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(54) LOCK SYSTEM FOR A BLOWOUT PREVENTER

(57) A lock system for a blowout preventer (BOP) includes an annular body, a movable rod positioned within the annular body, and an annular chamber defined between the annular body and the movable rod along a radial axis. The lock system also includes a locking sleeve positioned within the annular chamber, wherein the locking sleeve is configured to deform along the radial axis from a first position in which the locking sleeve blocks movement of the movable rod relative to the annular body and a second position in which the locking sleeve enables movement of the movable rod relative to the annular body. The lock system further includes a preload system.

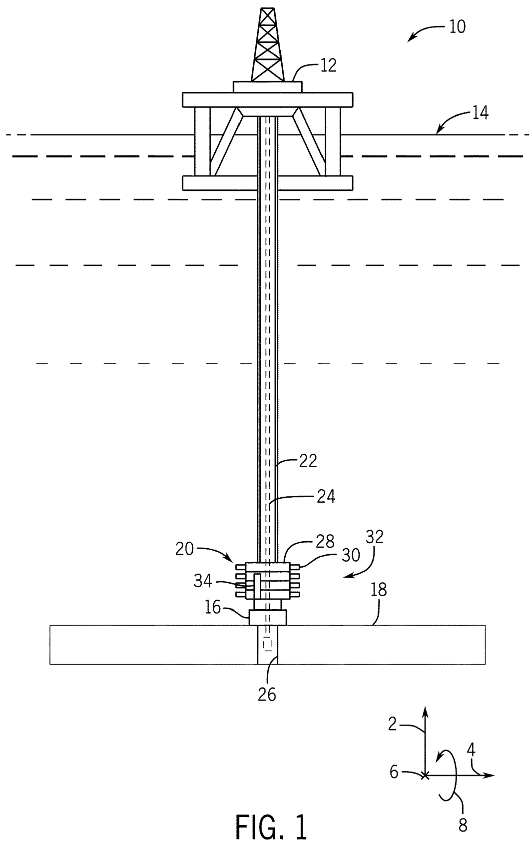

FIG. 1

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Description

BACKGROUND

[0001] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0002] A blowout preventer (BOP) stack is installed on a wellhead to seal and control an oil and gas well during drilling operations. A drill string may be suspended inside a drilling riser from a rig through the BOP stack into the wellbore. During drilling operations, a drilling fluid is delivered through the drill string and returned up through an annulus between the drill string and a casing that lines the wellbore. In the event of a rapid invasion of formation fluid in the annulus, commonly known as a "kick," a movable component within the BOP stack may be actuated to seal the annulus and to control fluid pressure in the wellbore, thereby protecting well equipment disposed above the BOP stack.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Various features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying figures in which like characters represent like parts throughout the figures, wherein:

FIG. 1 is a schematic diagram of an offshore system that has a blowout preventer (BOP) and a lock system, in accordance with an embodiment of the present disclosure;

FIG. 2 is perspective view of a lock assembly of the lock system of FIG, 1, in accordance with an embodiment of the present disclosure;

FIG. 3 is a cross-sectional side view of a portion the BOP of FIG. 1 and the lock assembly of FIG. 2, wherein the BOP is in a closed position, in accordance with an embodiment of the present disclosure;

FIG. 4 is a cross-sectional side view of the portion of the BOP of FIG. 3 and the lock assembly of FIG. 2, wherein the BOP is in an open position, in accordance with an embodiment of the present disclosure;

FIG. 5 is a cross-sectional perspective view of the lock assembly of FIG. 2, in accordance with an embodiment of the present disclosure;

FIG. 6 is a cross-sectional perspective view of a preload system of the lock assembly of FIG. 2, wherein a piston of the preload system is in a first piston position, in accordance with an embodiment of the present disclosure;

FIG. 7 is a cross-sectional perspective view of the preload system of FIG. 6, wherein the piston of the preload system is in a second piston position, in accordance with an embodiment of the present disclosure;

FIG. 8 is a cross-sectional perspective view of a portion of the preload system of FIGS. 6 and 7, in accordance with an embodiment of the present disclosure;

FIG. 9 is a cross-sectional perspective view of an unlocking system of the lock assembly of FIG. 2, in accordance with an embodiment of the present disclosure; and

FIG. 10 is a perspective view of a portion of the lock assembly of FIG. 2, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0004] One or more specific embodiments of the present disclosure will be described below. These described embodiments are only exemplary of the present disclosure. Additionally, in an effort to provide a concise description of these exemplary embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0005] The present disclosure is generally directed to blowout preventers (BOPs). In particular, the present disclosure is generally directed to a BOP that includes a lock system that is configured to adjust between an unlocked configuration in which the lock system enables movement of rams of the BOP and a locked configuration in which the lock system blocks movement of the rams of the BOP.

[0006] While certain embodiments disclosed herein relate to an offshore system (e.g., subsea system) to facilitate discussion, it should be understood that the BOP and the lock system may be used in an on-shore system (e.g., land-based system). Furthermore, while certain embodiments disclosed herein relate to a drilling system that may be used to carry out drilling operations to facilitate discussion, it should be appreciated that the BOP and the lock system may be adapted for use in any of a variety of contexts and during any of a variety of operations. For example, the BOP and the lock system may be used in a production system and/or in a pressure control equipment (PCE) stack that is positioned vertically above a wellhead during various intervention operations (e.g., inspection or service operations), such as wireline operations in which a tool supported on a wireline is lowered through the PCE stack to enable inspection and/or maintenance of a well. In such cases, the BOP may be adjusted from an open configuration to a closed configuration (e.g., to seal about the wireline extending through the PCE stack) to isolate the environment, as well as other surface equipment, from pressurized fluid within the well. In the present disclosure, a conduit may be any of a variety of tubular or cylindrical structures, such as a drill string, wireline, Streamline™, slickline, coiled tubing, or other spoolable rod.

[0007] FIG. 1 is an embodiment of an offshore system 10 (e.g., offshore drilling system; subsea system). To facilitate discussion, the offshore system 10 and its components may be described with reference to a vertical axis or direction 2, an axial axis or direction 4, a lateral axis or direction 6, and a circumferential axis or direction 8. The offshore system 10 includes a vessel or platform 12 at a sea surface 14 and a wellhead 16 positioned at a sea floor 18. The offshore system 10 also includes a BOP stack 20 positioned above the wellhead 16, and a riser 22 that extends between the BOP stack 20 and the vessel or platform 12. Downhole operations may be carried out by a conduit 24 that extends from the vessel or platform 12, through the riser 22, through the BOP stack 20, through the wellhead 16, and into a wellbore 26.

[0008] The BOP stack 20 may include one or more BOPs 28 stacked along the vertical axis 2 relative to one another. One or more of the BOPs 28 may include opposed rams that are configured to move along the axial axis 4 toward and away from one another to adjust the BOP 28 between an open position and a closed position. In the open position, the opposed rams may be withdrawn from a central bore of the BOP 28, and thus, the BOP 28 may enable fluid flow through the central bore. In the closed position, the opposed rams may be positioned in the central bore of the BOP 28, and thus, the BOP 28 may block fluid flow through the central bore.

[0009] The BOP stack 20 may include any suitable number of BOPs 28. Additionally, the BOP stack 20 may include any of a variety of different types of BOPs 28 (e.g., having shear rams, blind rams, blind shear rams, pipe rams). For example, in certain embodiments, the BOP stack 20 may include one or more BOPs 28 having opposed shear rams or blades configured to sever the conduit 24 to block fluid flow through the central bore and/or one or more BOPs 28 having opposed pipe rams configured to engage the conduit 24 to block fluid flow through the central bore (e.g., through an annulus about the conduit 24).

[0010] As shown, the BOP stack 20 may include one or more lock assemblies 30. For example, one lock assembly 30 may be positioned at each end (e.g., along the axial axis 4) of the BOP 28. The lock assembly 30 may be part of a lock system 32 that operates to adjust components of the lock assembly 30 to achieve an unlocked configuration in which the lock assembly 30 enables movement of the rams of the BOP 28 and a locked configuration in which the lock assembly 30 blocks movement of the rams of the BOP 28. In operation, while the BOP 28 is in the open position, the closed position, and/or any position therebetween, the lock assembly 30 may be in the locked configuration to maintain the BOP 28 in the open position, the closed position, and/or the position therebetween. However, the lock assembly 30 may be adjusted to the unlocked configuration to enable the rams of the BOP 28 to move relative to the central bore to move between the open position and the closed position. For example, in response to an indication of an increased pressure within the wellbore 26 or another indication (e.g., operator input; test cycle) that the rams of the BOP 28 should be moved from the open position to the closed position, the lock system 32 may operate to adjust the lock assembly 30 from the locked configuration to the unlocked configuration to enable the rams of the BOP 28 to move from the open position to the closed position, thereby sealing the central bore of the BOP 28. A pressure within an accumulator 34 (e.g., pressure vessel) of the BOP 28 may be used to drive the rams of the BOP 28 to move from the open position to the closed position. As discussed in more detail below, the pressure within the accumulator 34 may also be used to adjust various components and/or actuators associated with the lock assembly 30 (e.g., to adjust the lock assembly 30 between the locked configuration and the unlocked configuration).

[0011] FIG. 2 is a perspective view of an embodiment of the lock assembly 30. As shown, the lock assembly 30 includes a lock portion 40 and an actuator portion 42 coupled to one another. The lock assembly 30 may extend from a first end 44 (e.g., distal end) to a second end 46 (e.g., proximal end) along the axial axis 4. The first end 44 may include a first end plate 48 (e.g., annular plate; radially-extending portion), and the second end 46 may include a second end plate 50 (e.g., annular plate; radially-extending portion) that is configured to contact and/or couple to a housing of the BOP 28 (FIG. 1) via one or more fasteners (e.g., threaded fasteners, such as bolts). An intermediate plate 52 (e.g., annular plate; radially-extending portion) may be positioned between (e.g., at an intersection of) the lock portion 40 and the actuator portion 42. A rod 54 (e.g., bar, cylinder) may extend from the first end 44 of the lock assembly 30. The rod 54 may be coupled to and may move with a connector

56 that extends from the second end 46 of the lock assembly 30. As discussed in more detail below, the connector 56 may be configured to contact and/or to couple to a ram of the BOP 28. Additionally, the lock portion 40 may include a body 60 (e.g., annular body; cylinder), a preload system 62, a pressure intensifier 64, and a tubing 66 that is fluidly coupled to the pressure intensifier 64. The pressure intensifier 64 may receive a first pressure and output a second pressure that is greater than the first pressure (e.g., about 2 to 5 times greater than the first pressure). For example, the first pressure may be about 34 Megapascal (MPa) or 5,000 pound-force per square inch (psi), and the second pressure may be about or greater than 70 MPa or 10,000 psi. The first pressure may be provided by a fluid from the accumulator 34 of FIG. 1, and the pressure intensifier 64 may multiply this pressure to the second pressure that is an appropriate pressure for effective operation of the lock assembly 30 (e.g., to provide an unlocking pressure, which may substantially correspond to or be greater than a pressure of a viscoelastic fluid in an annular chamber of the lock assembly 30, or which may otherwise facilitate adjusting the lock assembly 30 to the unlocked configuration).

[0012] FIG. 3 is a cross-sectional side view of a portion of the BOP 28 having the lock assembly 30. In the illustrated embodiment, the BOP 28 is in a closed position 70 (e.g., closed configuration) in which rams 72, 74 (e.g., ram bodies) of the BOP 28 are positioned within a central bore 76 of the BOP 28, seal against the conduit 24 that extends through the central bore 76 (e.g., seal an annular space about the conduit 24), and/or block a fluid flow through the central bore 76 of the BOP 28. The rams 72, 74 may move toward and away from one another to adjust the BOP 28 between the closed position 70 and an open position in which the rams 72, 74 are withdrawn from the central bore 76 of the BOP 28 and/or enable the fluid flow through the central bore 76 of the BOP 28. To facilitate discussion, one lock assembly 30 is shown in FIG. 3 (and in FIG. 4); however, it should be appreciated that each ram 72, 74 of the BOP 28 may be coupled to and locked via a respective lock assembly 30.

[0013] As shown, the lock assembly 30 is coupled to the ram 72, such as via the connector 56. Furthermore, the connector 56 is coupled to the rod 54, such as via one or more connecting elements. For example, the connector 56 may be coupled to a piston 80, which may be coupled to a connecting rod 82. The connecting rod 82 may also be coupled to the rod 54. The one or more connecting elements may be coupled to one another via any of a variety of suitable connecting interfaces, such as threaded interfaces, bolts, welds, or the like. For example, the connector 56 may be coupled to the piston 80 via a threaded interface 84, the piston 80 may be coupled to the connecting rod 82 via a threaded interface 86, and the connecting rod 82 may be coupled to the rod 54 via one or more fasteners 88 (e.g., bolts). It should be appreciated that the connector 56 may be coupled to the rod 54 via any number of suitable connecting elements. In some embodiments, the connector 56 and the rod 54 (and any intermediate connecting elements, such as the piston 80) may be formed as a unitary structure (e.g., one-piece, such as via additive manufacturing techniques). Regardless of the number of elements and the structure, the connector 56, the rod 54, and any intermediate connecting elements may form a movable rod 90 that is configured to move along the axial axis 4 with the ram 72 and relative to the body 60 of the lock assembly 30 and/or relative to a body 92 (e.g., housing) of the BOP 28 while the lock assembly 30 is in the unlocked configuration.

[0014] In particular, while the lock assembly 30 is in the unlocked configuration, the movable rod 90 may be driven to move along the axial axis 4 via any suitable drive system, such as a piston system 94 that includes the piston 80 within the actuator portion 42 of the lock assembly 30. The piston 80 may be positioned within an actuator body 96 (e.g., annular body) that defines a chamber 98. The piston 80 divides the chamber 98 into a first portion 100 (e.g., sealed portion) and a second portion 102 (e.g., sealed portion). In operation, a fluid from a fluid source (e.g., a source of accumulator pressure; a fluid pressurized via the accumulator 34 of FIG. 1) that is provided to the first portion 100 of the chamber 98 may exert a force on the piston 80 to drive the piston 80 in a direction of arrow 104 (e.g., toward the central bore 76), to thereby drive the movable rod 90 and the ram 72 attached thereto in the direction of arrow 104. Similarly, while the lock assembly 30 is in the unlocked configuration, the fluid from the fluid source that is provided to the second portion 102 of the chamber 98 may exert a force on the piston 80 to drive the piston 80 in a direction of arrow 106 (e.g., away from the central bore 76), to thereby drive the movable rod 90 and the ram 72 attached thereto in the direction of arrow 106. It should be appreciated that various seals 108 (e.g., annular seals) may be provided to seal the chamber 98, as well as the portions 100, 102 of the chamber 98.

[0015] As noted above, the lock assembly 30 may adjust between the unlocked configuration in which the movable rod 90 is able to move along the axial axis 4 and the locked configuration in which the movable rod 90 is blocked from moving along the axial axis 4. The lock portion 40 includes the body 60 that circumferentially surrounds the rod 54. The lock portion 40 also includes the first end plate 48 and the intermediate plate 52. The first end plate 48 is shown as a physically separate structure that is coupled to the body 60 (e.g., to a radially-expanded end portion 110 of the body 60) via one or more fasteners 112 (e.g., bolts), and the intermediate plate 52 is shown as integrally-formed (e.g., one-piece) with the body 60. However, it should be appreciated that these either of these plates 48, 52 may be physically separate or integrally-formed with the body 60.

[0016] The rod 54 extends along the axial axis 4 from a first rod end 114 to a second rod end 116. In some embodiments, the first rod end 114 may extend beyond the first end plate 48 along the axial axis 4, and thus, the first rod end 114 may provide a visual indication (e.g., visible to an operator; visible or detectable via a camera, such as a camera of a remotely operated vehicle [ROV] or an autonomous underwater vehicle [AUV]) that is indicative of a position of the ram 72 relative to the central bore 76 (e.g., because the ram 72 is coupled to and moves with the rod 54). In some embodiments, an indicator element 118 (e.g., cap) may be provided at and/or coupled to the first rod end 114. The indicator element 118 and/or the rod 54 may have features (e.g., color, reflective coating, circumferentially-extending lines, other marks) that facilitate visualization by the operator, the camera, or the like and/or determination of the position of the ram 72 relative to the central bore 76 (e.g., by the operator and/or by a processor that processes images obtained by the camera). For example, a radially-outer surface 120 of the rod 54 may have the features and/or an axially-facing end surface 122 of the indicator element 118 may have the features.

[0017] The lock portion 40 of the lock assembly 30 may also include a locking sleeve 130 (e.g., annular sleeve). The locking sleeve 130 may be formed from any suitable material (e.g., steel) and may have any suitable thickness that enables the locking sleeve 130 to perform the functions disclosed herein (e.g., deform under pressure while withstanding a pulling force from translation of the rod 54). The locking sleeve 130 is positioned between the rod 54 and the body 60 along a radial axis 132 of the lock assembly 30. Furthermore, the locking sleeve 130 may be positioned within an annular chamber 134 defined between the rod 54 and the body 60 along the radial axis 132 of the lock assembly 30. The locking sleeve 130 may not move along the axial axis 4 relative to the body 60, but at least a center portion 136 of the locking sleeve 130 may flex (e.g., bend, move) along the radial axis 4 relative to the body 60. For example, the first end plate 48 and a stop 138 (e.g., annular stop or sleeve) may contact the locking sleeve 130 and block movement of the locking sleeve 130 along the axial axis 4 relative to the body 60; however, the annular chamber 134 may enable movement of at least the center portion 136 of the locking sleeve 130 along the radial axis 4 relative to the body 60. In some embodiments, the locking sleeve 130 is configured such that a radially-inner surface of the locking sleeve 130 flexes and/or directly contacts a radially-outer surface of the rod 54 over an entire length (e.g., along the axial axis 4) of the locking sleeve 130 when exposed to sufficient pressure, as described below.

[0018] A fluid (e.g., a locking fluid; a high-viscosity fluid; a viscoelastic fluid) is trapped within a first portion 140 (e.g., locking portion; radially-outer portion) of the annular chamber 134 between the locking sleeve 130 and the body 60 along the radial axis 132. The fluid may be a viscoelastic fluid, such as a viscoelastic fluid with a silicone base and/or that is more compressible than hydraulic fluid and/or that is more deformable under pressure than hydraulic fluid (e.g., the hydraulic fluid that is used in an unlocking system, as described below). While the fluid within the first portion 140 is at a first pressure (e.g., locking pressure), the fluid may drive the locking sleeve 130 radially-inwardly against the rod 54 (e.g., to engage the rod 54; shrink the locking sleeve 130 onto to the rod 54). In this way, contact and friction between the locking sleeve 130 and the rod 54 may block movement of the rod 54 (e.g., completely stop or prevent movement of the rod 54) relative to the locking sleeve 130 and the body 60 (as well as relative to the central bore 76 and the body 92 of the BOP 28).

[0019] However, when the fluid within the first portion 140 of the annular chamber 134 is at a second pressure (e.g., unlocking pressure, lower than the first pressure), the locking sleeve 130 may release from and/or disengage from the rod 54 (e.g., move radially-outwardly from the rod 54). Thus, there may be insufficient contact and friction between the locking sleeve 130 and the rod 54 to block movement of the rod 54 relative to the locking sleeve 130 and the body 60 coupled thereto. Accordingly, the rod 54 may be able to move relative to the locking sleeve 130 and the body 60 (e.g., upon application of a fluid into the first portion 100 of the chamber 98 to drive the piston 80).

[0020] To facilitate movement of the rod 54 relative to the body 60, a fluid (e.g., unlocking fluid; hydraulic fluid) may be provided to a second portion 142 (e.g., unlocking portion; radially-inner portion) of the annular chamber 134 between the locking sleeve 130 and the rod 54 along the radial axis 132. The fluid may form a film (e.g., oil film) that separates the locking sleeve 130 from the rod 54, thereby resulting in and/or working in conjunction with the second pressure within the first portion 140 of the annular chamber 134 to cause insufficient contact and friction between the locking sleeve 130 and the rod 54 and enabling movement of the rod 54 relative to the locking sleeve 130 and the body 60.

[0021] FIG. 4 is a cross-sectional side view of the BOP 28 having the lock assembly 30, and the BOP 28 is in an open position 150 (e.g., open configuration) in which the rams 72, 74 (e.g., ram bodies) of the BOP 28 are withdrawn from the central bore 76 of the BOP 28 and/or enable a fluid flow through the central bore 76 of the BOP 28. As shown, the movable rod 90 moves with the ram 72 relative to the body 60 of the lock assembly 30 and relative to the body 92 of the BOP 28. The other illustrated features are described in detail above with respect to FIG. 3.

[0022] It should be appreciated that the lock assembly 30 may be in the locked configuration (e.g., in which the locking sleeve 130 blocks movement of the movable rod 90) while the BOP 28 is in the closed position 70 of FIG. 3, while the BOP 28 is in the open position 150 of FIG. 4, and/or any position therebetween. The lock assembly 30 may be in the unlocked configuration (e.g., in which the locking sleeve 130 does not block movement of the movable rod 90) to enable the ram 72 to move along the axial axis 4, such as to adjust the BOP 28 between the closed position 70 and the open position 150.

[0023] FIG. 5 is a cross-sectional perspective view of the lock assembly 30 to illustrate certain features described above with respect to FIGS. 2-4. For example, the lock assembly 30 includes the locking portion 40 and associated components, as well as the actuator portion 42 and associated components. The movable rod 90 may include one or more components (e.g., the rod 54, the connector 56, the piston 80) that are configured to couple to the ram 72 of the BOP 28 (FIGS. 3 and 4). A pressure of a fluid within a first portion 140 of the annular chamber 134 may vary, which may cause an amount of friction between the locking sleeve 130 and the movable rod 90 to vary, thereby adjusting the lock assembly 30 between the locked configuration and the unlocked configuration. Other structural features and operational characteristics disclosed herein may be utilized, such as the fluid within the second portion 142 of the annular chamber 134 to facilitate adjusting the lock assembly 30 to the unlocked configuration. The other illustrated features are described in detail above with respect to FIG. 3.

[0024] FIGS. 6 and 7 are cross-sectional perspective views of a portion of the lock assembly 30. In FIG. 6, a preload piston 160 of the preload system 62 is in a first position 162 (e.g., low-pressure position, unlocked position). In FIG. 7, the preload piston 160 is in a second position 164 (e.g., high-pressure position, locked position). The preload system 62 may be configured to adjust and/or to maintain a pressure within the first portion 140 of the annular chamber 134.

[0025] As shown, the preload system 62 may include a preload cylinder 170, a fluid passageway 172, a pressure sensor 174, and the preload piston 160. A first end portion 176 of the preload cylinder 170 may be coupled to and/or supported by the first end plate 48 of the lock assembly 30, and a second end portion 178 of the preload cylinder 170 may be coupled to and/or supported by the body 60 (e.g., a radially-outer wall or a side wall 180 of the body 60). As shown, the preload cylinder 170 may have a bend 182 (e.g., approximately 90 degree bend) that enables the first end portion 176 to be supported by and accessible (e.g., to an operator, an ROV, or an AUV) at the first end plate 48, and that enables the second end portion 178 to be supported by the body 60 to place the fluid passageway 172 in fluid communication with the annular chamber 134. Together the fluid passageway 172 and the annular chamber 134 may form a pressurized fluid chamber 184.

[0026] While the preload piston 160 is within the in fluid passageway 172 and while a valve 190 (e.g., check valve; one-way valve) is closed, the pressurized fluid chamber 184 may be closed (e.g., the fluid is trapped). In operation, the preload piston 160 may move between the first position 162 of FIG. 6 and the second position 164 of FIG. 7, which may adjust the volume of the pressurized fluid chamber 184, and may thus also adjust the pressure of the fluid that is trapped within the pressurized fluid chamber 184. For example, the preload piston 160 may initially be in the first position 162 of FIG. 6. In some cases, while the preload piston 160 is in the first position 162, the fluid within the pressurized fluid chamber 184 is at a pressure (e.g., the second pressure) that enables movement of the rod 54 relative to the locking sleeve 130 and the body 60. Then, the preload piston 160 may move to a position (e.g., the second position 164 of FIG. 7) so that fluid within the pressurized fluid chamber 184 is at the another pressure (e.g., the first pressure; until the first pressure is reached) that causes the fluid to drive the locking sleeve 130 radially-inwardly against the rod 54 to block movement of the rod 54 relative to the locking sleeve 130 and the body 60.

[0027] In some cases, while the preload piston 160 is in the first position 162, the pressurized fluid chamber 184 is at a pressure (e.g., the first pressure) that is sufficient to cause the fluid to drive the locking sleeve 130 radially-inwardly against the rod to block movement of the rod 54 relative to the locking sleeve 130 and the body 60. However, upon changes in pressure within the pressurized fluid chamber 184 due to leaks, temperature changes, and/or other factors, the preload piston 160 may be stroked forward from the first position 162 shown in FIG. 6 toward or to the second position 164 shown in FIG. 7 to achieve a pressure (e.g., the first pressure; until the first pressure is reached) that is again sufficient to cause the fluid to drive the locking sleeve 130 radially-inwardly against the rod to block movement of the rod 54 relative to the locking sleeve 130 and the body 60. In this way, the pressurized fluid chamber 184 may be repressurized multiple times (e.g., to account for leaks, temperature changes, or other factors), and thus, the pressure within the pressurized fluid chamber 184 may be maintained (e.g., via rotation or stroking of the preload piston 160 via the ROV or the AUV) over time to maintain the lock.

[0028] In some embodiments, the pressure sensor 174 may monitor the pressure within the pressurized fluid chamber 184. A controller 192 (e.g., electronic controller) having a processor 194 and a memory device 196 may receive data indicative of the pressure within the pressurized fluid chamber 184 from the pressure sensor 174, and the controller 192 may instruct adjustment of the preload piston 160 to achieve a target pressure (e.g., the first pressure, the second pressure, or some other pressure). For example, the controller 192 may instruct the ROV or the AUV to adjust the preload piston 160 in response to receipt of data that indicates that the pressure within the pressurized fluid chamber 184 does not equal (e.g., substantially equal) the target pressure and/or the controller 192 may instruct the ROV or the AUV to adjust the preload piston 160 until the data indicates that the target pressure has been reached. In some embodiments, the controller 192 may instruct an actuator that is coupled to the preload piston 160 to adjust the preload piston 160 in the same way. In some embodiments, the controller 192 may instruct display of the pressure to enable an operator to adjust the preload piston 160 (e.g., via control of the ROV or the AUV and/or via control of the actuator that is coupled to the preload piston 160 and/or via control of a tool that is configured to engage the preload piston 160).

[0029] It should be appreciated that the preload piston 160 may be driven to move via any suitable drive mechanism and via any suitable type of movement (e.g., linear and/or rotation). For example, the preload piston 160 may be threadably coupled to the preload cylinder 170 (e.g., via a threaded interface 188), and the preload piston 160 may be rotated in the circumferential direction 8 such that the preload piston 160 moves along the axial axis 4 within the fluid passageway 172 between the first position 162 and the second position 164. Regardless of the drive mechanism, in operation, the preload piston 160 may be moved to adjust the pressure within the pressurized fluid chamber 184 to maintain the configuration and/or to adjust the configuration of the lock assembly 30 (e.g., the locked configuration, the unlocked configuration). As shown, various seals, including one or more seals 198 (e.g., annular seals), may be provided to seal the pressurized fluid chamber 184 from the environment. Furthermore, two preload pistons 60 and associated components may be provided (e.g., on opposite sides of the lock assembly 30) to re-pressurize the pressurized fluid chamber 184.

[0030] The controller 192 may be part of or include a distributed controller or control system with one or more electronic controllers in communication with one another to carry out the various techniques disclosed herein. The processor 194 may also include one or more processors configured to execute software, such as software for processing signals and/or controlling the components associated with the BOP 28 and/or the lock system 32. The memory device 196 disclosed herein may include one or more memory devices (e.g., a volatile memory, such as random access memory [RAM], and/or a nonvolatile memory, such as read-only memory [ROM]) that may store a variety of information and may be used for various purposes. For example, the memory device 196 may store processor-executable instructions (e.g., firmware or software) for the processor 194 to execute, such as instructions for processing signals and/or controlling the components associated with the BOP 28 and/or the lock system 32. It should be appreciated that the controller 192 may include various other components, such as a communication device that is capable of receiving and/or sending data and/or control instructions to various other devices (e.g., a remote computing system; an ROV; an AUV; an actuator). The controller 192 may be configured to carry out any of the processes disclosed herein that may be electronically controlled.

[0031] As noted above, the valve 190 may be provided at the pressurized fluid chamber 184. Accordingly, FIG. 8 is a cross-sectional perspective of a portion of the lock assembly 30 having the valve 190. The valve 190 may be a check valve or a one-way valve that enables the fluid to escape from the pressurized fluid chamber 184, thereby reducing the pressure within the pressurized fluid chamber 184 and/or adjusting the lock assembly 30 to the unlocked configuration to enable the movement of the rod 54 relative to the locking sleeve 130 and the body 60. The valve 190 may enable quick adjustment of the lock assembly 30 (e.g., as compared to the adjustment due to moving the position of the preload piston 160) to the unlocked configuration and subsequent movement of the movable rod 90, which may be advantageous in the event of increased pressure within the wellbore 26 (FIG. 1) or at various other times.

[0032] As shown, the valve 190 may include a pin 200, an annular component 202, and a sealing element 204 (e.g., ball) positioned within a valve channel 205 formed in the preload cylinder 170. The valve 190 is shown in a closed configuration 208; however, when the valve 190 is in an open configuration (e.g., when a seal between the sealing element 204 and the annular component 202 is broken, such as via displacement of the sealing element 204 due to movement of the pin 200), the fluid within the pressurized fluid chamber 184 may flow across the sealing element 204 and through a discharge passageway 206. In some embodiments, the fluid may flow through the discharge passageway 206 to a discharge vessel 208. In some embodiments, the valve 190 may be adjusted to the open configuration in conjunction with (e.g., at the same time, at overlapping times, at separate times in series) the movement of the preload piston 160 of FIGS. 6 and 7 to reduce the pressure within the pressurized fluid chamber 184. In some embodiments, the valve 190 may be adjusted to the open configuration in conjunction with the movement of the preload piston 160 of FIGS. 6 and 7 and/or in conjunction with delivery of the fluid to the second portion 142 of the annular chamber 134, as discussed in more detail below with respect to FIG. 9.

[0033] It should be appreciated that the pin 200 may be driven to move via any suitable drive mechanism and via any suitable type of movement (e.g., linear and/or rotation). For example, the pin 200 may be driven within the discharge passageway 206 (e.g., via an ROV, an AUV, an actuator, and/or a tool held by an operator) such that the pin 200 moves along the axial axis 4. In some embodiments, pressure from the accumulator 34 of FIG. 1 may be utilized to drive the pin 200. For example, a flow of fluid from a fluid source 210 (e.g., a source of accumulator pressure; a fluid pressurized via the accumulator 34 of FIG. 1) may be adjusted via a flow valve 212, and the flow of fluid may exert a force on the pin 200 to drive the pin 200 within the discharge passageway 206. Once the fluid is discharged via the valve 190, the pressurized fluid chamber 184 may be refilled via any suitable technique or mechanism. For example, the pressurized fluid chamber 184 may be refilled via an intake channel (e.g., closeable or sealable intake channel), such as an intake channel that extends through the body 60 to the annular chamber 134. In some embodiments, the valve 190 is a two-way valve that enables the pressurized fluid chamber 184 to be refilled through the valve 190.

[0034] FIG. 9 is a cross-sectional perspective view of a portion of the lock assembly 30 having the locking sleeve 130 and an unlocking system 230 (e.g., supplemental unlocking system). As discussed above, to facilitate movement of the rod 54 relative to the locking sleeve 130 and the body 60, a fluid (e.g., unlocking fluid; hydraulic fluid) may be provided to the second portion 142 of the annular chamber 134 between the locking sleeve 130 and the rod 54 along the radial axis 132. The fluid may form a film (e.g., oil film) that separates the locking sleeve 130 from the rod 54, thereby causing insufficient contact and friction between the locking sleeve 130 and the rod 54 (e.g., insufficient to lock the rod 54) and enabling movement of the rod 54 relative to the locking sleeve 130 and the body 60. As shown, the fluid may be from the pressure intensifier 64, and the fluid may flow (e.g., upon opening a valve) into the second portion 142 of the annular chamber 134 via the tubing 66, an unlocking passageway 224 formed in the first end plate 48, and/or via any other suitable flow path. The lock assembly 30 may include various seals, such as seals 226 (e.g., annular seals) that seal the portions 140, 142 of the annular chamber 134 from one another and/or from the environment.

[0035] FIG. 10 is a perspective view of a portion of the lock assembly 30 that illustrates details of the indicator element 118, which may be provided at and/or coupled to the first rod end 114. As noted above, the indicator element 118 and/or the rod 54 may have features (e.g., color, reflective coating, circumferentially-extending lines, other marks) that facilitate visualization by the operator, the camera, or the like and/or determination of the position of the ram 72 relative to the central bore 76 (e.g., by the operator and/or by a processor that processes images obtained by the camera). Other features, such as the preload cylinders 170, the pressure intensifier 64, and the tubing 66, are shown to facilitate understanding of the components.

[0036] The lock system 32 disclosed herein may be a system that securely blocks two parts (e.g., one insertable inside of the other) from moving in translation relative to one another. As discussed above, one part may be an annular body and the other part may be a movable rod (e.g., cylindrical shaft). A locking sleeve may be placed in the annular body, and a viscoelastic fluid may be provided between the annular body and the locking sleeve. The locking sleeve may be deformable so as to deform toward the movable rod in response to a pressure from the viscoelastic fluid and to apply a friction to block movement of the movable rod in translation relative to the annular body. The movable rod may move in translation relative to the annular body as part of a back-up or supplemental operation in which the pressure from the viscoelastic fluid is absent. The annular body may include an unlocking system that is configured to bring a fluid (e.g., hydraulic fluid) between the movable rod and the locking sleeve, and the fluid may be less compressible than the viscoelastic fluid. The locking sleeve may also be deformable to deform away from the movable rod in response to a pressure of the fluid between the movable rod and the locking sleeve, which may compress the viscoelastic fluid that is between the annular body and the locking sleeve. The movable rod may be free in translation while the locking sleeve is deformed away from the movable rod due to the pressure of the fluid between the movable rod and the locking sleeve.

[0037] Advantageously, the lock system disclosed herein may be utilized with a BOP, such as a BOP of an offshore system or an on-shore system. Thus, the lock system may be configured for use in a subsea environment and/or may have features that enable the lock system to be efficiently operated in a subsea environment or another remote environment even while the lock system is not physically accessible by an operator (e.g., operated by an ROV and/or an AUV and/or by automatic processes). For example, the lock system may include the preload system and/or may utilize pressure from the accumulator of the BOP stack. It should be appreciated that the lock assembly disclosed herein may be used with any of a variety of types of BOP's, including BOP's that have only a single ram (e.g., that seal the central bore with only the single ram; without an opposed ram). It should also be appreciated that any of the features disclosed above with respect to FIGS. 1-10 may be combined in any suitable manner.

[0038] While the disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the disclosure is not intended to be limited to the particular forms disclosed. Rather, the disclosure is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims.

[0039] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for [perform]ing [a function]..." or "step for [perform]ing [a function]...", it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

Claims

1. A lock system for a blowout preventer (BOP), comprising:

an annular body;
a movable rod positioned within the annular body;
an annular chamber defined between the annular body and the movable rod along a radial axis;
a locking sleeve positioned within the annular chamber, wherein the locking sleeve is configured to deform along the radial axis from a first position in which the locking sleeve blocks movement of the movable rod relative to the annular body and a second position in which the locking sleeve enables movement of the movable rod relative to the annular body; and
a preload system comprising:

a preload cylinder;
a fluid passageway defined in the preload cylinder and fluidly coupled to a first portion of the annular chamber, wherein the fluid passageway and the annular chamber form a pressurized fluid chamber, and the first portion of the annular chamber is located between the annular body and the locking sleeve along the radial axis; and
a piston configured to move within the fluid passageway to adjust a pressure of a fluid within the pressurized fluid chamber to thereby cause the locking sleeve to deform along the radial axis.

2. The lock system of claim 1, wherein the fluid within the pressurized fluid chamber comprises a viscoelastic fluid.

3. The lock system of claim 1, wherein a friction between the locking sleeve and the movable rod while the locking sleeve is in the first position is configured to block the movement of the movable rod relative to the annular body.

4. The lock system of claim 1, wherein the piston is threadably coupled to the fluid passageway.

5. The lock system of claim 1, wherein the fluid passageway comprises a bend to enable a first end portion of the fluid passageway to be accessible at an end plate of the lock system and to enable a second end portion of the fluid passageway to fluidly couple to the annular chamber.

6. The lock system of claim 1, comprising a pressure sensor configured to monitor a pressure within the pressurized fluid chamber.

7. The lock system of claim 6, comprising a controller that is configured to receive data from the pressure sensor and to instruct an actuator to adjust the piston based on the data.

8. The lock system of claim 1, comprising a discharge valve that is configured to discharge the fluid from the pressurized fluid chamber.

9. The lock system of claim 8, wherein the discharge valve comprises a one-way valve.

10. The lock system of claim 1, comprising a supplemental unlocking system that is configured to provide another fluid to a second portion of the annular chamber that is located between the locking sleeve and the movable rod along the radial axis.

11. A blowout preventer (BOP) system, comprising:

a ram configured to move relative to a central bore of the BOP system to adjust the BOP system between an open position and a closed position; and
a lock assembly, comprising:

an annular body;
a movable rod, wherein a first portion of the movable rod is positioned within the annular body and a second portion of the movable rod is coupled to the ram;
an annular chamber defined between the annular body and the movable rod along a radial axis of the lock assembly; and
a locking sleeve positioned within the annular chamber, wherein the locking sleeve is configured to deform along the radial axis from a first position in which the locking sleeve blocks movement of the movable rod relative to the annular body and a second position in which the locking sleeve enables movement of the movable rod relative to the annular body.

12. The BOP system of claim 11, wherein the lock assembly comprises a preload system comprising:

a preload cylinder;
a fluid passageway defined in the preload cylinder and fluidly coupled to a first portion of the annular chamber, wherein the fluid passageway and the annular chamber form a pressurized fluid chamber, and the first portion of the annular chamber is located between the annular body and the locking sleeve along the radial axis; and
a piston configured to move within the fluid passageway to adjust a pressure of a fluid within the pressurized fluid chamber to thereby cause the locking sleeve to deform along the radial axis.

13. The BOP system of claim 11, comprising a preload system that is configured to adjust a pressure of a fluid that is trapped within a first portion of the annular chamber that is located between the locking sleeve and the annular body along the radial axis.

14. The BOP system of claim 13, wherein the fluid comprises a viscoelastic fluid.

15. The BOP system of claim 13, comprising a supplemental unlocking system that is configured to provide an unlocking fluid to a second portion of the annular chamber that is located between the locking sleeve and the movable rod along the radial axis.

16. The BOP system of claim 15, comprising an accumulator, wherein the BOP system is configured to use an accumulator pressure of the accumulator to drive the ram to move relative to the central bore of the BOP system to adjust the BOP system between the open position and the closed position and to urge the unlocking fluid into the second portion of the annular chamber.

17. The BOP system of claim 11, comprising a discharge valve that is configured to discharge a fluid from the annular chamber.

18. The BOP system of claim 11, comprising a pressure sensor configured to monitor a pressure within the annular chamber.

19. A method of operating a lock system for a blowout preventer (BOP), comprising:

increasing a pressure of a locking fluid within a first annular chamber portion that is defined between an annular body and a locking sleeve along a radial axis to thereby drive the locking sleeve along the radial axis against a movable rod to lock the movable rod to the annular body;
providing an unlocking fluid within a second annular chamber portion that is defined between the movable rod and the locking sleeve along the radial axis to thereby drive the locking sleeve along the radial axis away from the movable rod to unlock the movable rod from the annular body; and
driving the movable rod and a ram coupled to the movable rod relative to a central bore of the BOP while the movable rod is unlocked from the annular body.

20. The method of claim 19, comprising using pressure from an accumulator to urge the unlocking fluid into the second annular chamber portion and to urge the movable rod and the ram relative to the central bore of the BOP.

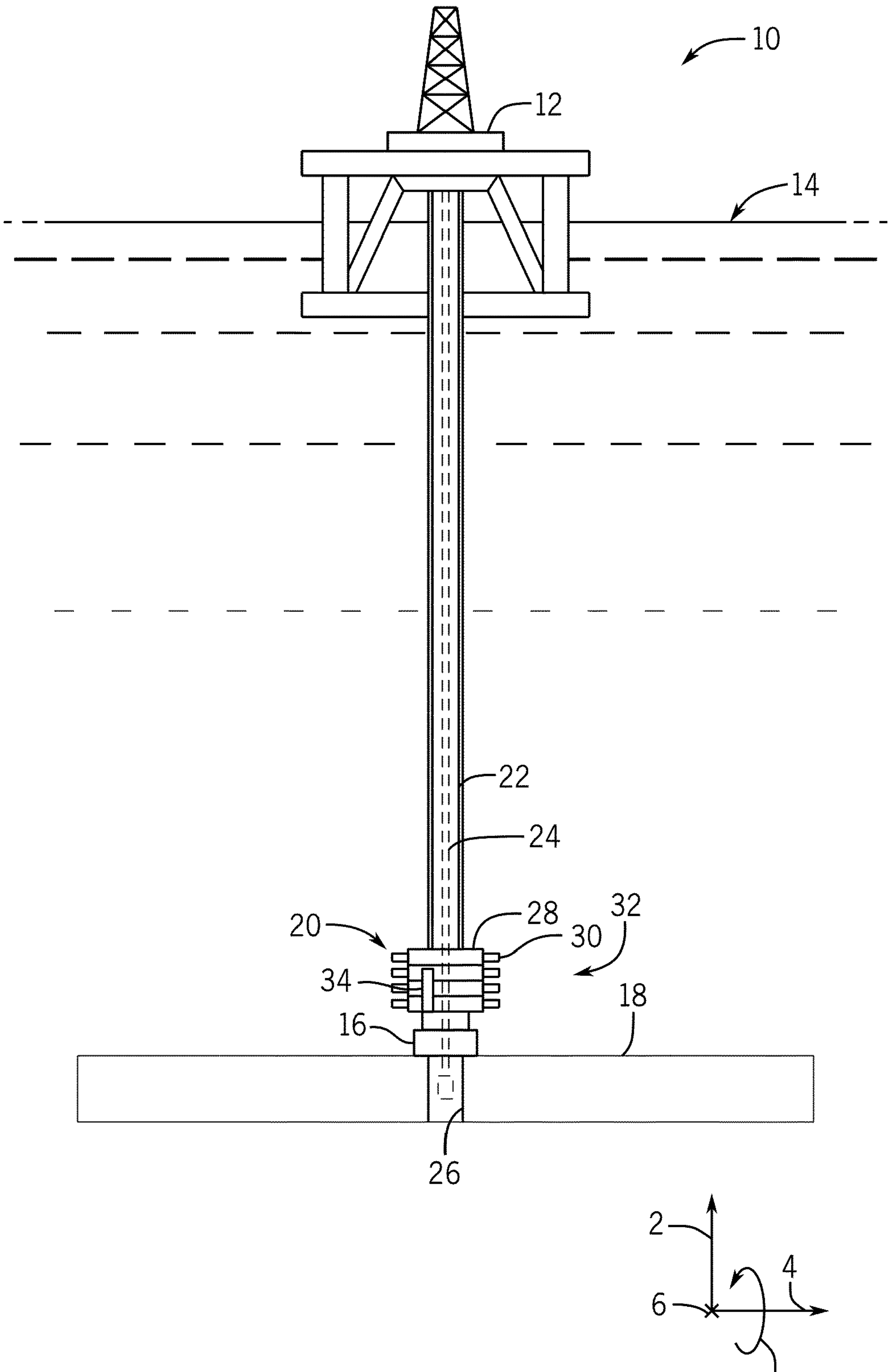

FIG. 1

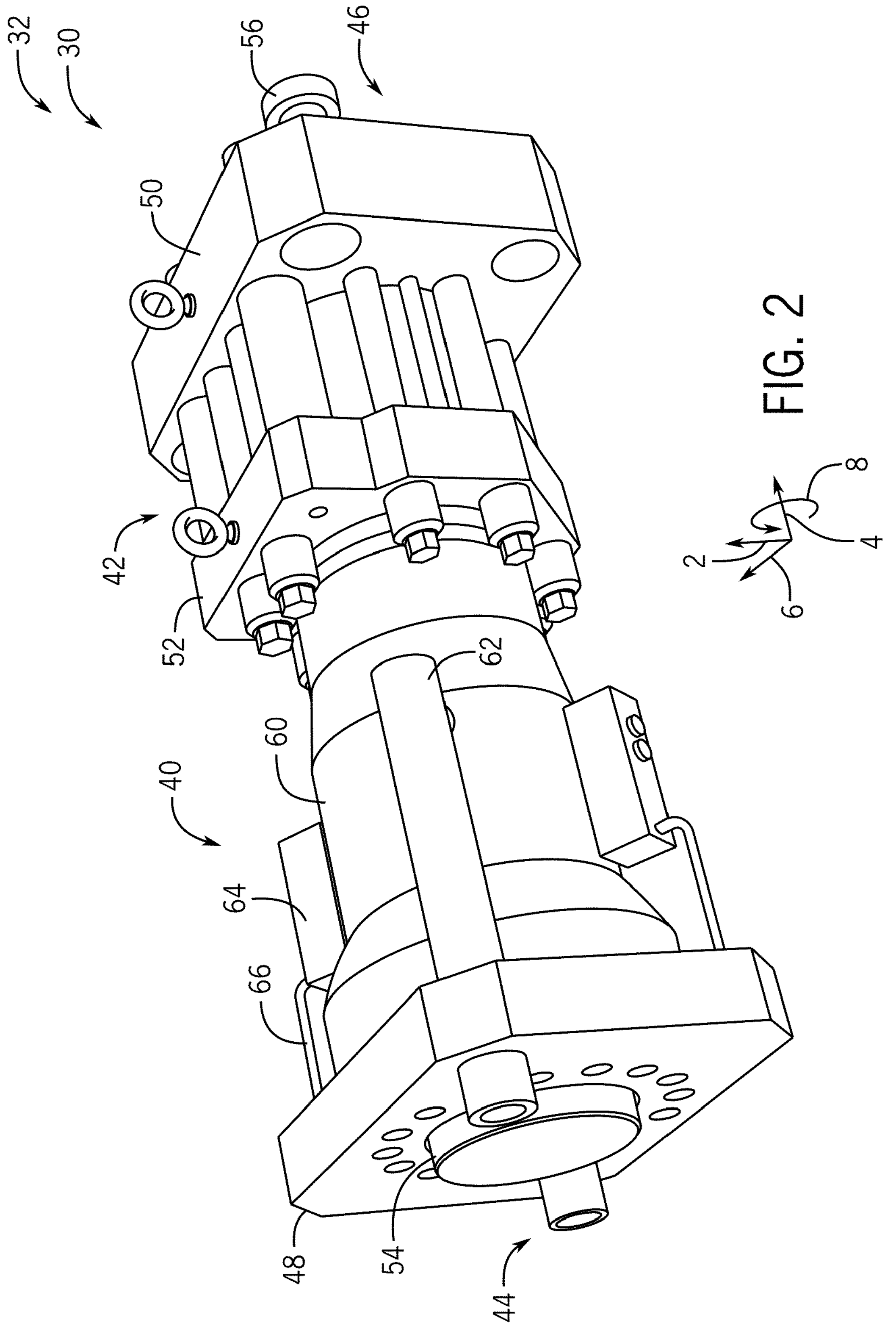

FIG. 2

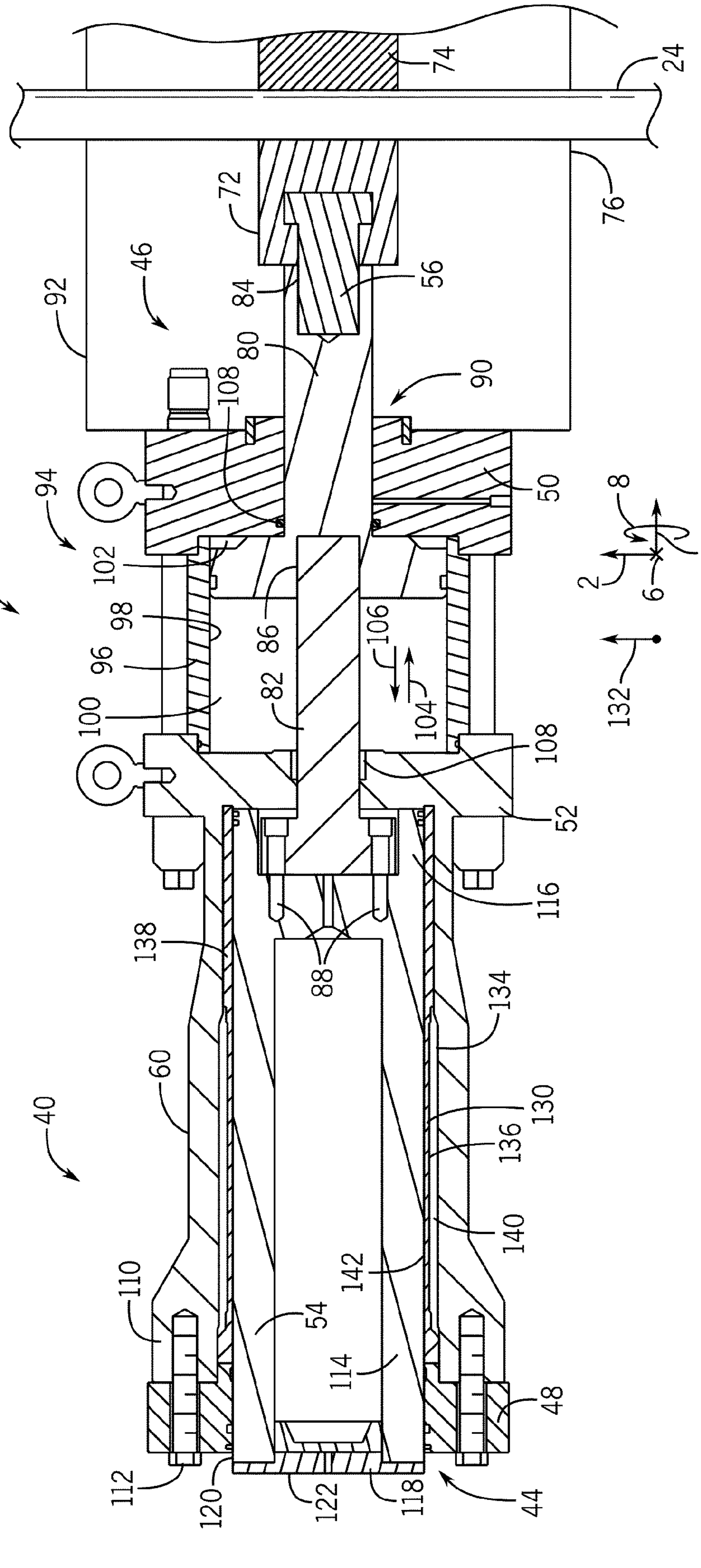
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FIG. 3

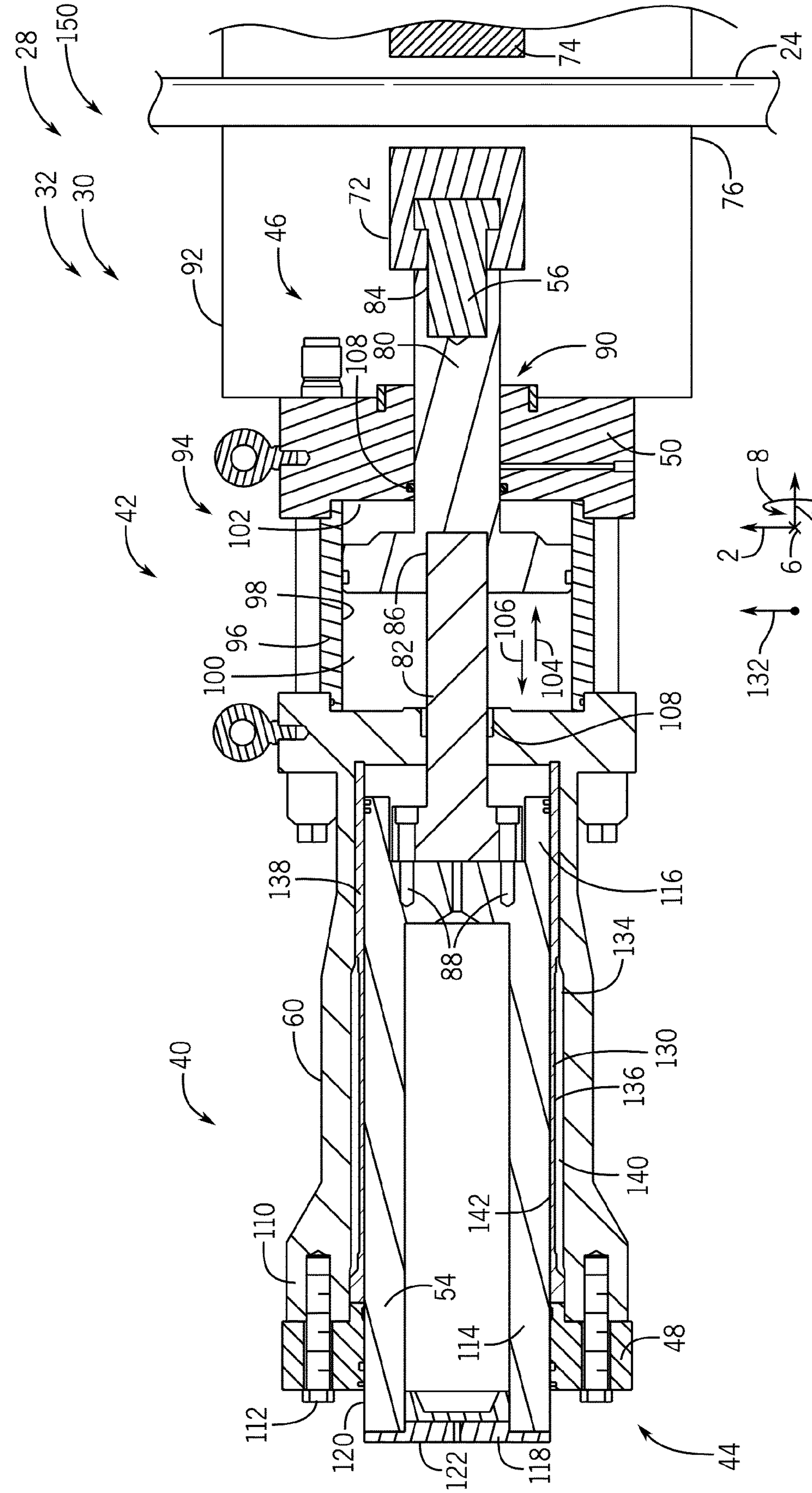
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FIG. 4

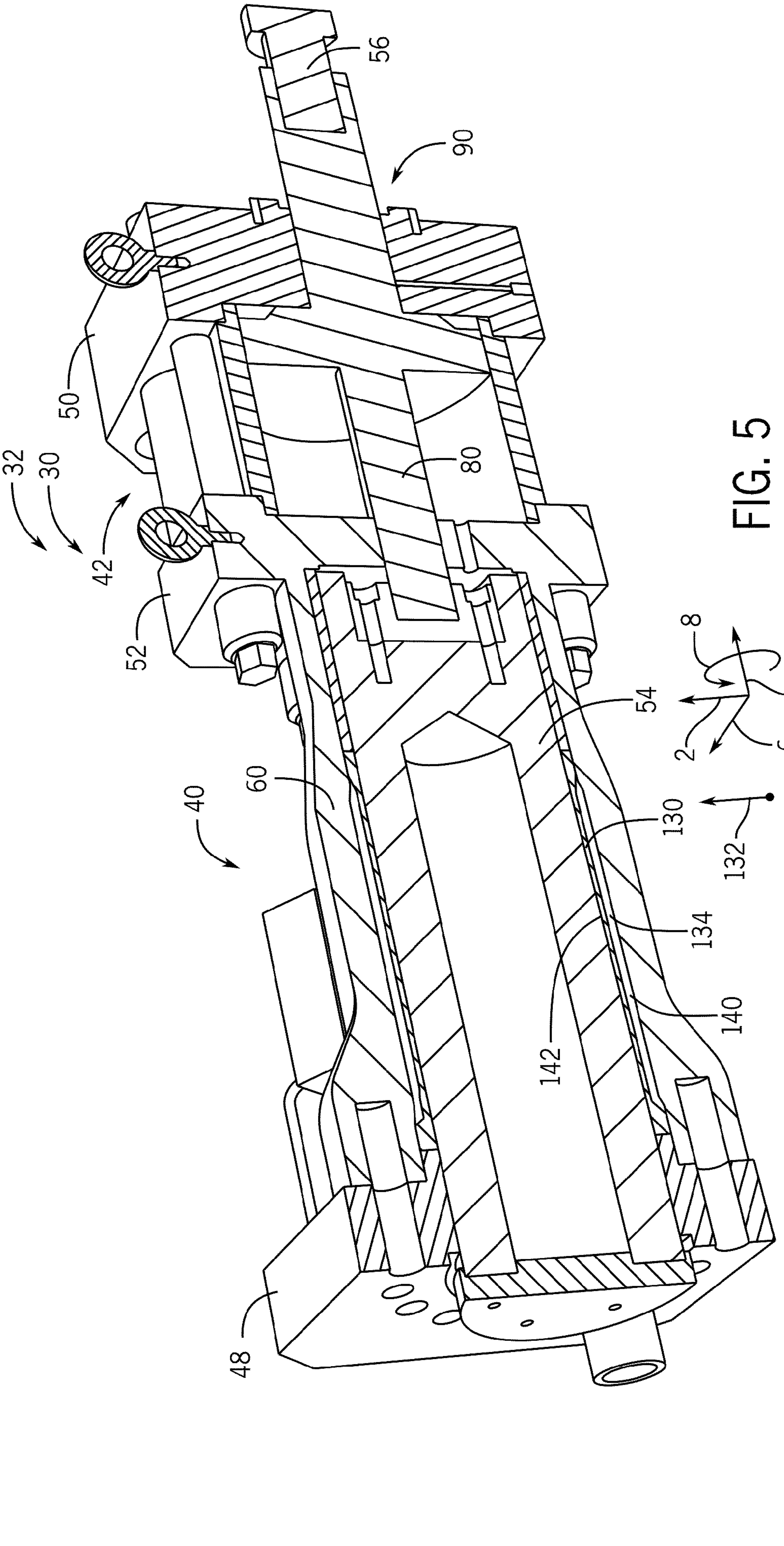

FIG. 5

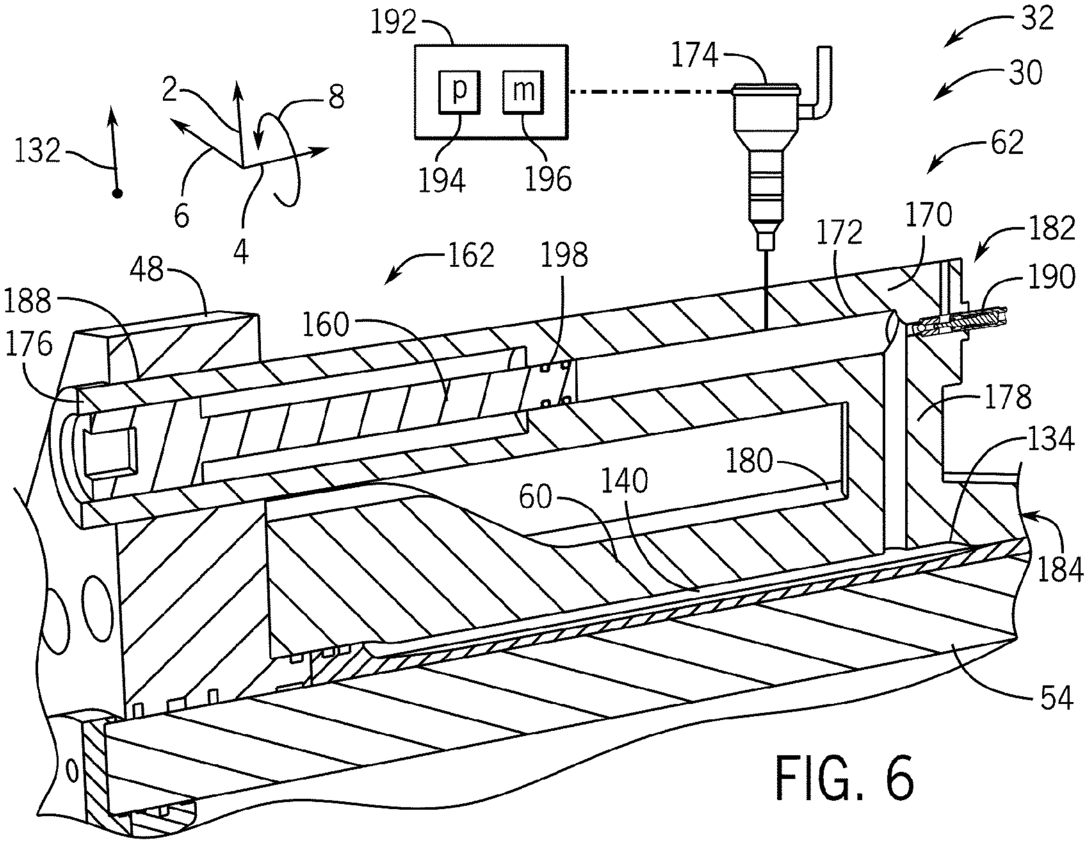
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FIG. 6

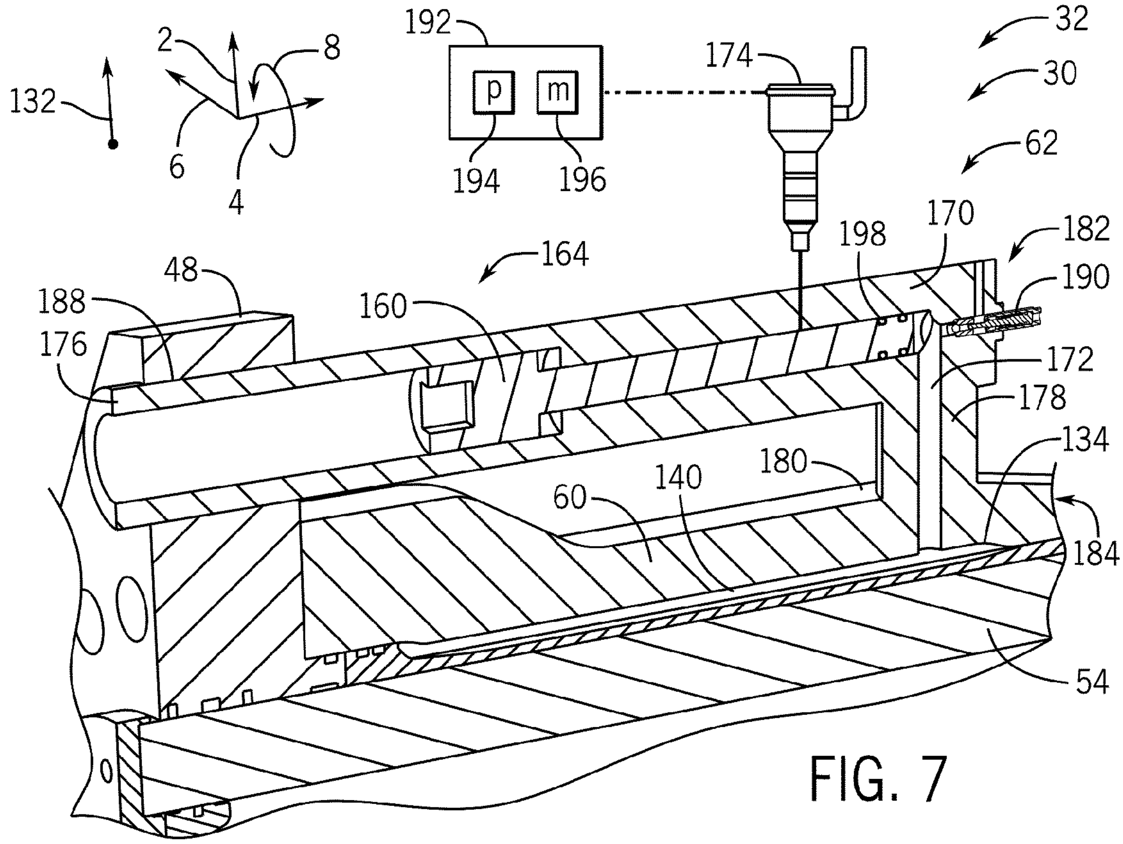
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FIG. 7

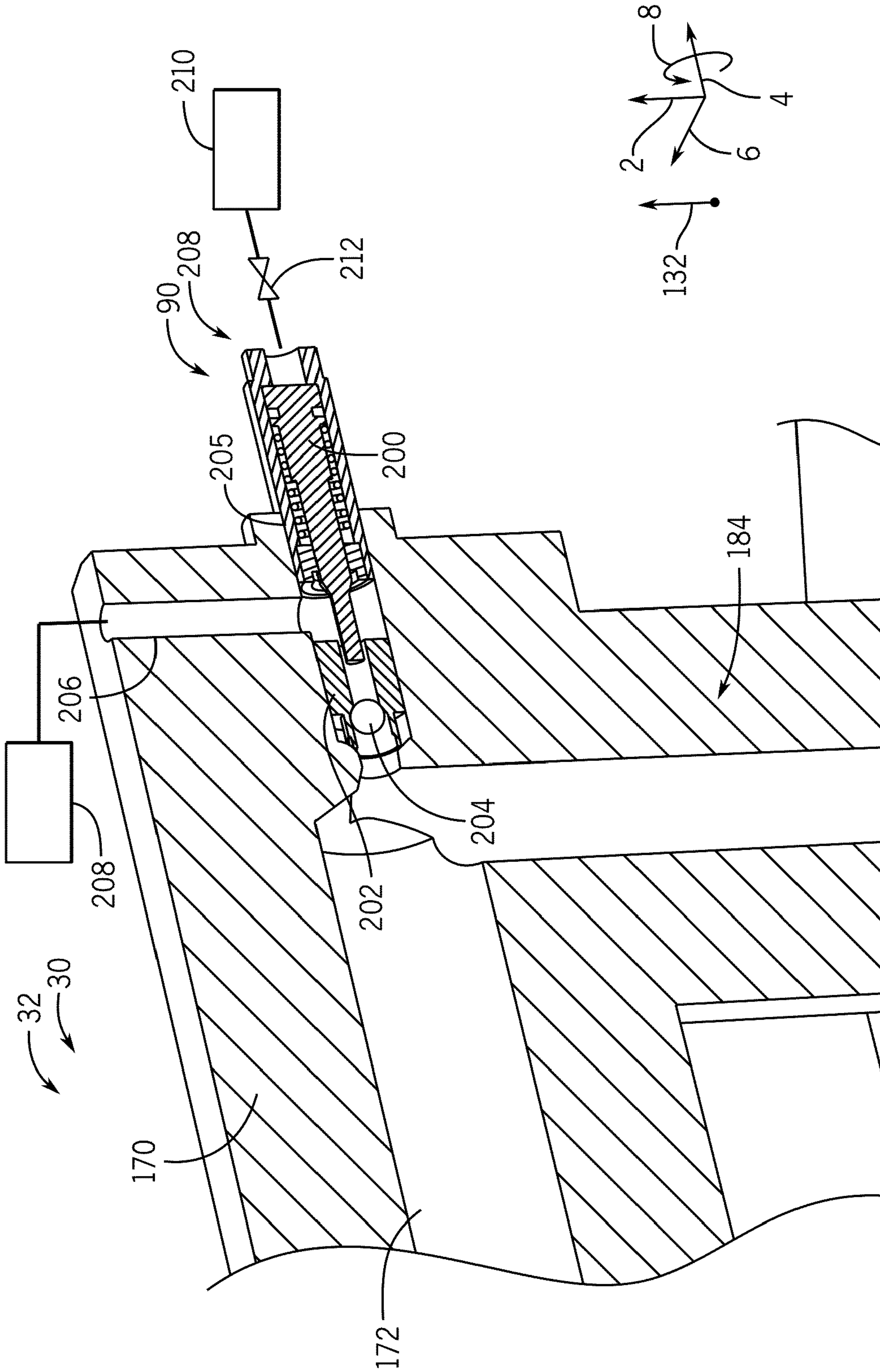

FIG. 8

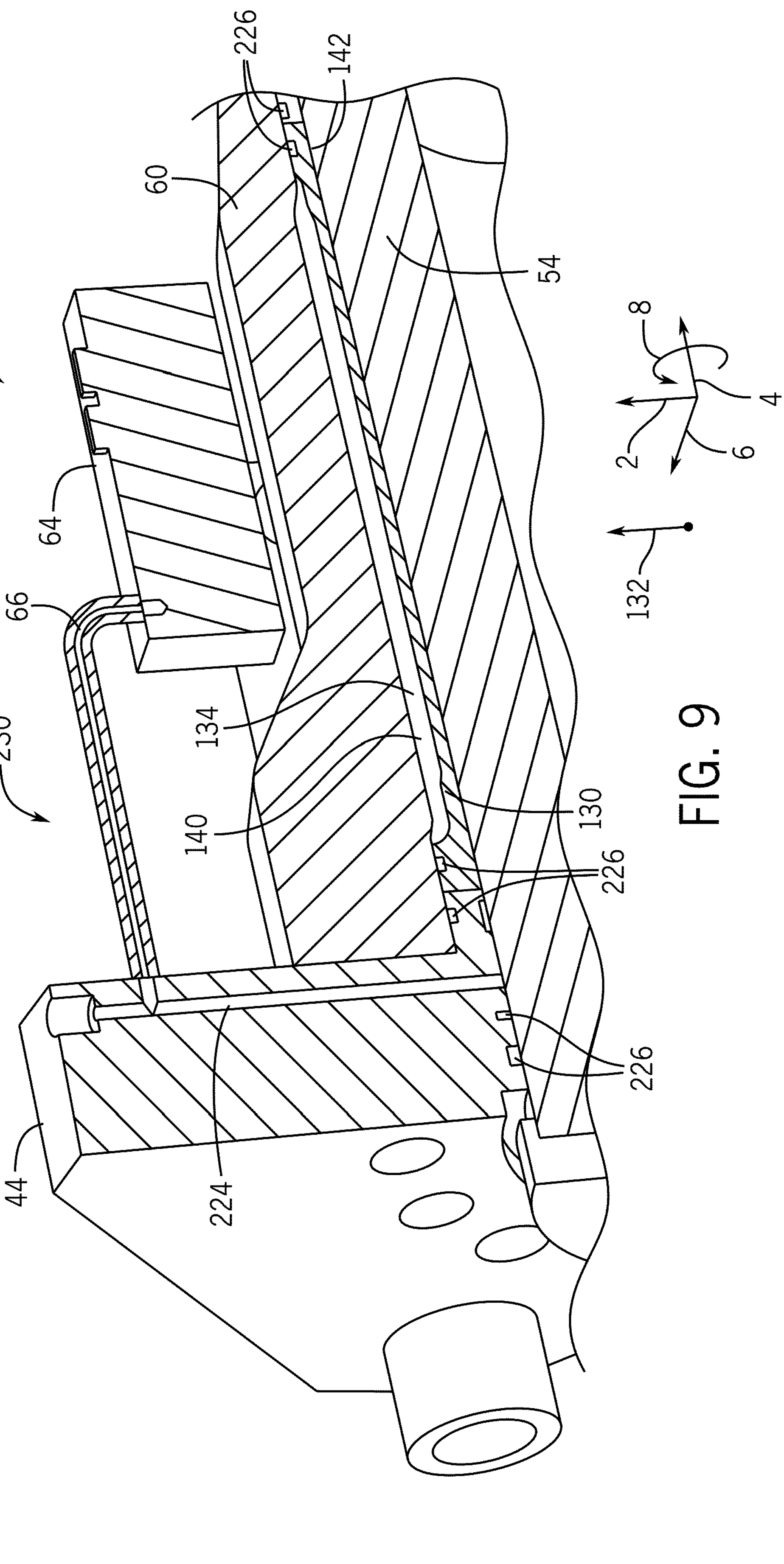

FIG. 9

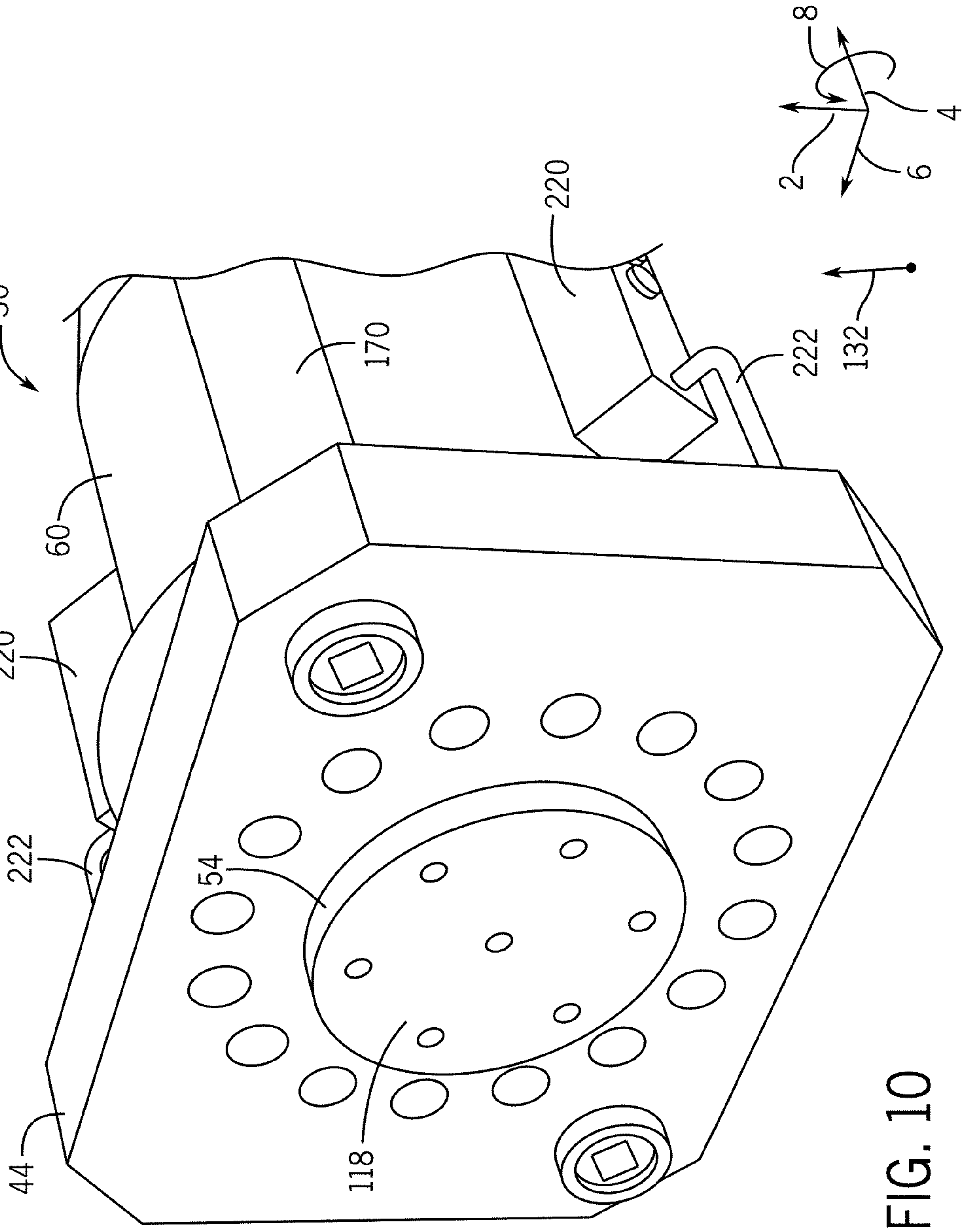

FIG. 10

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PARTIAL EUROPEAN SEARCH REPORT

under Rule 62a and/or 63 of the European Patent Convention. This report shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 19 30 6685

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 4 969 390 A (WILLIAMS III BOLIE C [US]) 13 November 1990 (1990-11-13) * the whole document * -----	1-10,19, 20	INV. E21B33/06 E21B33/064 E21B34/16
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A	US 4 052 995 A (ELLISON C MACK) 11 October 1977 (1977-10-11) * the whole document * -----	1-10,19, 20	

TECHNICAL FIELDS SEARCHED (IPC)

E21B

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

1

Place of search	Date of completion of the search	Examiner
Munich	24 September 2020	Pieper, Fabian

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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INCOMPLETE SEARCH SHEET C

Application Number
EP 19 30 6685

Claim(s) completely searchable:
1-10, 19, 20

Claim(s) not searched:
11-18

Reason for the limitation of the search:

In reply to the invitation pursuant to Rule 62a(1) EPC to indicate the claims on which the search is to be based, the applicant failed to supply the requested indication in due time.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 30 6685

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-09-2020

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82