that the at least one passive sealing element 54 includes an elastomer 76, which may include a necked profile to allow flow and spring in the elastomer 76, according to one or more embodiments of the present disclosure. As also shown in FIG. 9A, the elastomer 76 may be profiled to accommodate tool joint and drill pipe diameters, according to one or more embodiments of the present disclosure. As further shown in FIG. 9A, the elastomer 76 is surrounded by a metallic insert 78, which is also more clearly

shown in FIG. 9B. According to one or more embodiments of the present disclosure, the metallic insert 78 of the at least one passive sealing element 54 provides support to a lattice structure 82, which is shown in FIGS. 9A and 9C, for example. According to one or more embodiments of the present disclosure, the lattice structure 82 may be made from an elastomeric or polymeric material, for example, to allow the elastomer 76 to move while still providing robust support to the elastomer 76. According to one or more embodiments of the present disclosure, the passive sealing element 54 shown in FIG. 9A may include a sensor, such as an RFID tag, a nano-sensor, or another type of sensor disposed thereon or embedded therein for monitoring wear of the at least one passive sealing element.

[0049] Advantageously, the geometries of the passive sealing elements 54 shown in FIGS. 6A, 7A, 8A, and 9A facilitate not just sealing from the wellbore, but also sealing from the riser, thereby allowing sealing in both directions, according to one or more embodiments of the present disclosure.

[0050] As previously described, the at least one passive sealing element 54, regardless of geometry, may include at least one sensor, such as an RFID tag, a nano-sensor, or another type of sensor disposed thereon or embedded therein for monitoring wear of the at least one passive sealing element 54. That is, according to one or more embodiments of the present disclosure, similar to the active sealing element 60 as previously described, the active hybrid sealing assembly 52 may also include means for monitoring wear of the at least one passive sealing element 54 of the RCD assembly 48. Such means for monitoring wear of the at least one passive sealing element 54 may include a wireless seal monitoring system including the at least one sensor embedded within or disposed on the at least one passive sealing element 54, and a control system that communicates with the at least one sensor. According to one or more embodiments of the present disclosure, the control system is configured to determine a presence of wear in the at least one passive sealing element 54 based on information provided by the at least one sensor.

[0051] With respect to the wireless seal monitoring system according to one or more embodiments of the present disclosure, including an RFID tag as the at least one sensor embedded within or disposed on the at least one passive sealing element 54, U.S. Provisional Patent Application No. 63/236,352, entitled “WIRELESS WEAR DETECTION FOR SEALING ELEMENTS,” filed August 24, 2021, which has been incorporated by reference in

its entirety herein, is illustrative. In addition to the above, the wireless seal monitoring system according to one or more embodiments of the present disclosure may include a plurality of nano-sensors as the at least one sensor embedded within or disposed on the at least one passive sealing element 54. According to one or more embodiments of the present disclosure, each nano-sensor of the plurality of nano-sensors may include two electrodes printed onto a substrate using carbon nanotube ink. According to one or more embodiments of the present disclosure, a first electrode of the two electrodes is configured to receive application of an oscillating voltage, and the second electrode of the two electrodes is grounded to create an electric field. Depending on the magnitude of variation in the voltage, the control system communicates thickness changes in the elastomeric material 76 of the passive sealing element 54.

[0052] Referring now to FIG. 10, an approximate positioning of sensors on or within a seal element, such as the at least one passive sealing element 54, is shown according to one or more embodiments of the present disclosure. Advantageously, this approximate positioning of sensors may maximize the data as well as coverage across the seal element to monitor wear in critical areas. By placing a plurality of nano-sensors on or within the elastomeric material and/or on the insert of the seal element, according to one or more embodiments of the present disclosure, the plurality of nano-sensors would be able to accurately monitor the amount of wear within the seal element, and the associated control system would be able to communicate to operators when components of the seal element need to be replaced. In addition to gathering data, one or more embodiments of the present disclosure supports a fatigue analysis study of the RCD seal elements. That is, the data acquired by the plurality of nano-sensors may be used for fatigue and reliability modeling of the RCD seal elements, according to one or more embodiments of the present disclosure. While one or more embodiments of the present disclosure including a wireless seal monitoring system that includes a plurality of nano-sensors have been described primarily with respect to the at least one passive sealing element 54 of the RCD assembly 48, the plurality of nano-sensors may also be employed to monitor wear of the active sealing element 60 of the rotating active sealing assemblies 58, as previously described, without departing from the scope of the present disclosure.

[0053] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible

without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

1. A system, comprising:
a rotating control device housing comprising at least one passive sealing element;
and
a double cavity active housing disposed above the rotating control device housing,
wherein the double cavity active housing is configured to be activated by an
external power source.
2. The system of claim 1, further comprising a passive/active housing connection
disposed between the rotating control device housing and the double cavity active
housing.
3. The system of claim 2, wherein the passive/active housing connection comprises a
first pressure transducer.
4. The system of claim 1, wherein the at least one passive sealing element comprises a
sensor embedded therein.
5. The system of claim 4, wherein the sensor is a wear sensor.
6. The system of claim 1, wherein the double cavity active housing comprises two
rotating active sealing assemblies, each rotating active sealing assembly having an
active sealing element disposed therein.
7. The system of claim 6, wherein the double cavity active housing further comprises an
active housing connection disposed between the two rotating active sealing
assemblies.

8. The system of claim 7, wherein the active housing connection comprises a second pressure transducer.
9. The system of claim 6, wherein the double cavity active housing further comprises means for monitoring wear of the active sealing element.
10. The system of claim 1, further comprising a riser connection disposed above the double cavity active housing, the riser connection facilitating connection of the double cavity active housing to a riser.
11. The system of claim 10, wherein the riser connection comprises a third pressure transducer.
12. The system of claim 1, wherein the rotating control device housing further comprises a plurality of pistons.
13. The system of claim 1, wherein the rotating control device housing further comprises a shock and vibration sensor.
14. The system of claim 1, wherein the rotating control device housing further comprises a bearing assembly.
15. The system of claim 1, wherein the at least one passive sealing element comprises an elastomer surrounded by a metallic insert.
16. The system of claim 15, wherein the elastomer comprises a plurality of voids.
17. The system of claim 15, wherein the elastomer comprises a profile to accommodate at least one of a tool joint diameter and a drill pipe diameter.

18. The system of claim 15, wherein the metallic insert comprises a plurality of collet fingers.
19. The system of claim 15, wherein the at least one passive sealing element further comprises a lattice structure, and wherein the metallic insert supports the lattice structure.
20. The system of claim 1, wherein the at least one passive sealing element is configured to seal from above and below the at least one passive sealing element.
21. The system of claim 1, wherein the external power source provides hydraulic power.
22. The system of claim 1, wherein the external power source provides electric power.
23. A system comprising:
 - a rotating control device assembly comprising a first assembly; and at least one sensor that monitors wear of the first assembly,
 - wherein the first assembly comprises a latching profile; and
 - a second assembly comprising a corresponding latching profile, the second assembly configured to be dropped from an above location to enable the corresponding latching profile to mate with the latching profile of the first assembly.
24. The system of claim 23, wherein the first assembly comprises a first bearing assembly or a first sealing assembly, and wherein the second assembly comprises a second bearing assembly or a second sealing assembly.
25. The system of claim 23, wherein the first assembly comprises a passive sealing element, and wherein the second assembly comprises an active sealing element.

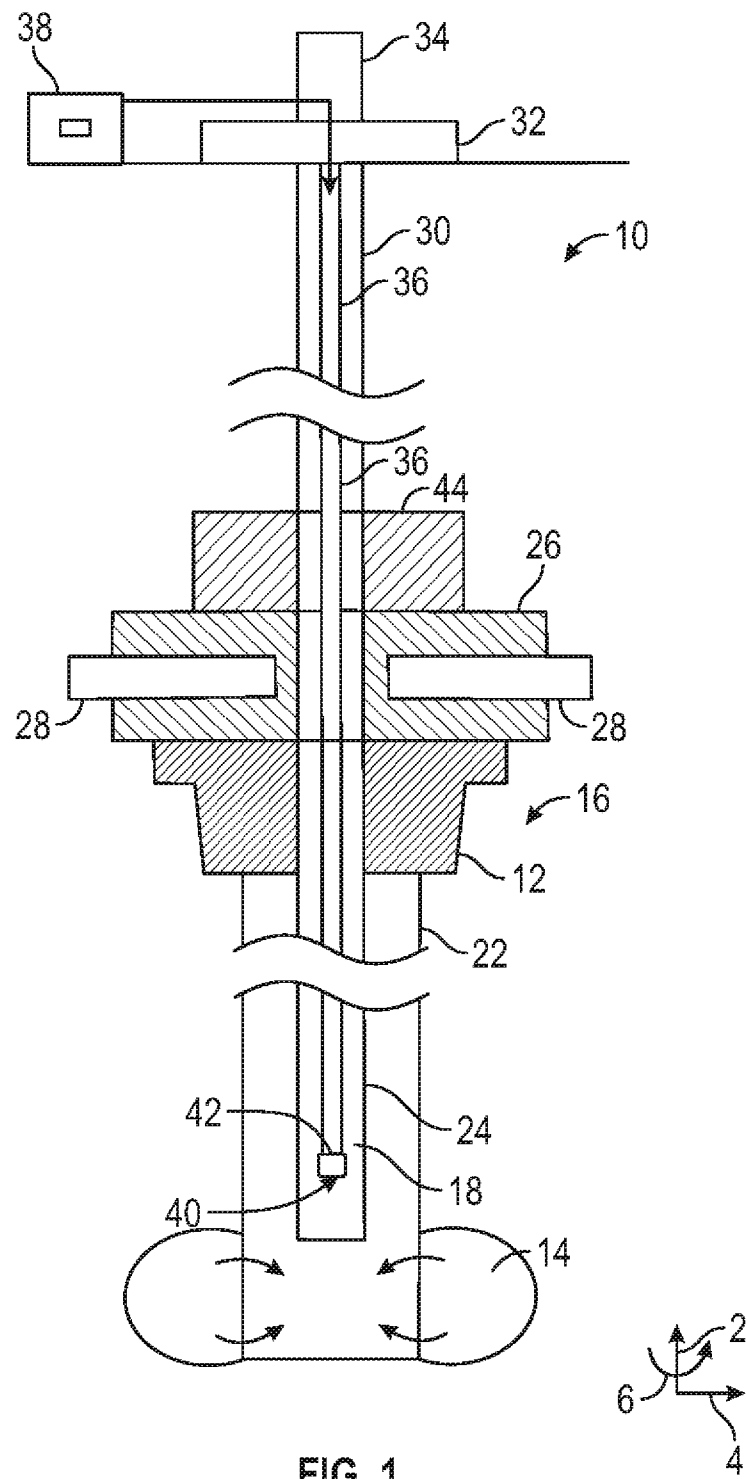
26. The system of claim 23, wherein the first and second assemblies comprise a passive sealing element.
27. The system of claim 23,
wherein the first assembly comprises a first hybrid sealing assembly,
wherein the second assembly comprises a second hybrid sealing assembly, and
wherein the first and second hybrid sealing assemblies comprise an active sealing assembly stacked on top of a passive sealing assembly.
28. A method comprising:
performing a drilling operation using a system comprising: a hybrid sealing assembly connected to a rotating control device assembly, wherein the hybrid sealing assembly comprises an active sealing assembly stacked on top of a passive sealing assembly;
monitoring wear of the passive sealing assembly of the hybrid sealing assembly;
detecting an imminent failure of the passive sealing assembly;
activating the active sealing assembly of the hybrid sealing assembly; and
continuing the drilling operation.
29. The method of claim 28, wherein the passive sealing assembly comprises a passive sealing element, and wherein the active sealing assembly comprises an active sealing element.
30. A system comprising:
a rotating control device assembly comprising: at least one passive sealing element; and at least one wear sensor;
a riser;
a first assembly housing; and
a second assembly housing,
wherein the first and second assembly housings are stacked between the rotating control device assembly and the riser, and

wherein at least one of the first and second assembly housings comprises an active sealing assembly housing.

31. The system of claim 30, wherein the at least one wear sensor is at least one selected from the group consisting of: an RFID sensor; and a nano-sensor.
32. The system of claim 30, wherein the active sealing assembly housing is activated by an external power source that provides either hydraulic power or electrical power.
33. A drilling system comprising:
a rotating control device assembly, comprising:
a rotating control device housing comprising a bore; and
a seal element comprising an elastomeric material, positioned within the rotating control device housing and configured to seal the bore, the seal element further comprising an insert surrounding the elastomeric material; and
a bearing assembly supported within the rotating control device housing and configured to enable the seal element to rotate relative to the rotating control device housing; and
a wireless seal monitoring system comprising:
at least one sensor embedded within or disposed on the seal element; and
a control system that communicates with the at least one sensor, wherein the control system is configured to determine a presence of wear in the seal element based on information provided by the at least one sensor.
34. The drilling system of claim 33, wherein the at least one sensor comprises a plurality of nano-sensors.

35. The drilling system of claim 34, wherein each nano-sensor of the plurality of nano-sensors comprises:
- a first electrode; and
 - a second electrode,
- wherein the first and second electrodes are printed onto a substrate using carbon nanotube ink, and
- wherein the first electrode is configured to receive application of an oscillating voltage and the second electrode is grounded to create an electric field.
36. The drilling system of claim 33, wherein the information comprises a change in thickness of the elastomeric material.
37. The drilling system of claim 33, wherein the at least one sensor is embedded within or disposed on the elastomeric material of the seal element.
38. The drilling system of claim 33,
- wherein a first sensor is embedded within or disposed on the elastomeric material of the seal element, and
 - wherein a second sensor is embedded within or disposed on the insert of the seal element.
39. The drilling system of claim 33, wherein the insert of the seal element is made of a metallic material.

1/10



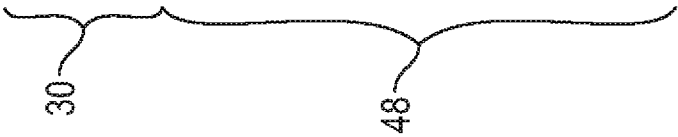


FIG. 2A

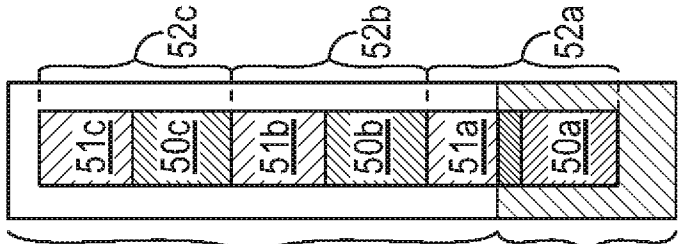


FIG. 2B

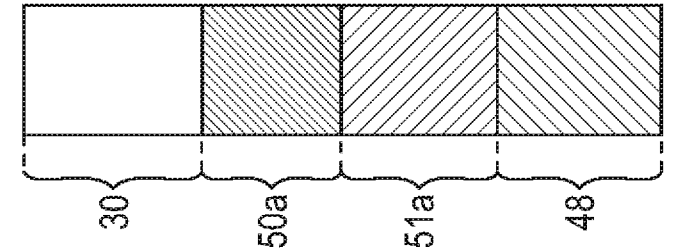


FIG. 2C

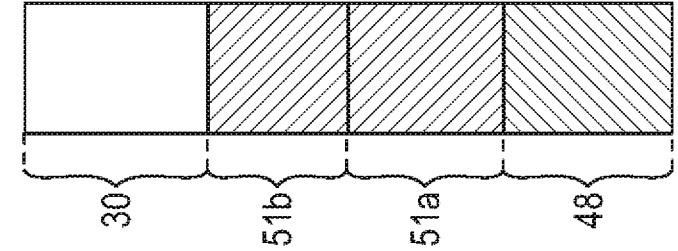


FIG. 2D

3/10

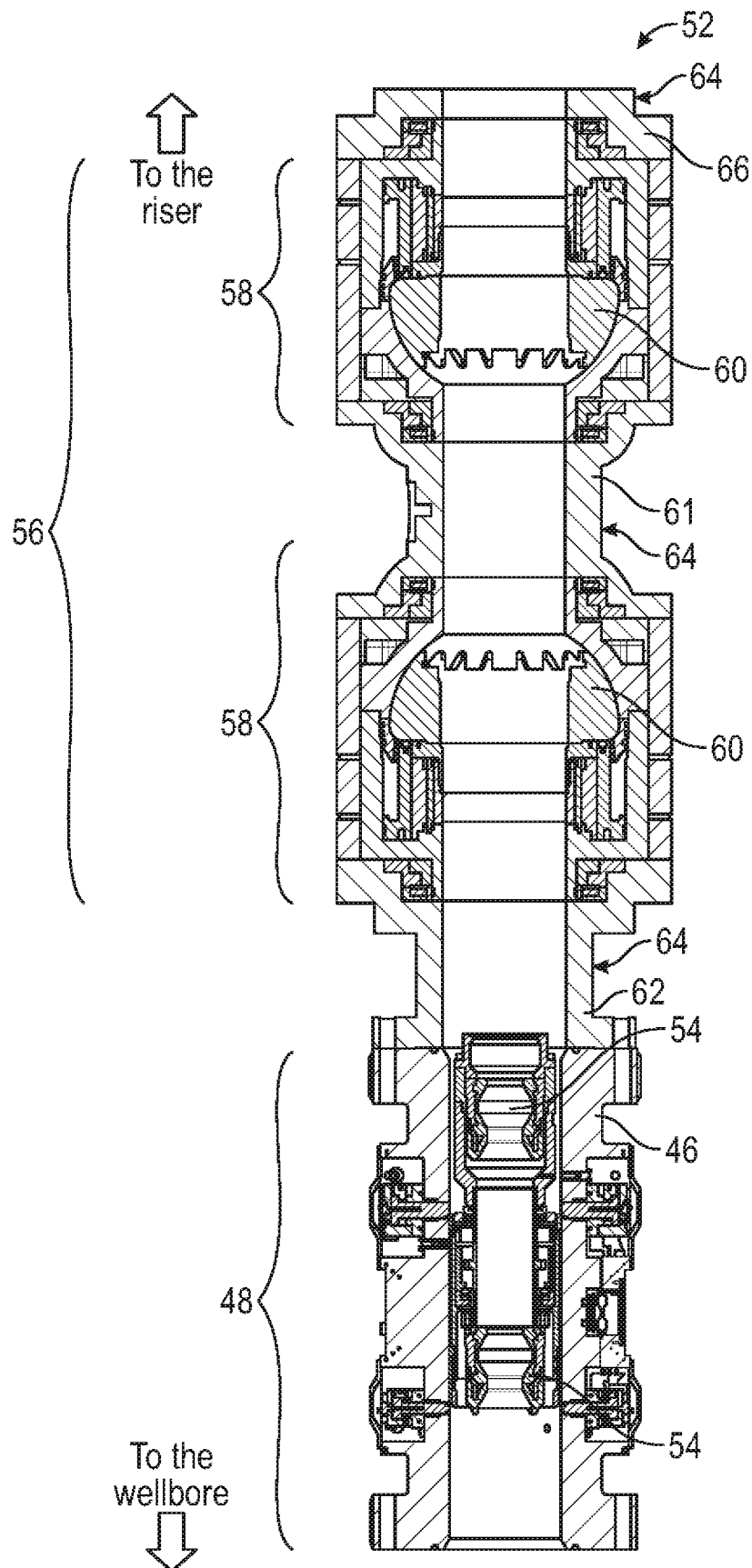


FIG. 3

4/10

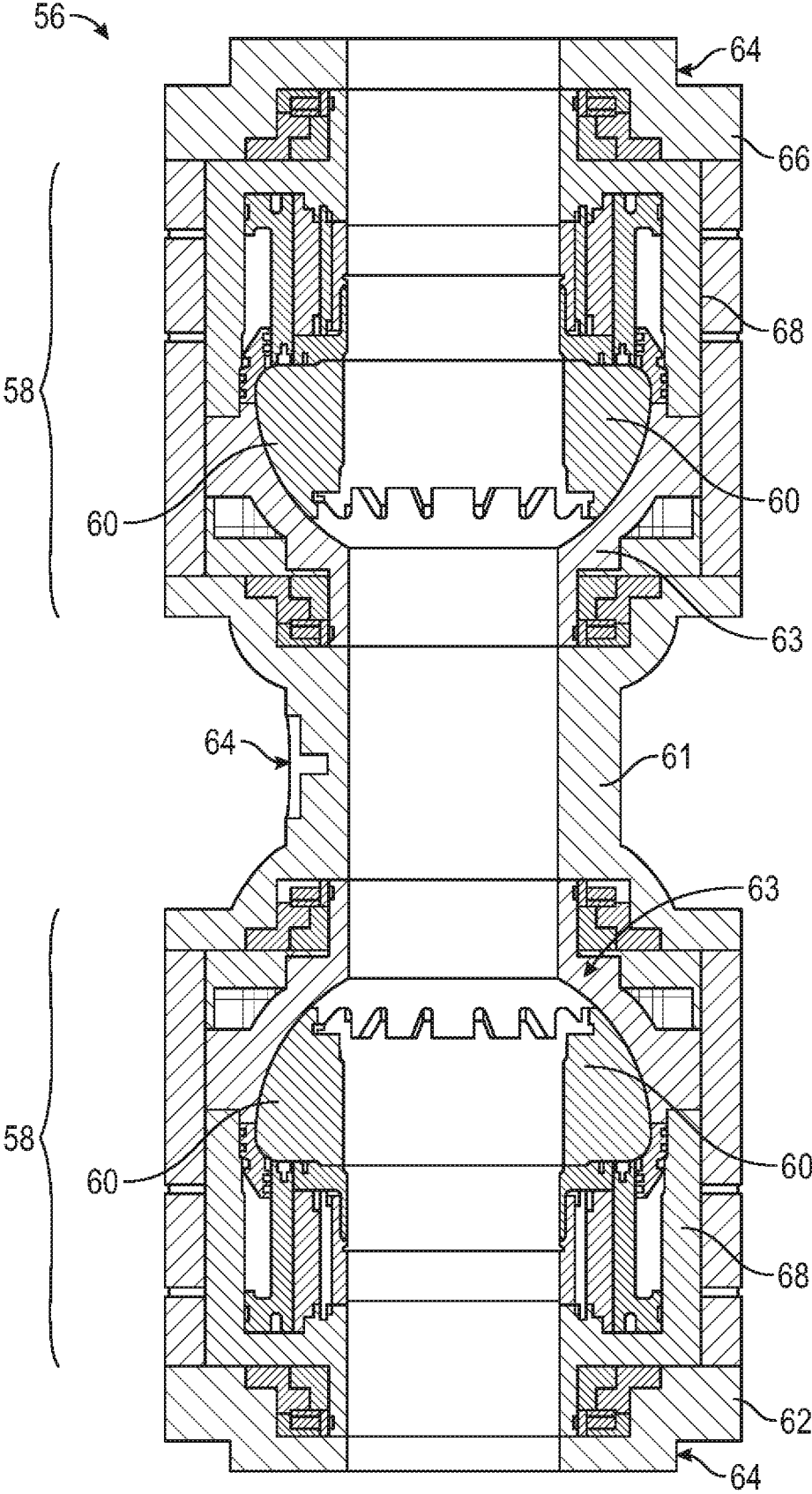


FIG. 4

5/10

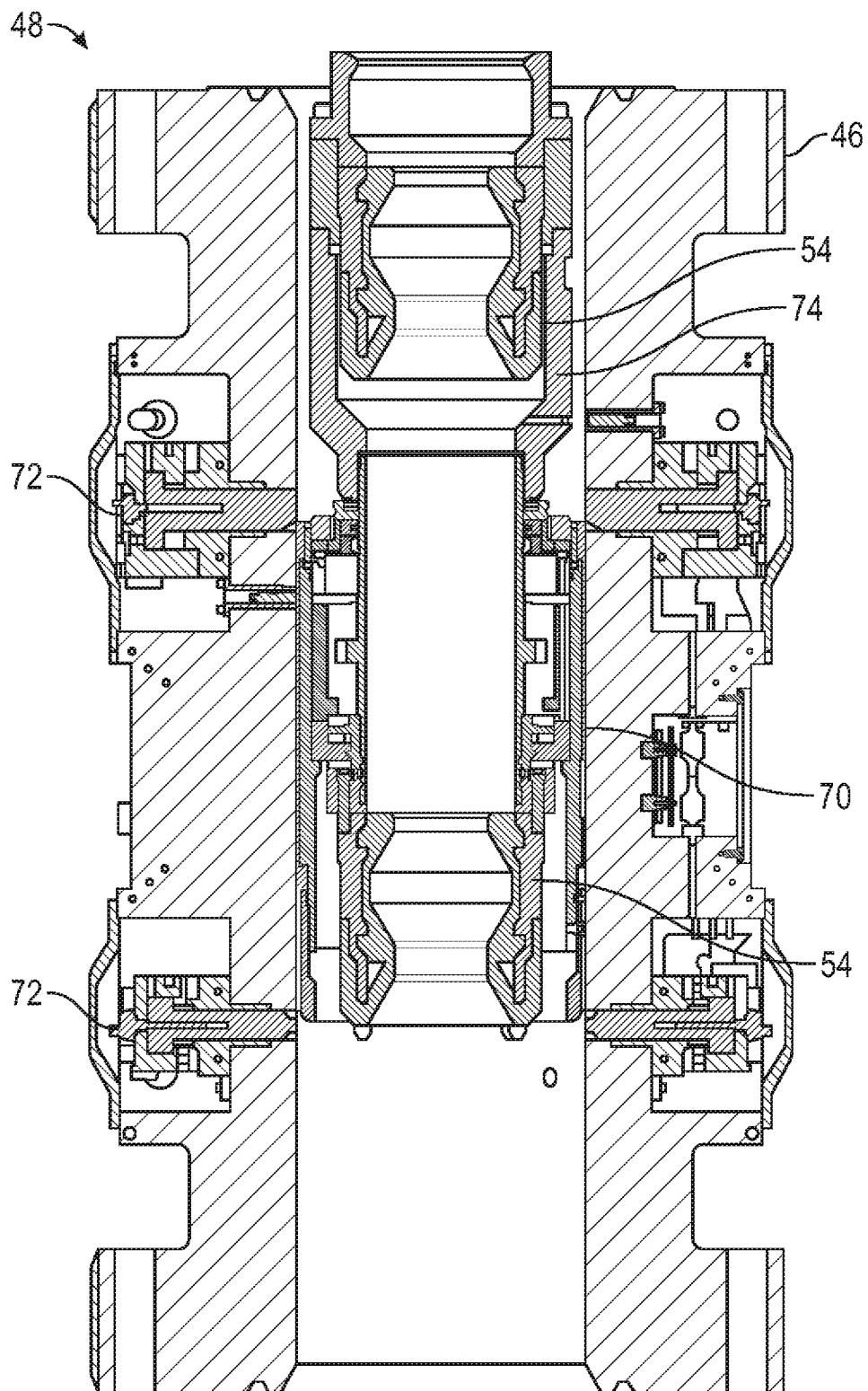


FIG. 5A

6/10

46

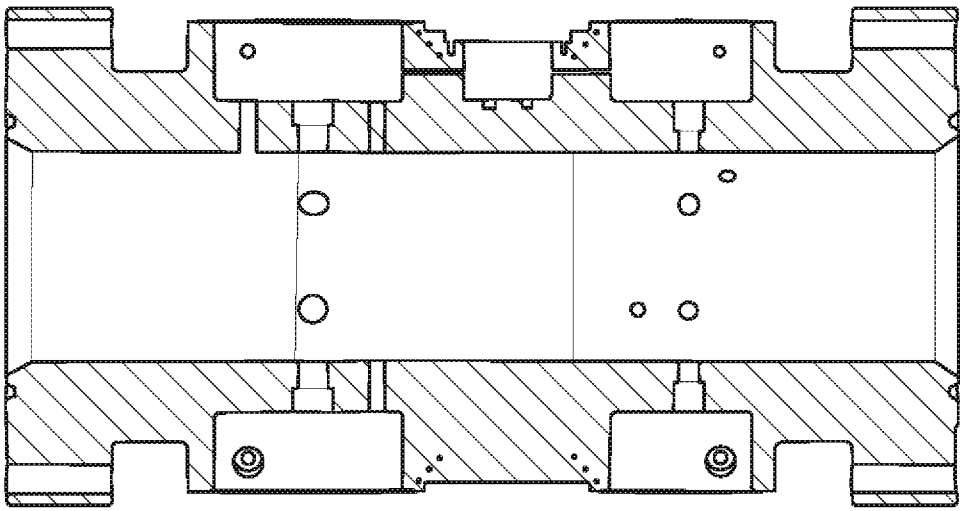


FIG. 5C

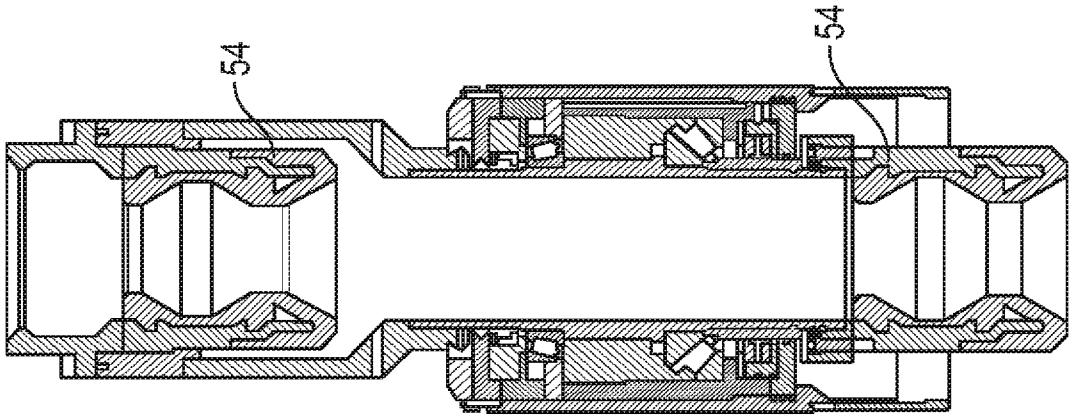


FIG. 5B

7/10

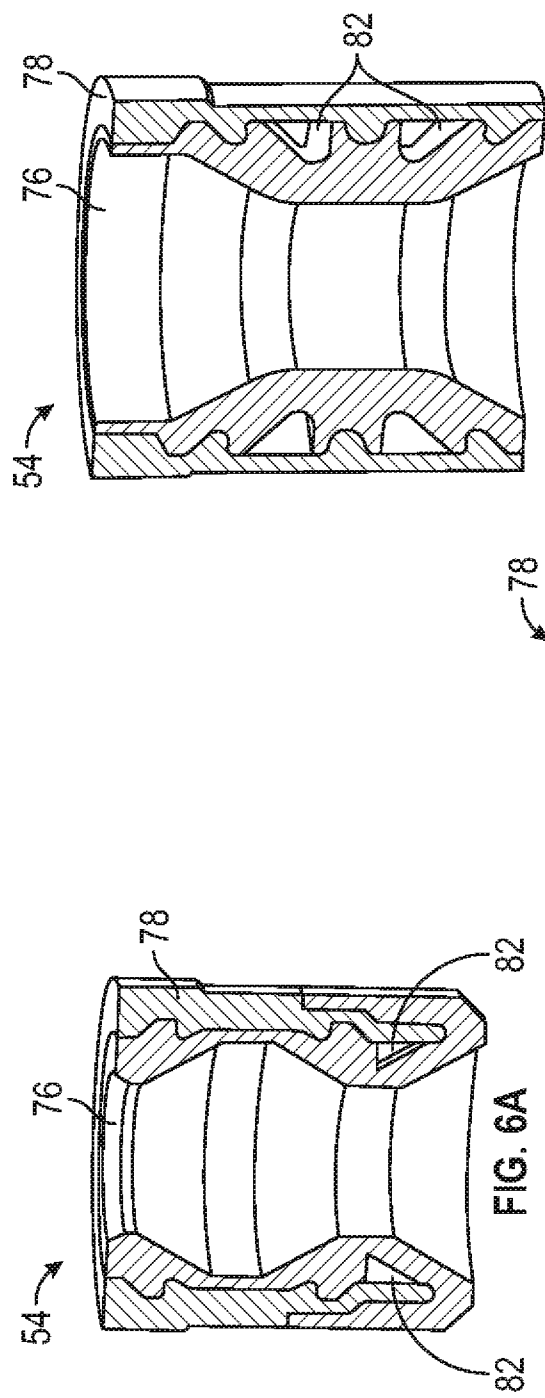


FIG. 6A

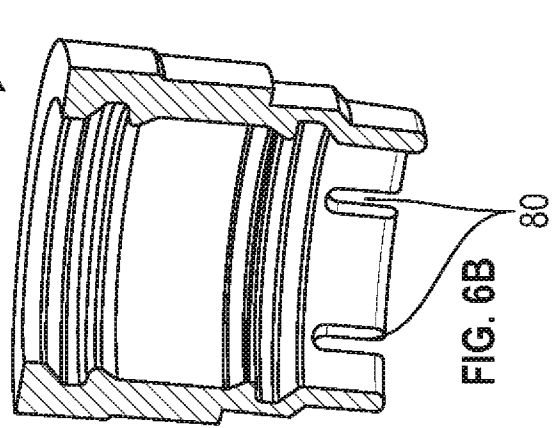


FIG. 6B

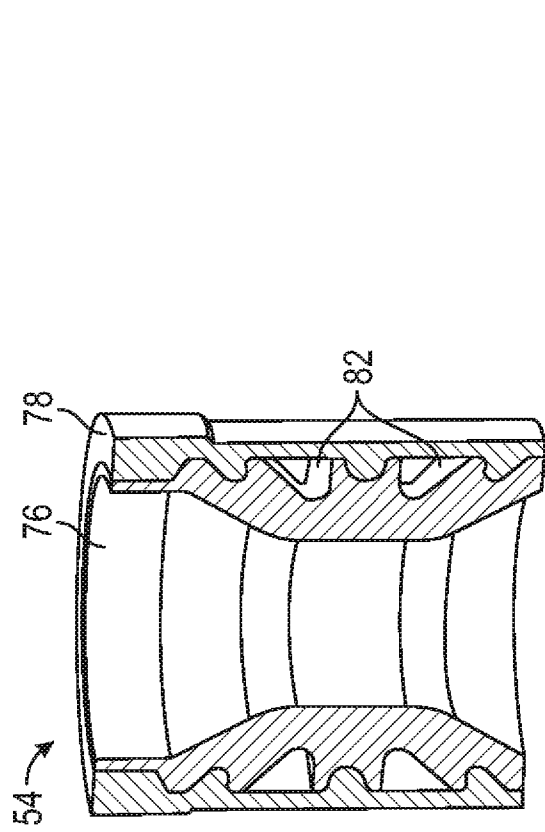


FIG. 7A

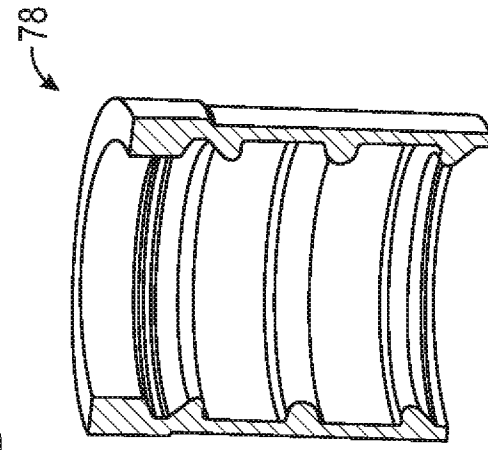
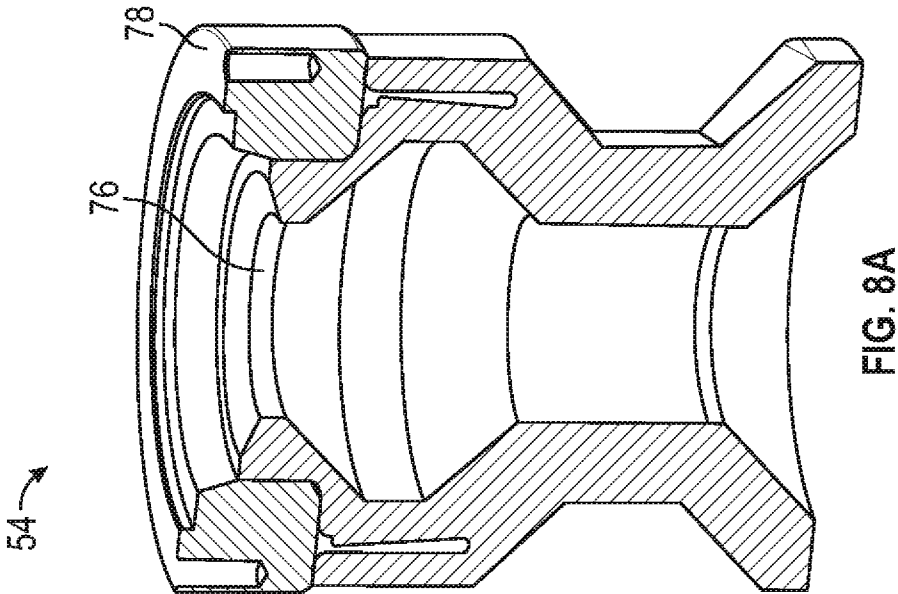
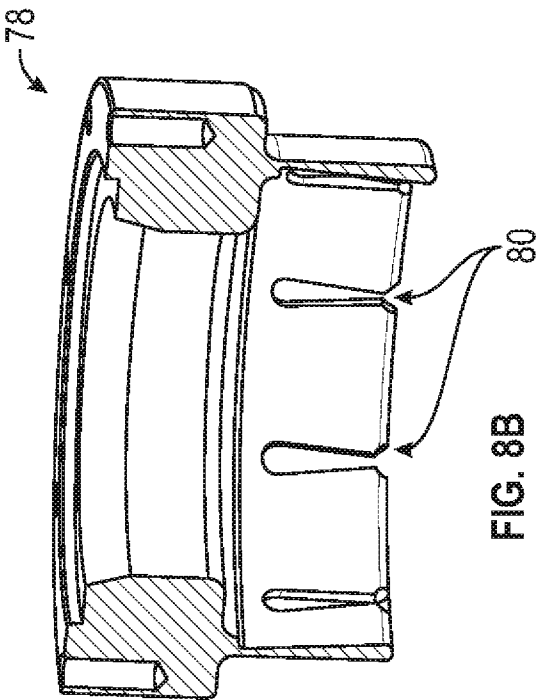


FIG. 7B



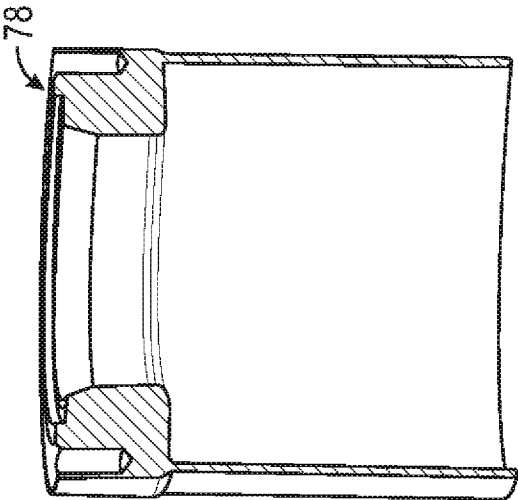


FIG. 9B

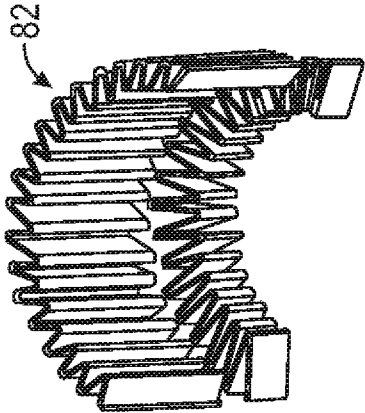


FIG. 9C

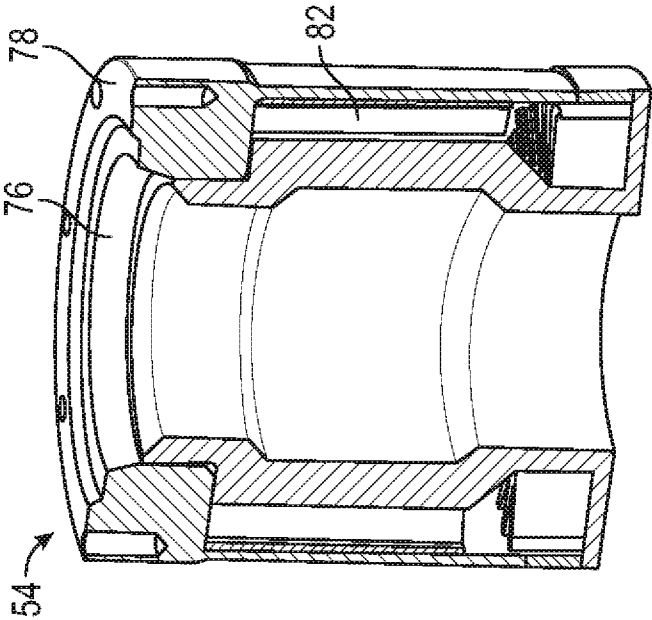


FIG. 9A

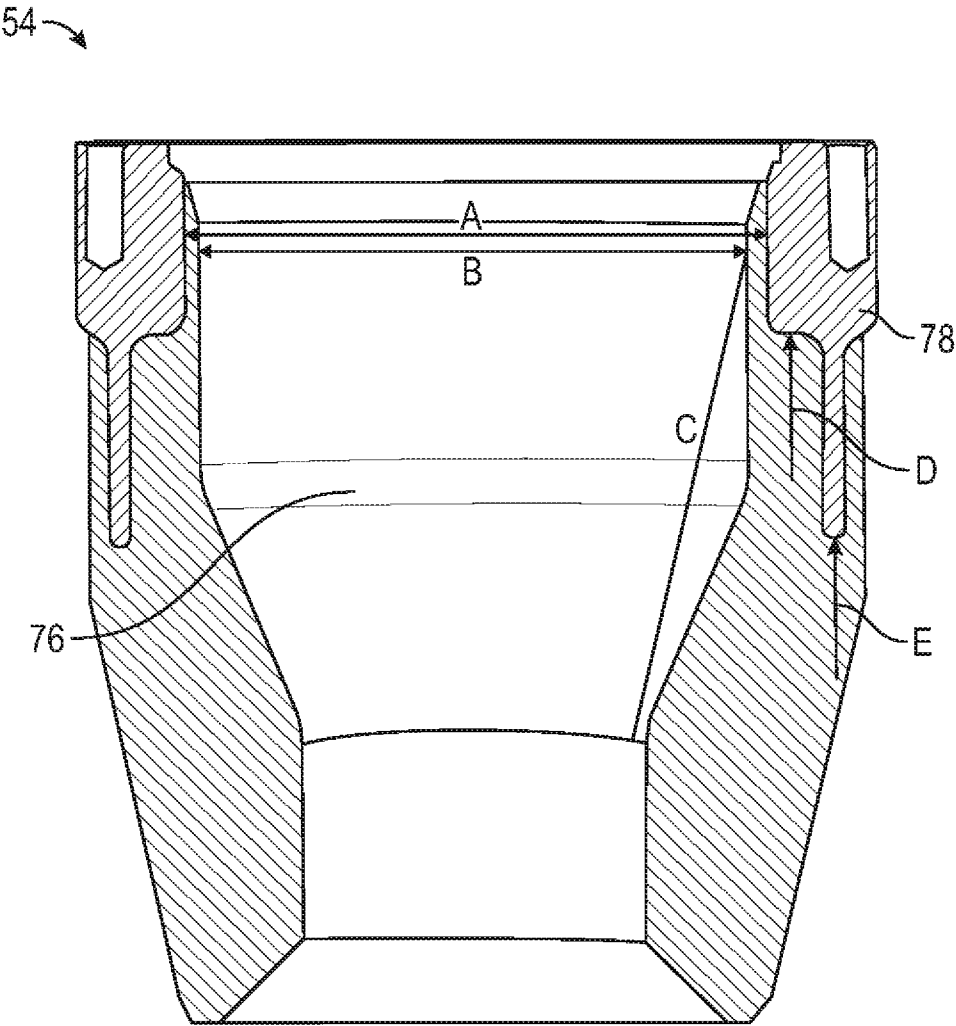


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/061356

A. CLASSIFICATION OF SUBJECT MATTER**E21B 33/08(2006.01)i; E21B 44/00(2006.01)i; E21B 41/00(2006.01)i; E21B 47/06(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 33/08(2006.01); E21B 21/08(2006.01); E21B 33/06(2006.01); E21B 33/13(2006.01); E21B 44/00(2006.01);
E21B 47/00(2006.01); E21B 7/00(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: rotating control device housing, double cavity active housing, wear sensor, pressure transducer, piston, shock and vibration sensor, metallic insert, elastomer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013-0118749 A1 (HANNEGAN et al.) 16 May 2013 (2013-05-16) paragraphs [0047], [0120]-[0122] and figures 2, 16A-16B	1,6,12,14,20-22
Y		2-5,7-11,13,15-19,25,27,30-32
Y	WO 03-042485 A2 (ORMEXLA USA, INC.) 22 May 2003 (2003-05-22) page 12, lines 9-24 and figures 2-3	2-3,7-8
Y	US 2015-0337599 A1 (BULLOCK et al.) 26 November 2015 (2015-11-26) paragraphs [0013], [0016]-[0019], [0024]-[0032] and figures 1-4	4-5,13,23-27,30-39
Y	US 2017-0009550 A1 (MANAGED PRESSURE OPERATIONS PTE. LTD.) 12 January 2017 (2017-01-12) paragraphs [0065], [0075] and figures 1-2	9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

23 May 2023

Date of mailing of the international search report

24 May 2023

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/061356

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 6016880 A (HALL et al.) 25 January 2000 (2000-01-25) column 3, lines 11-35 and figure 3	15-19,33-39
Y	US 2010-0218937 A1 (EDVARSEN et al.) 02 September 2010 (2010-09-02) paragraphs [0022], [0026] and figures 1-6	23-27
A	US 2020-0157910 A1 (SAUDI ARABIAN OIL COMPANY) 21 May 2020 (2020-05-21) paragraphs [0032]-[0035] and figures 3-4	1-39

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2023/061356

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				CA	2711621	C	05 June 2018
				CA	2855020	A1	31 January 2011
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Information on patent family members

International application No.

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				US	10781657	B2		22 September 2020	
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US	6016880	A	25 January 2000	AU	9778298	A		27 April 1999	
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				EA	200901310	A1		30 April 2010	
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				EP	2150681	A4		17 April 2013	
				EP	2150681	B1		15 November 2017	
				MX	2009011427	A		16 December 2009	
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				NO	326492	B1		15 December 2008	
				US	8066062	B2		29 November 2011	
				WO	2008-133523	A1		06 November 2008	
US	2020-0157910	A1	21 May 2020	EP	3870805	A1		01 September 2021	
				MA	53953	A		23 February 2022	
				US	10954739	B2		23 March 2021	
				WO	2020-104856	A1		28 May 2020	