CONTROL

(57) Abstract: A system and method is provided for a low profile rotating control device (LP-RCD) and its housing mounted on or integral with an annular blowout preventer seal, casing, or other housing. The LP-RCD and LP-RCD housing can fit within a limited space available on drilling rigs. An embodiment allows a LP-RCD to be removably disposed with a LP-RCD housing by rotating a bearing assembly rotating plate. A sealing element may be removably disposed with the LP-RCD bearing assembly by rotating a seal retainer ring. Alternatively, a sealing element may be removably disposed with the LP-RCD bearing assembly with a seal support member threadedly attached with the LP-RCD bearing assembly. The seal support member may be locked in position with a seal locking ring removably attached with threads with the LP-RCD bearing assembly over the seal support member. Spaced apart accumulators may be disposed radially outward of the bearings in the bearing assembly to provide self lubrication to the bearings.

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ROTATING CONTROL DEVICE

[0001] This application claims priority from US Application No. 12/893,391 (published as US 2011/0036638), which is a continuation-in-part of co-pending US Application No. 11/975,946 (published as US 2009/0101411) filed on October 23, 2007, which applications are hereby incorporated by reference for all purposes in their entirety and are assigned to the assignee of the present invention.

[0002] This invention relates to rotating control devices to be used in the field of fluid drilling equipment.

[0003] Conventional oilfield drilling typically uses hydrostatic pressure generated by the density of the drilling fluid or mud in the wellbore in addition to the pressure developed by pumping of the fluid to the borehole. However, some fluid reservoirs are considered economically undrillable with these conventional techniques. New and improved techniques, such as underbalanced drilling and managed pressure drilling, have been used successfully throughout the world. Managed pressure drilling is an adaptive drilling process used to more precisely control the annular pressure profile throughout the wellbore. The annular pressure profile is controlled in such a way that the well is either balanced at all times, or nearly balanced with low change in pressure. Underbalanced drilling is drilling with the hydrostatic head of the drilling fluid intentionally designed to be lower than the pressure of the formations being drilled. The hydrostatic head of the fluid may naturally be less than the formation pressure, or it can be induced.

[0004] These improved techniques present a need for pressure management devices, such as rotating control heads or devices (referred to as RCDs). RCDs, such as proposed in U.S. Patent No. 5,662,181, have provided a dependable seal in the annular space between a rotating tubular and the casing or a marine riser for purposes of controlling the pressure or fluid flow to the surface while drilling operations are conducted. Typically, a member of the RCD is designed to rotate with the tubular along with an internal sealing element(s) or seal(s) enabled by bearings. The seal of the RCD permits the tubular to move axially and slidably through the RCD. As best shown in FIG. 3 of the '181 patent, the RCD has its bearings positioned above a lower sealing element or stripper rubber seal, and an upper sealing element or stripper rubber seal is positioned directly and completely above the bearings. The '181 patent proposes positioning the RCD with a housing with a lateral outlet or port with a circular cross section for drilling fluid returns. As shown in FIG. 3 of the '181 patent, the diameter of a circular flange at the end of a circular conduit communicating with the port is
substantially smaller than the combined height of the RCD and housing. The term "tubular" as used herein means all forms of drill pipe, tubing, casing, riser, drill collars, liners, and other tubulars for drilling operations as are understood in the art.

U.S. Patent No. 6,138,774 proposes a pressure housing assembly with a RCD and an adjustable constant pressure regulator positioned at the sea floor over the well head for drilling at least the initial portion of the well with only sea water, and without a marine riser. As shown in FIG. 6 of the '774 patent, the diameters of the circular flanges are substantially smaller than the combined height of the RCD and pressure housing. Also shown in FIG. 6 of the '774 patent, a lubrication unit pressurized by a spring loaded piston is proposed that is separated from but in fluid communication with a housing disposed with a sealed bearing assembly. It is proposed that lubricant may be injected into fissures at the top and bottom of the bearing assembly to lubricate the internal components of the bearing assembly.

U.S. Patent No. 6,913,092 B2 proposes a seal housing with a RCD positioned above sea level on the upper section of a marine riser to facilitate a mechanically controlled pressurized system that is useful in underbalanced subsea drilling. A remote controlled external disconnect/ocncnet clamp is proposed for hydraulically clamping the bearing and seal assembly of the RCD to the seal housing. As best shown in FIG. 3 of the '092 patent, in one embodiment, the seal housing of the RCD is proposed to contain two lateral conduits extending radially outward to respective T-connectors for the return pressurized drilling fluid flow. As further shown in FIG. 3 of the '092 patent, each diameter of the two lateral conduits extending radially outward are substantially smaller than the combined height of the RCD and seal housing.

U.S. Patent No. 4,949,796 proposes a bearing assembly with a rotatable sealing element disposed with an assembly carrier. The assembly carrier is proposed to be removably attached with a stationary housing with a clamping assembly.

U.S. Patent No. 7,159,669 B2 proposes that the RCD positioned with an internal housing member be self-lubricating. The RCD proposed is similar to the Weatherford-Williams Model 7875 RCD available from Weatherford International of Houston, Texas. The '669 patent proposes two pressure compensation mechanisms that maintain a desired lubricant pressure in the bearing assembly. One pressure compensation mechanism is proposed to be disposed directly and completely above the bearings, and the other pressure compensation mechanism is proposed to be disposed directly and completely below the bearings. Both pressure compensation mechanisms are proposed to be disposed directly and completely between the upper and lower rotatable seals.
U.S. Patent No. 7,487,837 proposes a remotely actuated hydraulic piston latching assembly for latching and sealing a RCD with the upper section of a marine riser or a bell nipple positioned on the riser.

Pub. No. US 2006/0144622 A1 proposes a system and method for cooling a RCD while regulating the pressure on its upper radial seal. Gas, such as air, and liquid, such as oil, are alternatively proposed for use in a heat exchanger in the RCD.

An annular blowout preventer (BOP) has been often used in conventional hydrostatic pressure drilling. As proposed in U.S. Patent No. 4,626,135, when the BOP's annular seals are closed upon the drill string tubular, fluid is diverted via a lateral outlet or port away from the drill floor. However, drilling must cease because movement of the drill string tubular will damage or destroy the non-rotatable annular seals. During normal operations the BOP's annular seals are open, and drilling mud and cuttings return to the rig through the annular space. For example, the Hydril Company of Houston, Texas has offered the Compact GK® 7 1/16" - 3000 and 5000 psi annular blowout preventers.

Small drilling rigs with short substructure heights have been used to drill shallow wells with conventional drilling techniques as described above. Some small land drilling rigs are even truck mounted. However, smaller drilling rigs and structures are generally not equipped for managed pressure and/or underbalanced drilling because they lack pressure containment or management capability. At the time many such rigs were developed and constructed, managed pressure and/or underbalanced drilling was not used. As a result of their limited substructure height, there is little space left for additional equipment, particularly if the rig already uses a BOP.

As a result of the shortage of drilling rigs created by the high demand for oil and gas, smaller drilling rigs and structures are being used to drill deeper wells. In some locations where such smaller rigs are used, such as in western Canada and parts of the northwestern and southeastern United States, there exist shallow pockets of H₂S (sour gas), methane, and other dangerous gases that can escape to atmosphere immediately beneath the drill rig floor during drilling and/or workover operations. Several blowouts have occurred in drilling and/or workovers in such conditions. Even trace amounts of such escaping gases create health, safety, and environmental (USE) hazards, as they are harmful to humans and detrimental to the environment. There are U.S. and Canadian regulatory restrictions on the maximum amount of exposure workers can have to such gases. For example, the Occupational Safety and Health Administration (OSHA) sets an eight hour daily limit for a worker’s exposure to trace amounts of H₂S gas when not wearing a gas mask.
[00014] Smaller drilling rigs and structures are also typically not able to drill with compressible fluids, such as air, mist, gas, or foam, because such fluids require pressure containment. The inventors have appreciated that there are numerous occasions in which it would be economically desirable for such smaller rigs to drill with compressible fluids. Also, HSE hazards could result without pressure containment, such as airborne debris, sharp sands, and toxins.

[00015] As discussed above, RCDs and their housings proposed in the prior art cannot fit on many smaller drilling rigs or structures due to the combined height of the RCDs and their housings, particularly if the rigs or structures already use a BOP. The RCD's height is a result in part of the RCD's bearings being positioned above the RCD's lower sealing element, the RCD's accommodation, when desired, for an upper sealing element, the means for changing the sealing element(s), the configurations of the housing, the area of the lateral outlet or port in the housing, the thickness of the bottom flange of the housing, and the allowances made for bolts or nuts on the mounting threaded rods positioned with the bottom flange of the housing.

[00016] RCDs have also been proposed in U.S. Patent Nos. 3,128,614; 4,154,448; 4,208,056; 4,304,310; 4,361,185; 4,367,795; 4,441,551; 4,531,580; and 4,531,591. The inventors have appreciated that each of the referenced patents proposes a conduit in communication with a housing port with the port diameter substantially smaller than the height of the respective combined RCD and its housing.

[00017] U.S. Patent No. 4,531,580 proposes a RCD with a body including an upper outer member and a lower inner member. As shown in FIG. 2 of the '580 patent, a pair of bearing assemblies are located between the two members to allow rotation of the upper outer member about the lower inner member.

[00018] More recently, manufacturers such as Smith Services and Washington Rotating Control Heads, Inc. have offered their RDH 500® RCD and Series 1400 "SHORTY" rotating control head, respectively. Also, Weatherford International of Houston, Texas has offered its Model 9000 that has a 500 psi working and static pressure with a 9 inch (22.9 cm) internal diameter of its bearing assembly. Furthermore, International Pub. No. WO 2006/088379 A1 proposes a centralization and running tool (CTR) having a rotary packing housing with a number of seals for radial movement to take up angular deviations of the drill stem. While each of the above referenced RCDs proposes a conduit communicating with a housing port with the port diameter substantially smaller than the height of the respective combined RCD and its housing, some of the references also propose a flange on one end of the conduit. The
diameter of the proposed flange is also substantially smaller than the height of the respective combined RCD and its housing.

[00019] The above discussed U.S. Patent Nos. 3,128,614; 4,154,448; 4,208,056; 4,304,310; 4,361,185; 4,367,795; 4,441,551; 4,531,580; 4,531,591; 4,626,135; 4,949,796; 5,662,181; 6,138,774; 6,913,092 B2; 7,159,669 B2; and 7,487,837; Pub. No. U.S. 2006/0144622 AI; and International Pub. No. WO 2006/088379 A1 are incorporated herein by reference for all purposes in their entirety. The '796, '181, '774, '092, '669 and '837 patents and the '622 patent publication have been assigned to the assignee of the present invention. The '614 patent is assigned on its face to Grant Oil Tool Company. The '310 patent is assigned on its face to Smith International, Inc. of Houston, Texas. The '580 patent is assigned on its face to Cameron Iron Works, Inc. of Houston, Texas. The '591 patent is assigned on its face to Washington Rotating Control Heads. The '135 patent is assigned on its face to the Hydril Company of Houston, Texas. The '379 publication is assigned on its face to AGR Subsea AS of Straume, Norway.

[00020] As discussed above, the inventors have appreciated a need for a low profile RCD (LP-RCD) system and method for managed pressure drilling and/or underbalanced drilling. They have appreciated that it would be desirable to have a means for lubrication of the bearings of such a LP-RCD. They have appreciated that it would be desirable to be able to efficiently replace the seal from the bearing assembly while leaving the bearing assembly in place. They have appreciated that it would also be desirable to be able to efficiently remove the bearing assembly from its housing while leaving the housing in place.

[00021] A low profile RCD (LP-RCD) system and method for managed pressure drilling, underbalanced drilling, and for drilling with compressible fluids is disclosed. In several embodiments, the LP-RCD is positioned with a LP-RCD housing, both of which are configured to fit within the limited space available on some rigs, typically on top of a BOP or surface casing wellhead in advance of deploying a BOP. The lateral outlet or port in the LP-RCD housing for drilling fluid returns may have a flange having a diameter that is substantially the same as the height of the combined LP-RCD and LP-RCD housing. Advantageously, in one embodiment, an annular BOP seal is integral with a RCD housing so as to eliminate an attachment member, thereby resulting in a lower overall height of the combined BOP/RCD and easy access to the annular BOP seal upon removal of the RCD.

[00022] The ability to fit a LP-RCD in a limited space enables H2S and other dangerous gases to be diverted away from the area immediately beneath the rig floor during drilling
operations. The sealing element of the LP-RCD can be advantageously replaced from above, such as through the rotary table of the drilling rig, eliminating the need for physically dangerous and time consuming work under the drill rig floor. The LP-RCD enables smaller rigs with short substructure heights to drill with compressible fluids, such as air, mist, gas, or foam. One embodiment of the LP-RCD allows rotation of the inserted tubular about its longitudinal axis in multiple planes, which is beneficial if there is misalignment with the wellbore or if there are bent pipe sections in the drill string.

Another embodiment of the LP-RCD allows the LP-RCD to be removably disposed with a LP-RCD housing by rotating a bearing assembly rotating plate. The bearing assembly rotating plate is positioned with the LP-RCD housing on roller bearings. The LP-RCD bearing assembly outer member may have tabs positioned with receiving slots in the LP-RCD housing. The bearing assembly rotating plate may be rotated to a blocking position covering the bearing assembly outer member tabs and blocking removal of the LP-RCD from the LP-RCD housing. The bearing assembly rotating plate may also be rotated to an access position uncovering the bearing assembly outer member tabs and allowing removal of the LP-RCD from the LP-RCD housing.

A spring loaded lock member or pin may be movably disposed with the bearing assembly rotating plate. The lock pin may provide an attachment point for rotation of the plate. The lock pin may be moved to a locked position resisting relative rotation between the bearing assembly rotating plate and the LP-RCD housing. The lock pin may also be moved to an unlocked position allowing relative rotation between the bearing assembly rotating plate and the LP-RCD housing. The bearing assembly rotating plate may be locked in the access position and in a blocking position. In addition, a rod may be positioned through an access opening in the LP-RCD housing into a port in the bearing assembly rotating plate to rotate the bearing assembly rotating plate between blocking and access positions. A bearing assembly retainer plate may be disposed over the bearing assembly rotating plate and attached with the LP-RCD housing to block removal of the bearing assembly rotating plate.

The sealing element may be removably disposed with the LP-RCD bearing assembly by rotating a seal retainer ring. Tabs on a seal support member or ring that supports the seal may be disposed in slots in the LP-RCD bearing assembly inner member. The seal retainer ring may be disposed over the seal support ring. Tabs on the seal retainer ring may be positioned over the seal support ring tabs in the bearing assembly inner member slots. The seal retainer ring and its tabs may be rotated through a horizontal groove to a blocking position blocking removal of the sealing element from the bearing assembly. The seal
retainer ring may also be rotated to an access position allowing removal of the sealing element from the bearing assembly. Spring loaded flipper dogs on the seal retainer ring may be moved to locked positions when the seal retainer ring is in the blocking position preventing relative rotation between the seal retainer ring and the LP-RCD bearing assembly inner member. The flipper dogs may also be moved to unlocked positions allowing relative rotation between the seal retainer ring and the LP-RCD bearing assembly inner member.

Alternatively, the sealing element may be removably disposed with the LP-RCD bearing assembly with a seal support member threadedly attached with the LP-RCD bearing assembly. The seal support member may be locked into position with a seal locking ring threadedly attached with the LP-RCD bearing assembly over the seal support member.

Some embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

FIG. 1A is a side elevational view of a low profile rotating control device (LP-RCD), illustrated in phantom view, disposed in a LP-RCD housing positioned on a well head, along with an exemplary truck mounted drilling rig.

FIG. 1B is a prior art elevational view in partial cut away section of a nipple with a lateral conduit positioned on an annular BOP that is, in turn, mounted on a ram-type BOP stack.

FIG. 1C is similar to FIG. 1B, except that nipple has been replaced with a LP-RCD disposed in a LP-RCD housing, which housing is positioned with an attachment retainer ring mounted on the annular BOP, all of which are shown in elevational view in a cut away section.

FIG. 2 is an elevational section view of a LP-RCD and LP-RCD housing, which LP-RCD allows rotation of the inserted tubular about its longitudinal axis in a horizontal plane, and which LP-RCD housing is attached to a lower housing with swivel hinges.

FIG. 3 is similar to FIG. 2, except that the LP-RCD housing is directly attached to a lower housing.

FIG. 3A is a section view taken along line 3A-3A of FIGS. 2-3, to better illustrate the lateral conduit and its flange.
FIG. 4 is similar to FIG. 2, except that the LP-RCD housing is clamped to an attachment retainer ring that is bolted to a lower housing.

FIG. 5 is an elevational section view of a LP-RCD and LP-RCD housing, which LP-RCD allows rotation of the inserted tubular about its longitudinal axis in multiple planes, and which LP-RCD housing is threadably connected to an attachment retainer ring that is bolted to a lower housing.

FIG. 6 is an elevational section view of a LP-RCD and LP-RCD housing, which LP-RCD allows rotation of the inserted tubular about its longitudinal axis in a horizontal plane, and which LP-RCD bearings are positioned external to the stationary LP-RCD housing so that the outer member is rotatable.

FIG. 6A is a section view taken along line 6A-6A of FIG. 6, showing the cross section of an eccentric bolt.

FIG. 7 is an elevational section view of a nipple with a lateral conduit positioned on an integral combination housing for use with an annular BOP seal and a RCD, and a valve attached with the housing, which housing is mounted on a ram-type BOP stack.

FIG. 8 is an elevational section view of the integral housing as shown in FIG. 7 but with the nipple removed and a LP-RCD installed.

FIG. 9 is a schematic plan view of an integral housing with LP-RCD removed as shown in FIG. 7 with the valves positioned for communication between the housing and a shale shakers and/or other non-pressurized mud treatment.

FIG. 10 is a schematic plan view of an integral housing with LP-RCD installed as shown in FIG. 8 with the valves positioned for communication between the housing and a choke manifold.

FIG. 11 is an elevational section view of a LP-RCD bearing assembly inner member and outer member disposed with a LP-RCD housing, with a bearing assembly retainer plate secured over a bearing assembly rotating plate, and bearing assembly outer member tabs in corresponding LP-RCD housing bearing assembly receiving slots, and a seal retainer ring with seal retainer ring tabs and spring loaded flipper dogs secured in bearing assembly inner member receiving slots over a seal support ring with seal support ring tabs positioned in the corresponding bearing assembly inner member receiving slots, and accumulators with accumulator pistons and springs disposed in the outer member.

FIG. 12 is a detail view of the upper left portion of FIG. 11 to better illustrate the bearing assembly retainer plate secured over the bearing assembly rotating plate, and one bearing assembly outer member tab in a corresponding LP-RCD housing bearing assembly
receiving slot, and the seal retainer ring with a seal retainer ring tab and a spring loaded 
flipper dog secured in a corresponding bearing assembly inner member receiving slot over a 
seal support ring with a seal support ring tab positioned in a corresponding bearing assembly 
inner member receiving slot, and an accumulator with accumulator piston and spring.

[00045] FIG. 11 is a plan view of the LP-RCD of FIG. 11 with the bearing assembly 
retainer plate over the bearing assembly rotating plate both partially cut away to show a LP-
RCD housing rotating plate roller bearing, and in phantom three other LP-RCD housing 
rotating plate roller bearings, four bearing assembly outer member tabs disposed in 
corresponding LP-RCD housing bearing assembly receiving slots, and a bearing assembly 
rotating plate rotation access opening in the LP-RCD housing, a bearing assembly rotating 
plate lock member or pin, the seal retainer ring with seal retainer ring spring loaded flipper 
dogs in the locked position, and in phantom the four seal retainer ring tabs positioned in the 
corresponding bearing assembly inner member receiving slots.

[00046] FIG. 12 is an exploded isometric view of the seal retainer ring with four seal 
retainer ring tabs and two spring loaded flippers over a top partial isometric view of the seal 
support ring disposed with the bearing assembly inner member with the seal support ring tabs 
aligned with corresponding bearing assembly inner member receiving slots.

[00047] FIG. 13 is a partial cross-sectional detail view of an exemplary seal retainer ring 
tab in a bearing assembly inner member receiving slot with a seal retainer ring spring loaded 
flipper dog in the unlocked position.

[00048] FIG. 14 is a similar view as FIG. 15 except with the spring loaded flipper dog in 
the locked position.

[00049] FIG. 15 is an exploded isometric view of the bearing assembly retainer plate with 
an exemplary socket head cap screw, a partial isometric view of the top of the bearing 
assembly outer member with bearing assembly outer member tabs, the bearing assembly 
rotating plate with rotating plate receiving slots and lock pin, and the top of the LP-RCD 
housing with LP-RCD housing rotating plate roller bearings and receiving slots for bearing 
assembly outer member tabs.

[00050] FIG. 16 is partial cross-sectional view of the bearing assembly retainer plate over 
the LP-RCD housing, the bearing assembly rotating plate over a bearing assembly outer 
member tab disposed in a corresponding LP-RCD housing bearing assembly receiving slot, 
with a bearing assembly rotating plate spring loaded lock member or pin disposed with the 
rotating plate and in a locked position with a LP-RCD housing lock pin receiving port.
FIG. 19 is a section view along line 19-19 of FIG. 18 illustrating the LP-RCD housing lock pin receiving groove and two lock pin receiving ports, and a bearing assembly outer member tab in a corresponding LP-RCD housing bearing assembly receiving slot.

FIG. 20 is a section view along line 20-20 of FIG. 18 illustrating the bearing assembly rotating plate spring loaded lock pin in the locked position with the LP-RCD housing lock pin receiving groove and one of the two lock pin receiving ports.

FIG. 21 is a partial elevational view along line 21-21 of FIG. 13 of the bearing assembly retainer plate over the LP-RCD housing, a bearing assembly rotating plate rotation opening in the LP-RCD housing exposing the bearing assembly rotating plate, a rod shown in phantom inserted in a rod insertion port in the bearing assembly rotating plate, also in phantom both an LP-RCD housing rotating plate roller bearing and the bearing assembly rotating plate spring loaded lock pin in the locked position with one of the two lock pin receiving ports.

FIG. 22 is the same view as FIG. 21 except with the spring loaded lock pin is shown in the unlocked position and moved to the right along the LP-RCD housing lock pin receiving groove when the bearing assembly rotating plate is rotated to the right with the inserted rod.

FIG. 23 is a plan view of FIG. 22 with the bearing assembly retainer plate partially cut away to expose the bearing assembly rotating plate rotation opening in the LP-RCD housing and the bearing assembly rotating plate partially cut away to show the rod insertion port.

FIG. 24 is an elevational section view similar to FIG. 11 with an alternative embodiment seal support ring threadedly attached with a LP-RCD bearing assembly inner member, and a seal locking ring threadedly attached with the LP-RCD bearing assembly inner member in a locked position over the seal support ring.

FIG. 25 is a detail view of FIG. 24 showing the seal support ring and seal locking ring.

Generally, a system and method is disclosed for converting a smaller drilling rig with a limited substructure height between a conventional open and non-pressurized mud-return system for hydrostatic pressure drilling, and a closed and pressurized mud-return system for managed pressure drilling or underbalanced drilling, using a low profile rotating control device (LP-RCD), generally designated as 10 in FIG. 1. The LP-RCD is positioned with a desired RCD housing (18, 40, 50, 80, 132, 172, 200). The LP-RCD is further
designated as 10A, 10B, IOC, or 10D in FIGS. 2-8 and 11-13 depending upon the type of rotation allowed for the inserted tubular (14, 110) about its longitudinal axis, and the location of its bearings. The LP-RCD is designated as 10A or 10D if it only allows rotation of the inserted tubular 14 about its longitudinal axis in a substantially horizontal plane, and has its bearings (24, 228) located inside of the LP-RCD housing (18, 40, 50, 172, 200) (FIGS. 2-4, 7-8, and 11-13), 10B if it allows rotation of the inserted tubular 110 about its longitudinal axis in multiple planes (FIGS. 1C and 5), and 10C if it only allows rotation of the inserted tubular about its longitudinal axis in a substantially horizontal plane, and has its bearings (126, 128) located outside of the LP-RCD housing 132 (FIG. 6). It is contemplated that the different types of LP-RCDs (as shown with 10A, 10B, IOC, and 10D) can be used interchangeably to suit the particular application. It is contemplated that the height (H1, H2, 113, H4, 115, H7) of the combined LP-RCD 10 positioned with the LP-RCD housing (18, 40, 50, 80, 132, 200) shown in FIGS. 2-6 and 11-13 may be relatively short, preferably ranging from approximately 15.0 inches (38.1 cm) to approximately 20.77 inches (52.8 cm), depending on the type of LP-RCD 10 and LP-RCD housing (18, 40, 50, 80, 132, 200) as described below, although other heights are contemplated as well.

Turning to FIG. 1A, an exemplary embodiment of a truck mounted drilling rig R is shown converted from conventional hydrostatic pressure drilling to managed pressure drilling and/or underbalanced drilling. LP-RCD 10, in phantom, is shown clamped with radial clamp 12 with an LP-RCD housing 80, which housing 80 is positioned directly on a well head W. The well head W is positioned over borehole B as is known in the art. Although a truck mounted drilling rig R is shown in FIG. 1, other drilling rig configurations and embodiments are contemplated for use with LP-RCD 10 for offshore and land drilling, including semi-submersibles, submersibles, drill ships, barge rigs, platform rigs, and land rigs. Although LP-RCD 10 is shown mounted on well head W, it is contemplated that LP-RCD 10 may be mounted on an annular BOP (See e.g. FIG. 1C), casing, or other housing that are known in the art. For example, LP-RCD 10 could be mounted on a Compact GK® annular BOP offered by the Hydril Company or annular BOPs offered by Cameron, both of Houston, Texas. Although the preferred use of any of the disclosed LP-RCDs 10 is for drilling for oil and gas, any of the disclosed LP-RCDs 10 may be used for drilling for other fluids and/or substances, such as water.

FIG. 1B shows a prior art assembly of a tubular T with lateral conduit O mounted on an annular BOP AB below a rig floor RF. Annular BOP AB is directly positioned on well
head W. A ram-type BOP stack RB is shown below the well head W, and, if desired, over another annular BOP J positioned with casing C in a borehole B.

Turning to FIG. 1C, LP-RCD 10B, which will be discussed below in detail in conjunction with the embodiment of FIG. 5, is mounted below rig floor RF on an annular BOP AB using an attachment member or retainer ring 96, which will also be discussed below in detail in conjunction with FIG. 5. As discussed herein, any of the LP-RCDs 10 can be mounted on the top of an annular BOP AB using alternative attachment means, such as for example by bolting or nuts used with a threaded rod. Although LP-LCD 10B is shown in FIG. 1C, any LP-RCD 10, as will be discussed below in detail, may be similarly positioned with the annular BOP AB of FIG. 1C or a gas handler BOP as proposed in U. S. Patent No. 4,626,135.

FIG. 2 shows tubular 14, in phantom view, inserted through LP-RCD 10A so that tubular 14 can extend through the lower member or housing US below. Tubular 14 can move slidingly through the LP-RCD 10A, and is rotatable about its longitudinal axis in a horizontal plane. The lower housing US in FIGS. 2-6 is preferably a compact BOP, although other lower housings are contemplated as described above. LP-RCD 10A includes a bearing assembly and a sealing element, which includes a radial stripper rubber seal 16 supported by a metal seal support member or ring 17 having a thread 19A on the ring 17 radially exterior surface. The bearing assembly includes an inner member 26, an outer member 28, and a plurality of bearings 24 therebetween. Inner member 26 has a passage with thread 19B on the top of its interior surface for a threaded connection with corresponding thread 19A of metal seal ring 17.

LP-RCD 10A is positioned with an LP-RCD housing 18 with radial clamp 12. Clamp 12 may be manual, mechanical, hydraulic, pneumatic, or some other form of remotely operated means. Bottom or lower flange 23 of LP-RCD housing 18 is positioned and fixed on top of the lower housing HS with a plurality of equally spaced attachment members or swivel hinges 20 that are attached to the lower housing HS with threaded rod/nut 22 assemblies. Swivel hinges 20 can be rotated about a vertical axis prior to tightening of the threaded rod/nut 22 assemblies. Before the threaded rod/nut 22 assemblies are tightened, swivel hinges 20 allow for rotation of the LP-RCD housing 18 so that conduit 29, further described below, can be aligned with the drilling rig’s existing line or conduit to, for example, its mud pits, shale shakers or choke manifold as discussed herein. Other types of connection means are contemplated as well, some of which are shown in FIGS. 3-6 and/or described below.
Stripper rubber seal 16 seals radially around tubular 14, which extends through passage 8. Metal seal support member or ring 17 is sealed with radial seal 21 in inner member 26 of LP-RCD 10A. Inner member 26 and seal 16 are rotatable in a horizontal plane with tubular 14. A plurality of bearings 24 positioned between inner member 26 and outer member 28 enable inner member 26 and seal 16 to rotate relative to stationary outer member 28. As can now be understood, bearings 24 for the LP-RCD 10A are positioned radially inside LP-RCD housing 18. As can also now be understood, the threaded connection between metal seal support ring 17 and inner member 26 allows seal 16 to be inspected for wear and/or replaced from above. It is contemplated that stripper rubber seal 16 may be inspected and/or replaced from above, such as through the rotary table or floor RF of the drilling rig, in all embodiments of the LP-RCD 10, eliminating the need for physically dangerous and time consuming work under drill rig floor RF.

Reviewing both FIGS 2 and 3, LP-RCD housing conduit 29 initially extends laterally from the housing port, generally shown as 30, with the conduit width greater than its height, and transitions, generally shown as 31, to a flange port, generally shown as 32, that is substantially circular, as is best shown in FIG. 3A. The shape of conduit 29 allows access to threaded rod/nut assemblies 22. It is also contemplated that conduit 29 may be manufactured as a separate part from LP-RCD housing 18, and may be welded to or otherwise sealed with LP-RCD housing 18. The cross sectional or flow areas of the two ports (30, 32), as well as the cross sectional or flow areas of the transition 31, are substantially identical, and as such are maximized, as is shown in FIGS. 2, 3 and 3A. However, different cross sectional shapes and areas are contemplated as well. It is further contemplated that conduit 29 and port 30 may be in alignment with a portion of seal 16. A line or conduit (not shown), including a flexible conduit, may be connected to the flange 34. It is also contemplated that a flexible conduit could be attached directly to the port 30 as compared to a rigid conduit 29. It is contemplated that return drilling fluid would flow from the annulus A through ports (30, 32), which are in communication, as shown with arrows in FIG. 2.

Turning now to FIG. 2, it is contemplated that height h1 of the combined LP-RCD 10A positioned with LP-RCD housing 18 would be approximately 16 inches (40.6 cm), although other heights are contemplated. It is further contemplated that outer diameter D1 of flange 34 would be approximately 15 inches (38.1 cm), although other diameters, shapes and sizes are contemplated as well. As can now be understood, it is contemplated that the outer flange diameter D1 may be substantially the same as housing height H1. For the embodiment shown in FIG. 2, it is contemplated that the ratio of diameter D1 to height H1 may be .94.
although other optimized ratios are contemplated as well. In the preferred embodiment, it is contemplated that outer diameter D1 of flange 34 may be substantially parallel with height H1. It is also contemplated that diameter 1/2 of port 32 may be greater than fifty percent of the height H1. It is also contemplated that the seal height SI may be greater than fifty percent of height H1.

[00067] Turning now to FIG. 3, the LP-RCD housing 40 is sealed with radial seal 42 and attached with threaded rod/nut assemblies 22 to lower member or housing US using attachment member 43. Attachment member 43 may have a plurality of radially equally spaced openings 44 for threaded rod/nut assemblies 22. It is contemplated that height 112 of the combined LP-RCD 10A positioned with LP-RCD housing 40 would be 18.69 inches (47.5 cm), although other heights are contemplated. It is contemplated that the outer diameter D1 of flange 34 may be 15.0 inches (38.1 cm), although other diameters, shapes and sizes are contemplated as well. For the embodiment shown in FIG. 3, it is contemplated that the ratio of diameter D1 to height 112 may be .80, although other ratios are contemplated as well. It is also contemplated that seal height S2 may be greater than fifty percent of height 112.

[00068] Turning next to FIG. 4, LP-RCD housing 50 is sealed with radial seal 70 and clamped with radial clamp 62 to an attachment member or retainer ring 64. Clamp 62 may be manual, mechanical, hydraulic, pneumatic, or some other form of remotely operated means. Clamp 62 is received about base shoulder 51 of LP-RCD housing 50 and radial shoulder 65 of retainer ring 64. Before clamp 62 is secured, LP-RCD housing 50 may be rotated so that conduit 60, described below, is aligned with the drilling rig’s existing line or conduit to, for example, its mud pits, shale shakers or choke manifold as discussed herein. Retainer ring 64 is sealed with radial seal 68 and bolted with bolts 66 to lower housing US. The retainer ring has a plurality of equally spaced openings 69 with recesses 67 for receiving bolts 66.

[00069] LP-RCD housing conduit 60 extends from the housing port, shown generally as 52. Conduit 60 has a width greater than its height, and then transitions, generally shown as 54, to a flange port, shown generally as 56, that is substantially circular. The cross sectional or flow areas of the two ports (52, 56), which are in communication, as well as the cross sectional or flow areas of the transition 54 therebetween, are substantially identical. However, different cross sectional areas and shapes are contemplated as well. It is contemplated that conduit 60 and port 52 may be in alignment with a portion of seal 16. A line or conduit (not shown), including a flexible conduit, may be connected to the flange 58. It is also contemplated that a flexible conduit may be attached directly to port 52 as compared to rigid conduit 60. It is contemplated that height 113 of the combined LP-RCD 104 and LP-RCD housing 50 in FIG.
4 would be 19.27 inches (49 cm), although other heights are contemplated. It is further contemplated that outer diameter \( D_1 \) of flange 58 may be 15.0 inches (38.1 cm), although other diameters and sizes are contemplated as well. For the embodiment shown in FIG. 4, it is contemplated that the ratio of diameter \( D_1 \) to height \( H_3 \) may be .78, although other ratios are contemplated as well. It is also contemplated that the seal height \( S_3 \) may be greater than fifty percent of height \( H_3 \).

[00070] FIG. 5 shows a tubular 110, in phantom view, inserted through LP-RCD 10B to lower member or housing US. Tubular 110 is rotatable in its inserted position about its longitudinal axis CL in multiple planes. This is desirable when the longitudinal axis CL of tubular 110 is not completely vertical, which can occur, for example, if there is misalignment with the wellbore or if there are bent pipe sections in the drill string. The longitudinal axis CL of the tubular 110 is shown in FIG. 5 deviated from the vertical axis V of the wellbore, resulting in the tubular 110 rotating about its longitudinal axis CL in a plane that is not horizontal. While it is contemplated that longitudinal axis CL would be able to deviate from vertical axis V, it is also contemplated that longitudinal axis CL of tubular 110 may be coaxial with vertical axis V, and tubular 110 may rotate about its longitudinal axis CL in a horizontal plane.

[00071] LP-RCD 10B includes a bearing assembly and a sealing element, which includes a stripper rubber seal 83 supported by a metal seal support member or ring 85 having a thread 87A on ring 85 radially exterior surface. The bearing assembly includes an inner member 82, an outer ball member 84, and a plurality of bearings 90 therebetween. The inner member 82 has thread 87B on the top of its interior surface for a threaded connection with metal seal support ring 85. Exterior surface 84A of outer ball member 84 is preferably convex. Outer member 84 is sealed with seals 86 to socket member 88 that is concave on its interior surface 88A corresponding with the convex surface 84A of the outer member 84. LP-RCD 10B and socket member 88 thereby form a ball and socket type joint or connection. LP-RCD 10B is held by socket member 88, which is in turn attached to LP-RCD housing 80 with a radial clamp 12. As previously discussed, clamp 12 may be manual, mechanical, hydraulic, pneumatic, or some other form of remotely operated means. It is also contemplated that socket member 88 may be manufactured as a part of LP-RCD housing 80, and not clamped thereto.

[00072] LP-RCD housing 80 is sealed with radial seal 94 and threadably connected with radial thread 92A to attachment member or retainer ring 96. Although radial thread 92A is shown on the inside of the LP-RCD housing 80 and thread 92B on the radially outwardly
facing surface of retainer ring 96, it is also contemplated that a radial thread could alternatively be located on the radially outwardly facing surface of a LP-RCD housing 80, and a corresponding thread on the inside of a retainer ring. In such an alternative embodiment, the retainer ring would be located outside of the LP-RCD housing. As best shown in FIG. 5, the threaded connection allows for some rotation of LP-RCD housing 80 so that the conduit 100, described below, can be aligned with the drilling rig’s existing line or conduit, for example, to its mud pits, shale shakers or choke manifold as discussed herein. Retainer ring 96 is sealed with radial seal 98 and bolted with bolts 114 to the lower member or housing 118. Retainer ring 96 has a plurality of equally spaced openings 117 spaced radially inward of thread 92B with recesses 116 sized for the head of bolts 114.

Stripper rubber seal 83 seals radially around tubular 110, which extends through passage 7. Metal seal support member or ring 85 is sealed by radial seal 89 with inner member 82 of LP-RCD 10B. Inner member 82 and seal 83 are rotatable with tubular 110 in a plane that is 90° from the longitudinal axis or center line CL of tubular 110. A plurality of bearings 90 positioned between inner member 82 and outer member 84 allow inner member 82 to rotate relative to outer member 84. As best shown in FIG. 5, the ball and socket type joint additionally allows outer member 84, bearings 90, and inner member 82 to rotate together relative to socket member 88. As can now be understood, LP-RCD 10B allows the inserted tubular 110 to rotate about its longitudinal axis in multiple planes, including the horizontal plane. Also, as can now be understood, LP-RCD 10B accommodates misaligned and/or bent tubulars 110, and reduces side loading. It is contemplated that stripper rubber seal 83 may be inspected and, if needed, replaced through the rotary table of the drilling rig in all embodiments of the disclosed LP-RCDs, eliminating the need for physically dangerous and time consuming work under the drill rig floor.

LP-RCD housing 80 includes conduit 100 that initially extends from the housing port, generally shown as 102, with conduit 100 having a width greater than its height, and transitions, generally shown as 118, to a flange port, generally shown as 106, that is substantially circular. The cross sectional or flow areas of the two ports (102, 106), which are in communication, as well as the different cross sectional areas of the transition 118 therebetween, are substantially identical, similar to that shown in FIG. 3A. However, different cross sectional areas and shapes are contemplated as well. It is contemplated that conduit 100 and port 102 may be in alignment with a portion of seal 83. A line or conduit (not shown), including a flexible conduit, may be connected to the flange 108. It is also contemplated that outlet conduit 100 may be manufactured as a separate part from LP-RCD
housing 80, and may be welded to LP-RCD housing 80. It is also contemplated that a flexible conduit may be attached directly to port 102 as compared to a rigid conduit 100.

[00075] It is contemplated that height H4 of the combined LP-RCD 10B and the LP-RCD housing 80 in FIG. 5 may be 14.50 inches (38.1 cm), although other heights are contemplated. It is further contemplated that the outer diameter D1 of flange 108 may be approximately 15.0 inches (38.1 cm), although other diameters and sizes are contemplated as well. For the embodiment shown in FIG. 5, it is contemplated that the ratio of diameter D1 to height 114 may be 1.03, although other ratios are contemplated as well. It is also contemplated that seal height S4 may be greater than fifty percent of height H4.

[00076] Turning to FIG. 6, a tubular 14, in phantom view, is shown inserted through LP-RCD IOC to the lower housing 118. Tubular 14 can move sliding! through LP-RCD IOC, and is rotatable about its longitudinal axis in a horizontal plane. LP-RCD IOC includes a bearing assembly and a sealing element, which includes a radial stripper rubber seal 138 supported by metal seal support member or ring 134 attached thereto. The bearing assembly includes top ring 120, side ring 122, eccentric bolts 124, a plurality of radial bearings 128, and a plurality of thrust bearings 126. Metal seal support ring 134 has a plurality of openings, and top ring 120 has a plurality of equally spaced threaded bores 137, that may be aligned for connection using bolts 136. Bolts 136 enable inspection and replacement of stripper rubber seal 138 from above. Other connection means, as are known in the art, are contemplated as well.

[00077] LP-RCD IOC is positioned with an LP-RCD housing 132 with the bearing assembly. As best shown in FIG. 6A, eccentric bolts 124 may be positioned through oval shaped bolt channels 130 through side ring 122. Bolts 124 are threadably connected into threaded bores 131 in top ring 120. When bolts 124 are tightened, side ring 122 moves upward and inward, creating pressure on thrust bearings 126, which creates pressure against radial flange 125 of LP-RCD housing 132, positioning LP-RCD IOC with LP-RCD housing 132. The variable pressure on thrust bearings 126, which may be induced before a tubular 14 is inserted into or rotating about its longitudinal axis in the LP-RCD IOC, allows improved thrust bearing 126 performance. Bolts 124 may be tightened manually, mechanically, hydraulically, pneumatically, or some other form of remotely operated means. As an alternative embodiment, it is contemplated that washers, shims, or spacers, as are known in the art, may be positioned on non-eccentric bolts inserted into top ring 120 and side ring 122. It is also contemplated that spacers may be positioned above thrust bearings 126. Other connection means as are known in the art are contemplated as well.
The bottom or lower flange 163 of LP-RCD housing 132 is positioned on top of lower member or housing HS with a plurality of attachment members or swivel hinges 140 that may be bolted to lower housing HS with bolts 142. Swivel hinges 140, similar to swivel hinges 20 shown in FIG. 2, may be rotated about a vertical axis prior to tightening of the bolts 142. Other types of connections as are known in the art are contemplated as well, some of which are shown in FIGS. 2-5 and/or described above. The stripper rubber seal 138 seals radially around the tubular 14, which extends through passage 6. As discussed above, seal 138 may be attached to the metal seal support member or ring 134, which support ring 134 may be, in turn, bolted to top ring 120 with bolts 136. As can now be understood, it is contemplated that stripper rubber seal 138 may be inspected and, if needed, replaced through the rotary table of the drilling rig in all embodiments of the LP-RCD 10, eliminating the need for physically dangerous and time consuming work under the drill rig floor.

Top ring 120, side ring 122, and stripper rubber seal 138 are rotatable in a horizontal plane with the tubular 14. A plurality of radial 128 and thrust 126 bearings positioned between the LP-RCD housing 132 on the one hand, and the top ring 120 and side ring 122 on the other hand, allow seal 138, top ring 120, and side ring 122 to rotate relative to the LP-RCD stationary housing 132. The inner race for the radial bearings, shown generally as 128, may be machined in the outside surfaces of the LP-RCD housing 132. As can now be understood, the bearings (126, 128) of LP-RCD IOC are positioned outside of LP-RCD housing 132.

LP-RCD housing 132 includes dual and opposed conduits (144, 162) that initially extend from dual and opposed housing ports, generally shown as (146, 160), with a width (preferably 14 inches or 35.6 cm) greater than their height (preferably 2 inches or 5.1 cm), and transition, generally shown as (150, 158), to flange ports, generally shown as (148, 156), that are substantially circular. The shape of conduits (144, 162) allow access to bolts 142. Housing ports (146, 160) are in communication with their respective flange ports (148, 156). The two ports, each of equal area, provide twice as much flow area than a single port. Other dimensions are also contemplated. It is also contemplated that conduits (144, 162) may be manufactured as a separate part from the LP-RCD housing 132, and be welded to the LP-RCD housing 132. The cross sectional or flow areas of the ports (146, 148, 156, 160), as well as the cross sectional or flow areas of the transition between them (150, 158) are preferably substantially identical. However, different cross sectional areas and shapes are contemplated as well. Lines or conduits (not shown), including flexible conduits, may be connected to flanges (152, 154).
It is contemplated that height H5 of the combined LP-RCD IOC positioned with LP-RCD housing 132 in FIG. 6 may be 15.0 inches (38.1 cm), although other heights are contemplated. It is further contemplated that the outer diameter D3 of flanges (152, 154) may be 6.0 inches (15.2 cm), although other diameters and sizes are contemplated as well. For the embodiment shown in FIG. 6, it is contemplated that the ratio of diameter D3 to height H5 may be 0.4, although other ratios are contemplated as well. In the preferred embodiment, it is contemplated that diameter D3 of flanges (152, 154) may be substantially parallel with height H5.

Although two conduits (144, 162) are shown in FIG. 6, it is also contemplated that only one larger area conduit may be used instead, such as shown in FIGS. 1A, 1C, 2-5 and 7. Also, although two conduits (144, 162) are shown only in FIG. 6, it is also contemplated that two conduits could be used with any LP-RCD and LP-RCD housing (18, 40, 50, 80, 132, 172) of the present invention shown in FIGS. 1A, 1C, 2-7 to provide more flow area or less flow area per conduit. It is contemplated that two conduits may be useful to reduce a restriction of the flow of mud returns if the stripper rubber seal (16, 83, 138) is stretched over the outside diameter of an oversized tool joint or if a foreign obstruction, partly restricts the returns into the conduits. The two conduits would also reduce pressure spikes within the wellbore whenever a tool joint is tripped into or out of the LP-RCD with the rig pumps operating. Alternatively, when tripping a tool joint out through the LP-RCD, one of the two conduits may be used as an inlet channel for the pumping of mud from the surface to replace the volume of drill string and bottom hole assembly that is being removed from the wellbore. Otherwise, a vacuum may be created on the wellbore when tripping out, in a piston effect known as swabbing, thereby inviting kicks. It is also contemplated that two conduits may facilitate using lifting slings or fork tracks to more easily maneuver the LP-RCD on location. It is further contemplated, though not shown, that seal 138 may have a height greater than fifty percent of height H5.

Turning to FIG. 7, a nipple or tubular TA with lateral conduit OA is attached with integral housing 172 using radial clamp 12. Integral housing 172 is mounted above a ram-type BOP stack RB shown below the well head WV, and, if desired, over another annular BOP J positioned with casing C in a borehole B. Integral housing 172 contains known components K, such as piston P, containment member 184, and a plurality of connectors 182, for an annular BOP, such as proposed in U.S. Patent No. 4,626,135. Annular seal E along axis DL may be closed upon the inserted tubular 14 with components K, such as proposed in
the '135 patent. It is contemplated that components **K** may preferably be compact, such as those in the Compact GK® annular BOP offered by the Hydril Company of Houston, Texas. [00084] Housing 172 has a lateral conduit **174** with housing port 178 that is substantially circular, and perpendicular to axis DL. Port 178 is above seal E while being in communication with seal E. It is also contemplated that conduit **174** may be manufactured as a separate part from LP-RCD housing **172**, and may be welded to LP-RCD housing **172**. If desired, valve **V1** may be attached to flange 176, and a second lateral conduit 192 may be attached with valve **VI**. Valve VI may be manual, mechanical, electrical, hydraulic, pneumatic, or some other remotely operated means. Sensors S will be discussed below in detail in conjunction with FIG. 8.

[00085] FIG. 7 shows how integral housing **172** may be configured for conventional drilling. It is contemplated that when valve **V1** is closed, drilling returns may flow through open conduit OA to mud pits, shale shakers and/or other non-pressurized mud treatment equipment. It should be noted that the presence of nipple or tubular **TA** with lateral conduit **OA** is optional, depending upon the desired configuration. Should nipple or tubular **TA** with lateral conduit OA not be present, returns during conventional drilling may be taken through port **178** (optional), valve **V1** and conduit **192**. As will be discussed below in conjunction with FIG. 9, other valves (V2, V3) and conduits (194, 196) are also contemplated, in both configurations valve **V1** is opened.

[00086] Turning to FIG. 8, LP-RCD **10A** is now attached with integral housing **172** using radial clamp **12**. LP-RCD **10A** includes a bearing assembly and a sealing element, which includes radial stripper rubber seal 16 supported with metal seal support member or ring **17** having thread **19A** on ring **17** exterior radial surface. While FIG 8 is shown with LP-RCD **10A**, other LP-RCDs as disclosed herein, such as LP-RCD **10B, 10C**, could be used. The bearing assembly includes inner member **26**, outer member **170**, and a plurality of bearings **24** therebetween, which bearings **24** enable inner member **26** to rotate relative to the stationary outer member **170**. Inner member **26** and outer member **170** are coaxial with longitudinal axis DL. Inner member 26 and seal 16 are rotatable with inserted tubular 14 in a horizontal plane about axis DL. Inner member **26** has thread **19B** on the top of its interior surface for a threaded connection with corresponding thread **19A** of the metal seal support member or ring 17. Valve **V1** is attached to flange **176**, and a second lateral conduit **192** is attached with valve VI. It is contemplated that conduit **174** and port **178** may be in alignment with a portion of seal 16. Annular seal E is coaxial with and below seal 16 along axis DL.
FIG. 8 shows how integral housing 172 and LP-RCD 10A may be configured for managed pressure drilling. It is contemplated that valve VI is open, and drilling returns may flow through housing port 178 and lateral conduit 192 to a pressure control device, such as a choke manifold (not shown). As will be discussed below in conjunction with FIG. 10, other valves (V2, V3) and conduits (194, 196) are also contemplated.

As can now be understood, an annular BOP seal E and its operating components K are integral with housing 172 and the LP-RCD 10A to provide an overall reduction in height H6 while providing functions of both an RCD and an annular BOP. Moreover, the need for an attachment member between a LP-RCD 10 and the BOP seal E, such as attachment members (20, 43, 64, 96, 140) along with a bottom or lower flange (23, 163) in FIGS. 2-6, have been eliminated. Therefore, both the time needed and the complexity required for rigging up and rigging down may be reduced, as there is no need to align and attach (or detach) a LP-RCD housing (18, 40, 50, 80, 132), such as shown in FIGS. 2-6, with a lower housing HS using one of the methods previously described in conjunction with FIGS. 2-6. Furthermore, height H6 in FIG. 8 of the integral RCD and annular BOP may be less than a combination of any one of the heights (H1, H2, H3, H4, H5) shown in FIGS. 2-6 and the height of lower housing HS (which preferably is an annular BOP). This is made possible in part due to the elimination of the thicknesses of the attachment member (20, 43, 64, 96, 140), a bottom or lower flange (23, 163) and the top of lower housing HS.

It is contemplated that the operation of the integral housing 172 with annular BOP and LP-RCD 10A, as shown in FIG. 8, may be controlled remotely from a single integrated panel or console. Sensors S in housing 172 may detect pressure, temperature, flow, and/or other information as is known in the art, and relay such information to the panel or console. Such sensors S may be mechanical, electrical, hydraulic, pneumatic, or some other means as is known in the art. Control of LP-RCD 10A from such remote means includes bearing lubrication flow and cooling.

Threaded connection (19A, 19B) between ring 17 and inner member 26 allows seal 16 to be inspected or replaced from above when the seal 16 is worn. Full bore access may be obtained by removing clamp 12 and LP-RCD 10A including bearing assembly (24, 26, 170). Seal E may then be inspected or replaced from above by disconnecting connectors 182 from containment member 184, removing containment member 184 from housing 172 via the full bore access, thereby exposing seal E from above. It is also contemplated that removal of ring 17 while leaving the bearing assembly (24, 26, 170) in place may allow limited access to seal E for inspection from above.
I t should be understood that although housing lower flange 180 is shown over ram-type BOP stack RB in FIGS. 7-8, it may be positioned upon a lower housing, tubular, casing, riser, or other member using any connection means either described above or otherwise known in the art. It should also be understood that although LP-RCD 10A is shown in FIG. 8, it is contemplated that LP-RCD (10B, IOC) may be used as desired with housing 172.

Turning to FIG. 9, integral housing 172 is shown, as in FIG. 7, with no LP-RCD 10A installed. This reflects a configuration in which nipple or tubular TA with lateral conduit OA is not present during conventional drilling. Valve V1 is attached to housing 172 (e.g. such as shown in FIG. 7), and lateral conduit 192 is attached to valve VI. Other conduits (194, 196) and valves (V2, V3) are shown in communication with conduit 192, for example by a T-connection. Valves (V2, V3) may be manual, mechanical, electrical, hydraulic, pneumatic, or some other form of remotely operated means. One conduit 194 leads to a pressure control device, such as a choke manifold, and the other conduit 196 leads to the shale shakers and/or other non-pressurized mud treatment equipment. FIG. 9 shows a configuration for conventional drilling, as it is contemplated that valves (VI, V3) may be open, valve V2 may be closed, and drilling returns may flow through housing port 178 (shown in FIG. 7) and conduits (192, 196) to mud pits, shale shakers and/or other non-pressurized mud treatment equipment.

Turning to FIG. 10, integral housing 172 is shown, as in FIG. 8, with LP-RCD 10A installed and attached. FIG. 10 shows a configuration for managed pressure drilling, as it is contemplated that valves (VI, V2) are open, valve V3 is closed, and drilling returns may flow through housing port 178 and conduits (192, 194) to a pressure control device, such as a choke manifold.

It is contemplated that the desired LP-RCD 10 may have any type or combination of seals to seal with inserted tubulars (14, 110), including active and/or passive stripper rubber seals. It is contemplated that the connection means between the different LP-RCD housings (18, 40, 50, 80, 132, 172) and the lower member or housing US shown in FIGS. 2-6 and/or described above, such as with threaded rod/nut assemblies 22, bolts (22, 66, 114, 142), swivel hinges (20, 140), retainer rings (64, 96), clamps 62, threads 92, and seals (42, 68, 94, 98), may be used interchangeably. Other attachment methods as are known in the art are contemplated as well.

Method of Use
[00096] LP-RCD 10 may be used for converting a smaller drilling rig or structure between conventional hydrostatic pressure drilling and managed pressure drilling or underbalanced drilling. A LP-RCD (10A, 10B, IOC) and corresponding LP-RCD housing (18, 40, 50, 80, 132, 172) may be mounted on top of a lower member or housing HS (which may be a BOP) using one of the attachment members and connection means shown in FIGS. 2-6 and/or described above, such as for example swivel hinges 140 and bolts 142 with LP-RCD IOC. Integral housing 172 may be used to house an annular BOP seal E, and a desired LP-RCD (10A, 10B, IOC) may then be positioned with housing 172 using one of the means shown in FIGS. 2-8 and/or described above, such as for example using radial clamp 12 with LP-RCD 10A.

[00097] Conduit(s) may be attached to the flange(s) (34, 58, 108, 152, 154, 176), including the conduit configurations and valves shown in FIGS. 9 and 10. The thrust bearings 126 for LP-RCD IOC, if used, may be preloaded with eccentric bolts 124 as described above. Drill string tubulars (14, 110), as shown in FIGS. 2-8, may then be inserted through a desired LP-RCD 10 for drilling or other operations. LP-RCD stripper rubber seal (16, 83, 138) rotates with tubulars (14, 110), allows them to slide through, and seals the annular space A so that drilling fluid returns (shown with arrows in FIG. 2) will be directed through the conduit(s) (29, 60, 100, 144, 162, 174). When desired the stripper rubber seal (16, 83, 138) may be inspected and, if needed, replaced from above, by removing ring (17, 85, 134). Moreover, for housing 172, shown in FIGS. 7-10, annular BOP seal E may be inspected and/or removed as described above.

[00098] For conventional drilling using housing 172 in the configuration shown in FIG. 7 with no LP-RCD 10 installed, valve V1 may be closed, so that drilling returns flow through lateral conduit OA to the mud pits, shale shakers or other non-pressurized mud treatment equipment. For conventional drilling with the conduit/valve configuration in FIG. 9 (and when nipple or tubular TA with lateral conduit OA is not present), valves (VI, V3) are open, valve V2 is closed so that drilling returns may flow through housing port 178 and conduits (192, 196) to mud pits, shale shakers and/or other non-pressurized mud treatment equipment. For managed pressure drilling using housing 172 in the configuration shown in FIG. 8 with LP-RCD 10A installed and attached, valve V1 is opened, so that drilling returns flow through housing port 178 and conduit 192 to a pressure control device, such as a choke manifold. For managed pressure drilling with the configuration in FIG. 10, valves (VI, V2) are open, valve V3 is closed so that drilling returns may flow through housing port 178 and conduits (192, 194) to a pressure control device, such as a choke manifold.
As is known by those knowledgeable in the art, during conventional drilling a well may receive an entry of water, gas, oil, or other formation fluid into the wellbore. This entry occurs because the pressure exerted by the column of drilling fluid or mud is not great enough to overcome the pressure exerted by the fluids in the formation being drilled. Rather than using the conventional practice of increasing the drilling fluid density to contain the entry, integral housing 172 allows for conversion in such circumstances, as well as others, to managed pressure drilling.

To convert from the configurations shown in FIGS. 7 and 9 for conventional drilling to the configurations shown in FIGS. 8 and 10 for managed pressure drilling, conventional drilling operations may be temporarily suspended, and seal E may be closed upon the static inserted tubular 14. It is contemplated that, if desired, the operator may kill the well temporarily by circulating a weighted fluid prior to effecting the conversion from conventional to managed pressure drilling. The operator may then insure that no pressure exists above seal E by checking the information received from sensor S. If required, any pressure above seal E may be bled via a suitable bleed port (not shown). Valve V1 may then be closed. If present, the nipple or tubular TA may then be removed, and the LP-RCD 10 positioned with housing 172 as shown in FIG. 8 using, for example, clamp 12. Valves (VI, V2) are then opened for the configuration shown in FIG. 10, and valve V3 is closed to insure that drilling returns flowing through housing port 178 are directed or diverted to the choke manifold. Seal E may then be opened, drilling operations resumed, and the well controlled using a choke and/or pumping rate for managed pressure drilling. If the operator had previously killed the well by circulating a weighted fluid, this fluid may then be replaced during managed pressure drilling by circulating a lighter weight drilling fluid, such as that in use prior to the kick. The operation of the integral annular BOP and LP-RCD 10A may be controlled remotely from a single integrated panel or console in communication with sensor S. Should it be desired to convert back from a managed pressure drilling mode to a conventional drilling mode, the above conversion operations may be reversed. It should be noted, however, that removal of LP-RCD 10A may not be necessary (but can be performed if desired). For example, conversion back to conventional drilling may be simply achieved by first ensuring that no pressure exists at surface under static conditions, then configuring valves VI, V2 and V3 to divert returns directly to the shale shakers and/or other non-pressurized mud treatment system, as shown in FIG. 9.

Interlocking LP-RCD System
Turning to FIG. 11, LP-RCD housing 200 is disposed over lower member or housing 202 with LP-RCD housing retainer ring or attachment member 206. Lower housing 202 may be a compact BOP, although other lower housings are contemplated. LP-RCD housing attachment member 206 has a plurality of openings for receiving bolts 204. Attachment member blocking shoulder 205 may be disposed with LP-RCD housing blocking shoulder 262. It is contemplated that LP-RCD housing attachment member 206 may be a 13 5/8 inch - 5000 psi flange designed as an Other End Connector (OEC) in accordance with both the American Petroleum Institute (API) Specification 6A and the American Society of Mechanical Engineers (ASME) Section VIII Division 2 Pressure Vessel Code. However, other sizes, shapes, strengths, designs, specifications and codes are contemplated. Before bolts 204 are tightened, LP-RCD housing attachment member 206 allows for the rotation of LP-RCD housing 200 about a vertical axis so that LP-RCD housing outlet conduit 266 and flange 258 may be aligned with the drilling rig's existing line or conduit to, for example, its mud pits, shale shakers or choke manifold. Other attachment means for LP-RCD housing 200 to lower member 202 are contemplated, including any means shown in any of the other Figures for any of the other embodiments, such as swivel hinges (FIGS. 2 and 6), direct attachment (FIG. 3) and clamping (FIG. 4).

As shown in FIGS. 11 and 12, LP-RCD 10D comprises a bearing assembly and a sealing element. The bearing assembly includes an inner member 226, an outer member 212, and a plurality of bearings 228 therebetween. It is contemplated that bearings 228 may be tapered to take both thrust and radial loads. However, other bearing shapes are contemplated, including cylindrical with no taper. The sealing element includes a radial stripper rubber seal 230 supported by a seal support member or ring 232. Seal support ring 232 may be metal, although other materials are contemplated. The stripper rubber seal 230 is advantageously disposed radially inward from bearings 228 within the inside bore of the bearing assembly inner member 226.

The seal element is removably positioned with bearing assembly inner member 226 with seal support ring tabs 234 in bearing assembly inner member receiving slots 236. Seal support ring tabs 234 in bearing assembly inner member receiving slots 236 resist relative rotation between seal support ring 232 and bearing assembly inner member 226. Seal retainer ring 238 is disposed over seal support ring 232 with seal retainer ring tabs 240 also in bearing assembly inner member receiving slots 236. As can be better understood from FIG. 14, when seal retainer ring 238 is initially positioned with bearing assembly inner member 226, seal retainer ring tabs 240 may be aligned with bearing assembly inner member receiving slots.
236 in the access position that allows seal support ring 232 to be positioned with or removed from bearing assembly inner member 226. Seal support ring tabs 234 are disposed in bearing assembly inner member receiving slots 236 providing support for seal support ring 232 and preventing relative rotation between seal support ring 232 and bearing assembly inner member 226.

[000105] After lowering seal retainer ring tabs 240 into bearing assembly inner member receiving slots 236 over seal support ring tabs 234, seal retainer ring 238 may then be rotated counterclockwise about a vertical axis moving seal retainer ring tabs 240 through the horizontal grooves 236A of receiving slots 236 from the access position to the blocking position. In the blocking position, at least some portion of seal retainer ring tabs 240 are in horizontal grooves 236A of receiving slots 236, thereby blocking removal of seal support ring 232 from bearing assembly inner member 226. When seal retainer ring 238 may not be rotated counterclockwise any further with seal retainer ring tabs 240 in the horizontal grooves 236A of receiving slots 236, seal retainer ring 238 is in its locked position. As can be understood, the locked position for seal retainer ring 238 is also a blocking position.

[000106] Spring loaded flipper dogs 242 are in their unlocked positions as shown in FIG. 15 when seal retainer ring 238 is not in its locked position. When seal retainer ring 238 is in its locked position after being rotated completely counterclockwise with seal retainer ring tabs 240 in the horizontal grooves 236A of receiving slots 236, flipper dogs 242 may be moved into their locked positions as shown in FIGS. 11-14 and 16. Flipper dogs 242 are disposed in bearing assembly inner member receiving slots 236 when in their locked positions. As can now be understood, the seal element 230 may be blocked and resisted from removal from the bearing assembly by moving seal retainer ring 238 counterclockwise to its blocking position. Seal retainer ring 238 may be locked with and prevented from rotating relative to the bearing assembly by moving the flipper dogs 242 to their locked positions. Other means for removably attaching the seal element with the bearing assembly are contemplated, including any means shown in any of the other Figures for any of the other embodiments, such as threads (FIGS. 2-5) and bolts (FIG. 6). To remove the seal 230 from the bearing assembly, flipper dogs 242 may be unlocked and seal retainer ring 238 may be rotated clockwise about a vertical axis moving seal retainer ring tabs 240 through the horizontal grooves 236A of receiving slots 236 from the blocking position to the access position. The access position allows for removal of seal 230 from the bearing assembly. Seal retainer ring 238 and seal support ring 232 with seal 230 may then be removed.
Returning to FIGS. 11-12, LP-RCD 10D is removably positioned with LP-RCD housing 200 with bearing assembly outer member tabs 214 in LP-RCD housing receiving slots 218. Bearing assembly rotating plate 210 is disposed with LP-RCD housing 200 over bearing assembly outer member tabs 214. Bearing assembly retainer plate 208 is positioned over bearing assembly rotating plate 210 and attached with LP-RCD housing 200 with exemplary screws 216. Other attachment means are contemplated.

As can be better understood from FIG. 17, bearing assembly rotating plate 210 may be positioned with LP-RCD housing 200 on LP-RCD housing rotating plate roller bearings 250. Rotating plate receiving slots 254 may be aligned with LP-RCD housing receiving slots 218 when bearing assembly rotating plate 210 is first disposed or assembled with LP-RCD housing 200. When rotating plate receiving slots 254 are aligned with LP-RCD housing receiving slots 218, then bearing assembly rotating plate 210 is in the access position. To position the bearing assembly with LP-RCD housing 200, bearing assembly outer member tabs 214 may be moved through rotating plate receiving slots 254 for placement in LP-RCD housing receiving slots 218. As can now be understood, the bearing assembly rotating plate access position allows access to the bearing assembly for its placement with or removal from the LP-RCD housing 200.

With bearing assembly outer member tabs 214 supported in LP-RCD housing receiving slots 218, bearing assembly rotating plate 210 may be rotated clockwise about a vertical axis, such as with lock member or pin 252 as an attachment point or other means, which are described in detail below with FIGS. 18-23, so that rotating plate receiving slots 254 are not in alignment with LP-RCD housing receiving slots 218. When rotating plate receiving slots 254 are not aligned with LP-RCD housing receiving slots 218, then bearing assembly rotating plate 210 is in the blocking position. As can now be understood, the bearing assembly rotating plate 210 in the blocking position blocks and resists removal of the LP-RCD 10D from the LP-RCD housing 200. Bearing assembly rotating plate 210 in the access position allows and does not resist removal of the LP-RCD 10D from the LP-RCD housing 200.

As will be discussed in detail below with FIGS. 18-23, when bearing assembly rotating plate 210 is rotated fully clockwise about a vertical axis, it may be locked in the blocking position. In the locked position, bearing assembly outer member tabs 214 are covered by bearing assembly rotating plate 210, and the bearing assembly is blocked from being removed from LP-RCD housing 200. When bearing assembly rotating plate 210 is fully rotated counterclockwise about a vertical axis, it may also be locked in the access
position with lock pin 252. When lock pin 252 is in its locked position, it resists relative rotation between bearing assembly rotating plate 210 and LP-RC’D housing 200. Other means for removably attaching the bearing assembly with the LP-RCD housing 200 are contemplated, including any means shown in any of the other Figures for any of the other embodiments, such as a clamping (FIGS. 2-5).

[000111] Returning to FIGS. 11 and 12, upper 268A and lower 268B radial seal sleeves are disposed between bearing assembly inner member 226 and outer member 212. As best shown in FIG. 12, each seal sleeve (268.4, 268B) may be held between an inner seal sleeve retaining ring 272.4 and an outer seal sleeve retainer ring 272B. Seal sleeve retaining rings (272.4, 272B) may be Spirolox retaining rings available from Smalley® Steel Ring Company of Lake Zurich, Illinois, although other types of retaining rings are contemplated. To remove lower seal sleeve 268B from the bearing assembly inner member 226, its inner seal sleeve retaining ring 272.4 may be removed to allow access for a pulling tool to grab the back side of the lower seal sleeve 268B.

[000112] An inner radial seal 270A and an outer radial seal 270B may be disposed with each seal sleeve (268.4, 268B). Inner seals 270.4 and outer seals 270B may be hydrodynamic rotary Kalsi Seals® available from Kalsi Engineering, Inc. of Sugar Land, Texas, although other types of seals are contemplated. Bearing assembly outer member 212 may have a top packing box 274 and a bottom packing box 276. The bearings 228 may be preloaded with top packing box 274, and the top packing box 274 and the preload held in place with angled beating assembly set screws 278. There may be a top packing box port 280 and a bottom packing box port 282 for tilling with lubricant. It is contemplated that if an outer seal 270B fails, the leak rate of the lubricant may be lowered or slowed with the use of the adjacent port (280, 282).

[00013] Cylindrical shaped accumulators (220, 220.4) may be disposed in bearing assembly outer member 212. An accumulator piston (222, 222.4) and spring (224, 224.4) are disposed in each accumulator (220, 220.4). Although two accumulators (220, 220.4) are shown, it is also contemplated that there may be only one accumulator, or preferably a plurality of spaced apart accumulators that are disposed radially outward from the bearings 228 in bearing assembly outer member 212. The plurality of accumulators may be spaced a substantially equal distance apart from each other. It is contemplated that there may be thirty (30) spaced apart accumulators (220, 220.4) of 1 in (2.54 cm) diameter, although other amounts and sizes are contemplated. It is also contemplated that there may be only one accumulator.
extending continuously radially around the entire circumference of bearing assembly outer member 212. Such an accumulator may have a single ring shaped piston and a spring.

As best shown in FIG. 12, each accumulator (220, 220A) may contain a lubricant that may be supplied through its accumulator lubricant port (256, 256A) to bearings 228. Springs (224, 224A) may supply the force to keep the bearing pressure above the wellbore pressure. It is contemplated that there may be a minimum lubricant pressure of 15 psi higher than the environment pressure, although other amounts are contemplated. Pistons (222, 222A) may move vertically to adjust as temperature changes affect the lubricant volume. The maximum piston stroke may be 3.46 inches (8.79 cm), although other piston strokes are contemplated. As can now be understood, the bearing assembly may be self-lubricating. An external source of lubrication during operation may not be required. It is contemplated that accumulators (220, 220A) may collectively have a 200 hour or greater supply of lubricant.

As can also now be understood, accumulators (220, 220A) advantageously are positioned radially outside of the bearings 228, allowing for a shorter LP-RCD housing height H7 than would be possible if the accumulators (220, 220A) were located directly above and below the bearings 228.

Accumulators (220, 220A) may be in radial alignment with the bearings 228. Seal retainer ring 238 and seal 230 may be directly radially inward of and in alignment with the bearing assembly. Accumulators (220, 220A) may be directly radially outward of and in alignment with the bearings 228. Bearing assembly rotating plate 210 may be directly radially outward of and in alignment with the bearing assembly. LP-RCD housing 200 may be directly radially outward of and in alignment with the bearing assembly. LP-RCD housing 200 may also be directly radially outward of and in alignment with the bearing assembly rotating plate 210. Bearing assembly retainer plate 208 may be directly radially outward of and in alignment with the bearing assembly. Bearing assembly retainer plate 208 may also be at least partially radially outward of the bearing assembly rotating plate 210.

Returning to FIG. 11, LP-RCD housing height H7 may be approximately 20.77 inches (52.8 cm), although other LP-RCD housing heights H7 are contemplated. As shown in FIG. 11, the combined LP-RCD IOD positioned with LP-RCD housing 200 may be height H7. Outer diameter D5 of LP-RCD housing outlet flange 258 may be approximately 15 inches (38.1 cm), although other diameters are contemplated. The ratio of outlet flange diameter D5 to LP-RCD housing height H7 may be .7 (or 70%) or higher, although other optimized ratios are contemplated. Outer diameter D5 of outlet flange 258 may be substantially parallel with LP-RCD housing height H7. Diameter 1)6 of LP-RCD housing
outlet port 260 may be approximately 7.06 inches (17.9 cm), although other diameters are contemplated. The ratio of LP-RCD housing outlet port diameter D6 to LP-RCD housing height H7 may be .3 (or 30%) or higher, although other optimized ratios are contemplated. Bearing assembly height B1 may be 9.62 inches (24.4 cm), although other bearing assembly heights are contemplated. The ratio of bearing assembly height B1 to LP-RCD housing height H7 may be .45 (or 45%) or higher, although other optimized ratios are contemplated. Seal height S5 may be approximately 8.5 inches (21.6 cm) or higher, although other seal heights are contemplated. The ratio of seal height S5 to LP-RCD housing height H7 may be .4 (or 40%) or higher, although other optimized ratios are contemplated.

The diameter of LP-RCD housing well bore 264 may be approximately 13.63 inches (34.6 cm), although other diameters are contemplated. Although outlet conduit 266 is shown unitary or monolithic with LP-RCD housing 200, it is also contemplated that outlet conduit 266 may not be unitary with LP-RCD housing 200 and may be welded to the side of LP-RCD housing 200. Distance D7 between the bearing assembly and the inside surface of LP-RCD housing 200 may be 1.69 inches (4.3 cm), although other distances are contemplated.

In FIG. 13, bearing assembly retainer plate 208 is disposed with LP-RCD housing 200 with a plurality of screws 216. Bearing assembly rotating plate 210 may be rotated about a vertical axis on LP-RCD housing rotating plate rollers or roller bearings 250 with lock member or pin 252 as an attachment point, which will be described below in detail with FIGS. 18-20, or with a rod through bearing assembly rotating plate rotation access opening 284 in LP-RCD housing 200, which will be described below in detail with FIGS. 21-23. As shown in FIG. 13, bearing assembly outer member tabs 214 are disposed in and supported by LP-RCD housing receiving slots 218. Bearing assembly rotating plate 210 has been rotated clockwise to a blocking position as the rotating plate receiving slots 254 are not in alignment with the LP-RCD housing receiving slots 218. Bearing assembly rotating plate 210 has been fully rotated in the clockwise direction so that it may be locked with lock member 252. Advantageously, bearing assembly rotating plate 210 blocks the removal of LP-RCD bearing assembly from LP-RCD housing 200 since bearing assembly rotating plate 210 covers the bearing assembly outer member tabs 214. With lock member 252 is in its locked position, as will be described below with FIGS. 18-20, lock member 252 advantageously resists bearing assembly rotating plate 210 from rotating to the access position.

Seal retainer ring 238 is also in a blocking position and is locked with bearing assembly inner member 226. Seal support ring 232 (not shown) with seal 230 are held by
bearing assembly inner member 226. Seal retainer ring tabs 240 are disposed in and supported by bearing assembly inner member receiving slots 236. Seal retainer ring tabs 240 have been lowered into bearing assembly inner member receiving slots 236 over seal support ring tabs 234 (not shown) in the access position. Seal retainer ring 238 has then been rotated counterclockwise about a vertical axis to a blocking position with seal retainer ring tabs 240 in horizontal grooves 236A of receiving slots 236. Seal retainer ring 238 has been fully rotated in a counterclockwise direction with seal retainer ring tabs 240 in horizontal grooves 236A of receiving slots 236. Seal retainer ring flipper dogs 242 are in their locked positions in bearing assembly inner member receiving slots 236 as shown in detail view in FIG. 16. In FIG. 15, seal retainer ring flipper dogs 242 are in their unlocked position. Advantageously, the flipper dogs 242 in their locked positions resist rotation of seal retainer ring 238 relative to bearing assembly inner member 226, thereby keeping seal retainer ring 238 from moving to its access position. Flipper dogs 242 in their unlocked positions do not resist rotation of seal retainer ring 238 relative to bearing assembly inner member 226.

Turning to FIG. 18, lock member or pin 252 is disposed in bearing assembly rotating plate spring cavity 294. Lock member 252 has an eye hook ring 290 attached with lock pin shaft 292. Lock member 252 is spring loaded with spring 296 in cavity 294. Lock member 252 is in its first locked position with lock pin shaft 292 extending in LP-RCD housing lock pin receiving port 286A. Advantageously, lock pin 252 in its first locked position resists rotation of bearing assembly rotating plate 210 relative to LP-RCD housing 200. Lock pin 252 in its unlocked position, such as shown in FIG. 22, does not resist the rotation of bearing assembly rotating plate 210 relative to LP-RCD housing 200. Spring 296 exerts a downward force on pin shaft 292 to resist retraction of shaft 292 from port 286A.

As best shown in FIG. 19, LP-RCD housing lock pin receiving groove 288 is disposed in LP-RCD housing 200 between the two LP-RCD housing lock pin receiving ports (286A, 286B). Lock pin 252 is in its locked position when lock pin shaft 292 is extending into either of the two LP-RCD housing lock pin receiving ports (286A, 286B). Bearing assembly outer member tab 214 is positioned in LP-RCD housing receiving slot 218. Although it is not shown in FIG. 19, bearing assembly rotating plate receiving slots 254 are not aligned with LP-RCD housing receiving slots 218 since rotating plate 210 is in the locked position and a blocking position covering tabs 214.

As best shown in FIGS. 20 and 22, to move lock pin 252 between ports (286A, 286B), a force with an upward component may be applied to ring 290, such as may be applied with a hook extending downward from the rig floor hooking ring 290, to lilt the end of lock
pin shaft 292 out of port 286 A. The upward force must be sufficient to overcome the downward force of spring 296 on lock pin 252. The bearing assembly rotating plate 210 may then be rotated counterclockwise about a vertical axis, or to the right in FIGS. 20 and 22, with a force with a horizontal component applied to lock pin ring 290 so that the lifted lock pin shaft 292 moves along groove 288 from port 286A to port 286B. The upward force may then be released from lock pin ring 290 to allow the downward force of the spring 296 to move pin shaft 292 into port 286B, placing lock pin 252 in its second locked position. As can now be understood, bearing assembly rotating plate 210 may be locked in a blocking position when lock pin 252 is in its first locking position. Bearing assembly rotating plate 210 may also be locked in the access position when lock pin 252 is in its second locking position. Lock pin 252 is in its unlocked position when shaft 292 is not resting in either port (286 A, 286B), such as for example in FIG. 22.

[000123] In FIG. 21, an alternative embodiment for rotating or moving bearing assembly rotating plate 210 is shown. Bearing assembly rotating plate 210 is disposed on LP-RCD housing rotating plate rollers or roller bearings 250. Bearing assembly retainer plate 208 is disposed with LP-RCD housing 200. Bearing assembly rotating plate rotation access opening 284 in LP-RCD housing 200 allows access to the side of bearing assembly rotating plate 210 through LP-RCD housing 200. Two rod insertion ports (302A, 302B) are disposed in the side of bearing assembly rotating plate 210. However, other numbers of rod insertion ports are contemplated, including only one port. If bearing assembly rotating plate 210 needs to be rotated, it is contemplated that it may be rotated exclusively using lock pin 252 as an attachment point. However, if bearing assembly rotating plate 210 cannot be moved by a force applied to lock pin 252 alone, such as if rotation is resisted by damaged roller bearings 250 or other causes, then as shown in FIG. 21 a rod 300 may be inserted into rod insertion port 302A and bearing assembly rotating plate 210 moved or rotated about a vertical axis with a force applied to rod 300.

[000124] In FIG. 22, lock pin 252 has been lifted to allow rotation of bearing assembly rotating plate 210 with rod 300 in port 302A. In FIGS. 22 and 23, rod 300 has moved rotating plate 210 to the right or counterclockwise from its position in FIG. 21. It is also contemplated that there may be no lock pin 252, and that a rod 300 in a port (302A, 302B) may be the exclusive means of rotating bearing assembly rotating plate 210. Turning to FIG. 23, moving bearing assembly rotating plate 210 counterclockwise about a vertical axis or to the right as shown moves bearing assembly rotating plate 210 toward its access position since
rotating plate receiving slots 254 are moved toward alignment with bearing assembly outer member tabs 214.

[000125] In FIGS. 24 and 25, alternative embodiment seal support ring or member 232A supports seal 230A. Thread 310 of seal support ring 232A is engaged with thread 312 of LP-RCD bearing assembly inner member 226A. Seal support ring receiving ports 318 may be used for rotating seal support ring 232A to threadingly attach with LP-RCD bearing assembly inner member 226A. Ports 318 may be threaded. Seal locking ring 314 is in a locked position over seal support ring 232A. Seal locking ring 314 may be removed to allow access to seal support ring 232A. Thread 316 of seal locking ring 314 is engaged with thread 312 of LP-RCD bearing assembly inner member 226A. FIG. 24 is otherwise the same as FIG. 11. As can now be understood, seal 230A of FIGS. 24 and 25 may be removably attached with the LP-RCD bearing assembly. Seal locking ring 314 may be used to prevent seal support ring 232A from becoming loosened or unattached from LP-RCD bearing assembly inner member 226A.

[000126] Interlocking LP-RCD Method of Use
[000127] To assemble the LP-RCD 10D, seal 230 may be disposed with the bearing assembly by aligning and resting seal support ring tabs 234 in bearing assembly inner member receiving slots 236. Seal retainer ring 238 may be disposed over seal support ring 232 by aligning and lowering seal retainer ring tabs 240 over seal support ring tabs 234 in bearing assembly inner member receiving slots 236. Seal retainer ring 238 may be rotated in a counterclockwise direction about a vertical axis with seal retainer ring tabs 240 in horizontal grooves 236A of bearing assembly inner member receiving slots 236. After further counterclockwise rotation is resisted, seal retainer ring flipper dogs 242 may be moved to their locked positions in bearing assembly inner member receiving slots 236. As can now be understood, seal 230 is locked with the bearing assembly and blocked from removal. [000128] The bearing assembly may be disposed with LP-RCD housing 200 by rotating bearing assembly rotating plate 210 to its access position in which bearing assembly rotating plate receiving slots 254 are aligned with LP-RCD housing receiving slots 218. Bearing assembly rotating plate 210 may be locked in its access position with lock pin 252 in its second locking position. The bearing assembly may be positioned with the LP-RCD housing 200 by aligning and lowering bearing assembly outer member tabs 214 through the bearing assembly receiving slots 254. The bearing assembly outer member tabs 214 may be supported in LP-RCD housing receiving slots 218. Lock member or pin 252 may then be retracted from its second locking position to the unlocked position. Bearing assembly
rotating plate 210 may be rotated clockwise about a vertical axis to the blocking position. 
Lock pin 252 may then be moved to its first locking position to prevent relative rotation of 
the bearing assembly rotating plate 210 with LP-RCD housing 200. As can now be understood, 
the bearing assembly is locked with the LP-RCD housing 200 and is blocked from removal. 
[000129] LP-RCD 10D may be used for converting a smaller drilling rig or structure 
between conventional hydrostatic pressure drilling and managed pressure drilling or 
underbalanced drilling. LP-RCD 10D and corresponding LP-RCD housing 200 as shown in 
FIG. 11 may be mounted on top of a lower member or housing (202, HS) (which may be a 
BOP) using one of the attachment members and connection means shown in FIGS. 2-6 and 
11 and/or described above, such as for example LP-RCD housing attachment member 206 in 
FIG. 11 and swivel hinges 140 in FIG. 6. 

[000130] Outlet flange 258 may be aligned as necessary before LP-RCD housing 200 is fully 
tightened against the lower member (202, HS). Conduit(s) may be attached to the outlet 
flange 258, including the conduit configurations and valves shown in FIGS. 9 and 10. The 
bearings 228 for LP-RCD 101) may be preloaded with top packing box 274, and the top 
packing box 274 and the preload held in place with angled bearing assembly set screws 278. 
Drill string tubulars may be inserted through the LP-RCD 10D for drilling or other 
operations. LP-RCD stripper rubber seal 230 rotates with tubulars, allows them to slide 
through, and seals the annular space so that drilling fluid returns will be directed through the 
outlet conduit 266. During operations, the bearings 228 may be self lubricated with 
accumulators (220, 220A). 

[000131] When desired, the stripper rubber seal 230 may be inspected and, if needed, 
replaced from above, by removing seal retainer ring 238 and lifting out seal support ring 232 
and seal 230. Seal retainer ring 238 may be removed by moving flipper dogs 242 from their 
locked positions as shown in FIG. 16 to their unlocked positions as shown in FIG. 15, and 
then rotating seal retainer ring 238 clockwise about a vertical axis from a blocking position to 
its access position. When seal retainer ring tabs 240 are aligned over seal support ring tabs 
234 in the access position, then seal retainer ring 238 and seal support ring 232 may be lifted 
out of the bearing assembly. The process may be reversed to assemble seal 230 back into the 
bearing assembly. 

[000132] When desired, the bearing assembly may be inspected and, if needed, replaced 
from above, by rotating bearing assembly rotating plate 210 counterclockwise about a vertical 
axis from a blocking position to its access position either with lock pin 252 as an attachment 
point, or with a rod 300 in rod receiving port 302A in bearing assembly rotating plate 210, or
with both. As shown in FIG. 22, lock pin 252 may be lifted from its first locked position then
turned to the right or counterclockwise about a vertical axis to move rotating plate 210 on
rotating plate roller bearings 250. Lock pin 252 may be moved from a first locked position in
port 286A to a second locked position in port 286B. Bearing assembly rotating plate
receiving slots 254 may be aligned with LP-RCD housing receiving slots 218 in the access
position, uncovering bearing assembly outer member tabs 214. The bearing assembly may
then be lifted from the LP-RCD housing 200. The process may be reversed to assemble
the bearing assembly back into the bearing assembly. To remove lower seal sleeve 268B from
the bearing assembly inner member 226, its inner seal sleeve retaining ring 272A may be
removed to allow access for a pulling tool to grab the back side of the lower seal sleeve 268B.

If alternative embodiment seal support ring or member 232A and seal 230A shown
in FIGS. 24 and 25 are used, seal 230A may be removably attached with LP-RCD bearing
assembly inner member 226A by threadedly attaching or unattaching seal support ring 232A
with LP-RCD bearing assembly inner member 226A. Seal locking ring 314 may be threaded
into the locked position over seal support ring 232A as shown in FIGS. 24 and 25 to prevent
seal support ring 232A from loosening during operations. When seal 230A needs to be
removed, seal locking ring 314 may be unthreaded, and then seal support ring 232A with seal
230A may be unthreaded and removed.

Although the invention has been described in terms of preferred embodiments as
set forth above, it should be understood that these embodiments are illustrative only and that
the claims are not limited to those embodiments. Those skilled in the art will be able to make
modifications and alternatives in view of the disclosure which are contemplated as falling
within the scope of the appended claims. Each feature disclosed or illustrated in the present
specification may be incorporated in the invention, whether alone or in any appropriate
combination with any other feature disclosed or illustrated herein.
CLAIMS:
1. A system for forming a borehole using a rotatable tubular, the system comprising:
   a housing disposed above the borehole, wherein said housing having a height and a port;
   a bearing assembly having an inner member and an outer member and being removably positioned with said housing, wherein said inner member rotatable with the tubular relative to the outer member, said inner member having a passage through which the tubular may extend;
   a bearing assembly rotating plate rotatably disposed with said housing and configured to rotate between a blocking position blocking removal of said bearing assembly from said housing, and an access position for removal of said bearing assembly from said housing;
   a seal to sealably engage the rotatable tubular with said bearing assembly; and
   a plurality of bearings disposed between said inner member and said outer member.
2. The system of claim 1, further comprising an attachment member for attaching said housing with a lower member, wherein said housing having a blocking shoulder, said attachment member having a blocking shoulder, and said attachment member blocking shoulder positioned with said housing blocking shoulder to attach said housing with said lower member.
3. The system of claim 1, wherein said housing further comprising a flange having an outer diameter and a flange port, said housing port communicating with said flange port, and said housing flange outer diameter being at least seventy percent of said housing height.
4. The system of claim 1, further comprising:
   a support member for supporting said seal with said bearing assembly, wherein said seal being removable from said bearing assembly; and
   a seal retainer ring rotatably disposed with said bearing assembly and configured to rotate between a blocking position blocking removal of said seal from said bearing assembly, and an access position for removal of said seal from said bearing assembly.
5. The system of claim 1, further comprising:
a support member supporting said seal with said bearing assembly, wherein said support member threadedly attached with said bearing assembly; and

a seal locking ring threadedly disposed with said bearing assembly and configured to rotate between a locked position blocking removal of said seal from said bearing assembly, and an access position allowing removal of said seal from said bearing assembly.

6. The system of claim 1, further comprising:

a plurality of accumulators configured to lubricate at least one of said plurality of bearings, and each of said accumulators spaced apart from each other accumulator and disposed radially outward from said plurality of bearings.

7. The system of claim 1, further comprising:

a plurality of rollers disposed between said housing and said bearing assembly rotating plate; and

a bearing assembly retainer plate disposed with said housing and configured to block removal of said bearing assembly rotating plate from said housing.

8. The system of claim 1, wherein said bearing assembly rotating plate further comprising:

a lock member movable between a locked position to resist relative rotation between said bearing assembly rotating plate and said housing, and an unlocked position to allow relative rotation between said bearing assembly rotating plate and said housing.

9. The system of claim 1, wherein said housing having an opening for radial access to said bearing assembly rotating plate, said housing access opening sized to receive a rod to be connected with said bearing assembly rotating plate.

10. The system of claim 1, wherein said bearing assembly outer member further comprising a plurality of tabs corresponding with a plurality of slots in said housing.

11. A rotating control apparatus, comprising:

a bearing assembly having an outer member and an inner member disposed with said outer member, said inner member having a passage;

a seal supported from said inner member and with the passage;

a plurality of bearings disposed between said outer member and said
inner member so that one member is rotatable relative to the other member;
said seal extending radially inward from said plurality of bearings;
a housing to receive at least a portion of said bearing assembly, wherein said housing having a height and a housing port; and
a housing flange having an outer diameter and a flange port, wherein said housing port communicating with said housing flange port, and said housing flange outer diameter being at least seventy percent of said housing height.

12. The apparatus of claim 11, further comprising:
   a bearing assembly rotating plate rotatably disposed with said housing
   and configured to rotate between a blocking position blocking removal of said bearing assembly from said housing, and an access position for removal of said bearing assembly from said housing.

13. The apparatus of claim 11, further comprising:
   a support member for supporting said seal with said bearing assembly, wherein said seal being removable from said bearing assembly; and
   a seal retainer ring rotatably disposed with said bearing assembly and configured to rotate between a blocking position blocking removal of said seal from said bearing assembly, and an access position for removal of said seal from said bearing assembly.

14. The system of claim 11, further comprising:
   a support member supporting said seal with said bearing assembly, wherein said support member threadedly attached with said bearing assembly; and
   a seal locking ring threadedly disposed with said bearing assembly and configured to rotate between a locked position blocking removal of said seal from said bearing assembly, and an access position allowing removal of said seal from said bearing assembly.

15. The apparatus of claim 11, further comprising:
   a plurality of accumulators configured to lubricate at least one of said plurality of bearings, and each of said accumulators spaced apart from each other accumulator and disposed radially outward from said plurality of bearings.
16. A system for managing the pressure of a fluid in a borehole while sealing a rotatable tubular, the system comprising:

- a housing communicating with the borehole, said housing having a height and a housing port;
- a bearing assembly having an outer member and a rotatable inner member having a passage through which the tubular may extend, said bearing assembly removably disposed with said housing;
- a plurality of bearings between said inner member and said outer member;
- a seal supported by said inner member for sealing with the rotatable tubular;
- said housing port communicating with and aligned with said seal;
- a support member for removably supporting said seal with said inner member; and
- a seal retainer ring rotatably disposed with said inner member and configured to rotate between a blocking position blocking removal of said seal from said inner member, and an access position for removal of said seal from said inner member.

17. The system of claim 16, wherein said housing further comprising a flange having a flange port with a flange port diameter, said housing port communicating with said flange port, and said flange port diameter being at least thirty percent of said housing height.

18. The system of claim 16, further comprising:

- a bearing assembly rotating plate rotatably disposed with said housing and configured to rotate between a blocking position blocking removal of said bearing assembly from said housing, and an access position for removal of said bearing assembly from said housing.

19. The system of claim 16, wherein said support member further comprising a plurality of tabs corresponding with a plurality of slots in said inner member.

20. The system of claim 16, wherein said seal retainer ring further comprising:

- a lock member movable between a locked position to resist relative rotation between said seal retainer ring and said bearing assembly, and an unlocked position to allow relative rotation between said seal retainer ring and said bearing assembly.

21. A rotating control apparatus, the apparatus comprising:
a housing having a housing height and a housing port;
a bearing assembly having an inner member and an outer member and
being removably positioned with said housing, wherein said inner member
rotatable relative to the outer member and having a passage;
a seal having a seal height supported from said bearing assembly;
a plurality of bearings disposed between said inner member and said
outer member; and
a plurality of accumulators configured to lubricate at least one of said
plurality of bearings, and each of said accumulators spaced apart from each
other accumulator and disposed radially outward from said plurality of
bearings and in said bearing assembly outer member.

22. The apparatus of claim 21, wherein said seal height is greater than forty
percent of said housing height.

23. The apparatus of claim 21, wherein each of said accumulators comprising a
piston and a spring.

24. The apparatus of claim 21, wherein said plurality of accumulators comprising
at least twenty accumulators spaced apart equidistance.

25. A method for assembling a rotating control device, comprising:
   aligning a bearing assembly rotating plate with a housing;
   moving a bearing assembly having an inner member and an outer
   member with bearings therebetween through said bearing assembly rotating
   plate and into the housing, wherein said bearing assembly inner member is
   rotatable relative to said bearing assembly outer member;
   rotating said bearing assembly rotating plate relative to said housing;
   and
   blocking removal of said bearing assembly from said housing after the
   step of rotating.

26. The method of claim 25, wherein the step of rotating is clockwise.

27. The method of claim 25, further comprising:
   rotating said bearing assembly rotating plate counterclockwise to an
   access position; and
   removing said bearing assembly from said housing.

28. The method of claim 25, wherein said housing comprising a flange having a
flange port, and further comprising:
aligning said flange port; and
attaching said housing with a lower member after the step of aligning said flange port.

29. The method of claim 25, further comprising:
removably supporting a seal with said inner member with a seal support member;
aligning a seal retainer plate with the bearing assembly;
rotating said seal retainer ring relative to said inner member; and
blocking removal of said seal from said inner member after the step of rotating said seal retainer ring.

30. The method of claim 29, further comprising locking said seal retainer ring with said inner member.

31. The method of claim 25, further comprising:
lubricating at least one of said bearings with one of a plurality of spaced apart accumulators disposed radially outward of said bearing assembly outer member.

32. A method for assembling a rotating control device, comprising:
aligning a seal with a bearing assembly having an inner member and an outer member with bearings therebetween, wherein said bearing assembly inner member is rotatable relative to said bearing assembly outer member;
supporting said seal from said inner member;
aligning a seal retainer ring with said inner member;
moving said seal retainer ring into said inner member;
rotating said seal retainer ring relative to said inner member; and
blocking removal of said seal from said inner member after the step of rotating.

33. The method of claim 32, wherein the step of rotating is counterclockwise.

34. The method of claim 32, further comprising:
rotating said seal retainer ring clockwise to an access position for removal of said seal from said inner member.

35. The method of claim 32, further comprising:
rotating a bearing assembly rotating plate relative to said housing; and
blocking removal of said bearing assembly from said housing after the step of rotating said bearing assembly rotating plate.
36. The method of claim 32, further comprising locking said seal retainer ring with said inner member.
FIG. 1B
(PRIOR ART)