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(54) SHEARING SEQUENCE FOR A BLOWOUT PREVENTER

(57) The present disclosure relates to a system that includes a body surrounding a bore, a first ram disposed adjacent a first end of the body and coupled to a first actuator, a second ram disposed adjacent to a second end opposite the first end of the body and coupled to a second actuator, and a controller communicatively coupled to the first and second actuators. The controller is configured to actuate the first actuator to direct the first ram toward a tubular string disposed in the bore, such that the first ram aligns the tubular string with a first shearing portion of the second ram when the first ram is in an actuated position, and to actuate the second actuator, after actuating the first actuator, to direct the second ram toward the tubular string such that the first and second rams completely cut the tubular string.

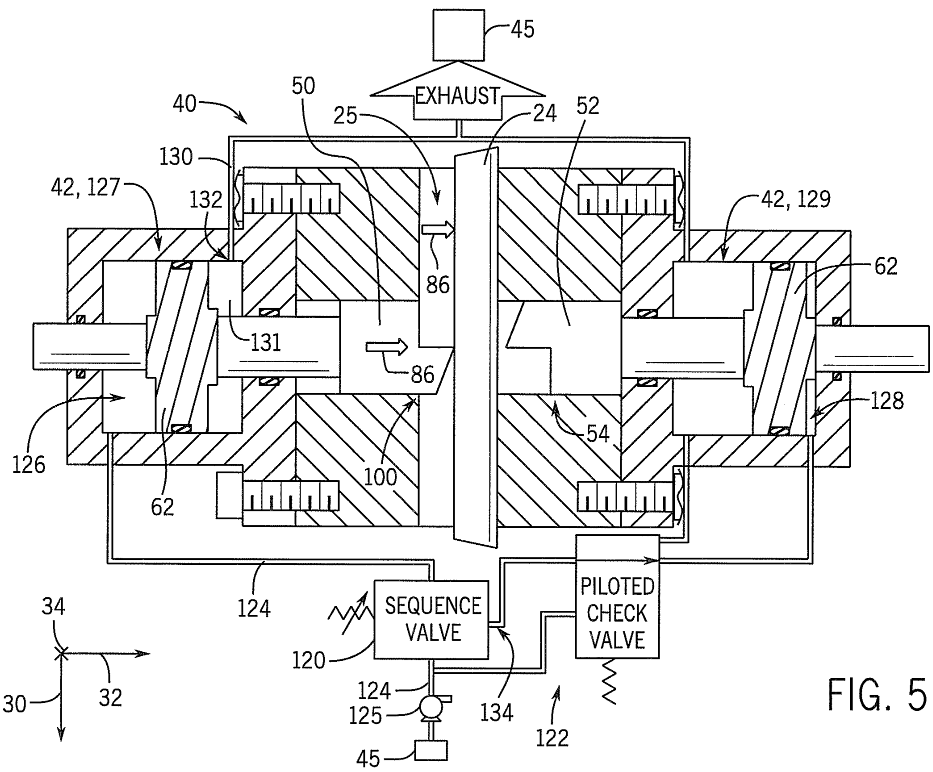

FIG. 5

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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 may be installed on a wellhead to seal and control an oil and gas well during drilling operations. A tubular string may be suspended inside a drilling riser and extend through the BOP stack into the wellhead. During drilling operations, a drilling fluid may be delivered through the tubular string and returned through a bore between the tubular string and a casing of the drilling riser. In the event of a rapid invasion of formation fluid in the bore, commonly known as a "kick," the BOP stack may be actuated to seal the drilling riser from the wellhead and to control a fluid pressure in the bore, 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 a mineral extraction system, in accordance with an embodiment of the present disclosure;

FIG. 2 is a perspective view of an embodiment of a BOP stack assembly that may be used in the mineral extraction system of FIG. 1, in accordance with an embodiment of the present disclosure;

FIG. 3 is a cross-sectional top view of a portion of a BOP of the BOP stack assembly of FIG. 2, illustrating first and second rams in an open position, in accordance with an embodiment of the present disclosure;

FIG. 4 is a cross-sectional top view of the portion of the BOP of the BOP stack assembly of FIG. 3, illustrating the first ram in a second position and the second ram in the open position, in accordance with an embodiment of the present disclosure;

FIG. 5 is a schematic of a portion of the BOP of FIG. 4, illustrating a hydraulic circuit that may be utilized to direct the first ram into the second position, in accordance with an embodiment of the present disclosure;

FIG. 6 is a cross-sectional top view of the portion of the BOP of FIGS. 3-5, illustrating both first and second rams in a second position, in accordance with an embodiment of the present disclosure;

FIG. 7 is a schematic of the portion of the BOP of FIG. 5, illustrating the hydraulic circuit of FIG. 5 that may be utilized to direct the second ram into the second position, in accordance with an embodiment of the present disclosure;

FIG. 8 is a schematic of the portion of the BOP of FIGS. 5 and 7, illustrating the hydraulic circuit of FIGS. 5 and 7 that may be utilized to direct the first and second rams back into the open position, in accordance with an embodiment of the present disclosure; and

FIG. 9 is a block diagram of a process that for the BOP of FIGS. 1-8 that may be utilized to carry out an enhanced shearing sequence, 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] Embodiments of the present disclosure relate to a blowout preventer ("BOP") system that may completely shear (e.g., cut) a tubular string to enhance a seal of a wellbore when blowout conditions are detected. A BOP may be included at a wellhead to block a fluid from inadvertently flowing from the wellhead to a drilling platform (e.g., through a drilling riser). For example, pressures may fluctuate within a natural reservoir, which may lead to a surge in fluid flow from the wellhead toward the drilling platform when the pressure reaches a threshold value. To block fluid from flowing toward the drilling platform during blowout conditions, the BOP may be actuated to cut the tubular string and seal the drilling riser from the wellhead (e.g., by covering a bore in the BOP coupling the wellhead to the drilling riser). In accordance with embodiments of the present disclosure, at least one BOP of a BOP stack may include shearing rams that may be configured to cut the tubular string and enhance a seal of the bore extending through the BOP.

[0006] In accordance with present embodiments, a BOP system may be operated utilizing an enhanced shearing sequence to enhance a seal between the wellhead and the drilling riser during blowout. For example, the BOP system may be configured to actuate a first ram of the BOP from an open position toward the tubular string and into the bore of the BOP. The first ram may contact the tubular string and align the tubular string with a shearing portion of a second ram of the BOP before the second ram is actuated. The second ram may then be actuated such that shearing portions of both the first and second rams fully contact the tubular string and perform a cut (e.g., a complete cut) of the tubular string. Completely cutting or shearing the tubular string may enable the first and second rams to completely cover the bore of the BOP, and thus, form an enhanced seal between the wellhead and the drilling riser.

[0007] With the foregoing in mind, FIG. 1 is a schematic of an embodiment of a mineral extraction system 10. The mineral extraction system 10 includes a vessel or platform 12 at a surface 14. A BOP stack assembly 16 is mounted to a wellhead 18 at a floor 20 (e.g., a sea floor for offshore operations). A tubular drilling riser 22 extends from the platform 12 to the BOP stack assembly 16. The riser 22 may return drilling fluid or mud to the platform 12 during drilling operations. Downhole operations are carried out by a tubular string 24 (e.g., drill string, production tubing string, or the like) that extends from the platform 12, through the riser 22, through a bore 25 of the BOP stack assembly 16, and into a wellbore 26.

[0008] To facilitate discussion, the BOP stack assembly 16 and its components may be described with reference to an axial axis or direction 30, a longitudinal axis or direction 32, and a lateral axis or direction 34. As shown, the BOP stack assembly 16 includes a BOP stack 38 having multiple BOPs 40 (e.g., ram BOPs) axially stacked (e.g., along the axial axis 30) relative to one another. As discussed in more detail below, each BOP 40 includes a pair of longitudinally opposed rams and corresponding actuators 42 that actuate and drive the rams toward and away from one another along the longitudinal axis 32. Although four BOPs 40 are shown, the BOP stack 38 may include any suitable number of BOPs (e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more). Additionally, the BOP stack 38 may include any of a variety of different types of rams. For example, in certain embodiments, the BOP stack 38 may include one or more BOPs 40 having opposed shear rams or blades configured to sever the tubular string 24 and seal off the wellbore 26 from the riser 22 and/or one or more BOPs 40 having opposed pipe rams configured to engage the tubular string 24 and to seal the bore 25 (e.g., an annulus around the tubular string 24).

[0009] FIG. 2 is a perspective view of an embodiment of the BOP stack assembly 16. As discussed above, the BOP stack 38 includes multiple BOPs 40 axially stacked (e.g., along the axial axis 30) relative to one another. As shown, the BOP stack 38 also includes one or more hydraulic accumulators 45. The hydraulic accumulators 45 may store and/or supply (e.g., via one or more pumps) hydraulic pressure to the actuators 42 that are configured to drive the rams of the BOPs 40. In certain embodiments, the hydraulic accumulators 45 and/or the actuators 42 may be communicatively coupled to a controller 46. The controller 46 may be configured to send signals to the hydraulic accumulators 45, the actuators 42, and/or one or more pumps to drive the rams of the BOPs 40 when blowout conditions exist. For example, the controller 46 may receive feedback from one or more sensors 47 (e.g., pressure sensors and/or flow sensors) that may monitor conditions of the wellbore 26 (e.g., a pressure of the fluid in the wellbore 26). The controller 46 may include memory 48 that stores threshold values indicative of blowout conditions. Accordingly, a processor 49 of the controller 46 may send a signal instructing the hydraulic accumulators 45, the actuators 42, and/or the one or more pumps to drive and/or actuate the rams when measured feedback received from the controller 46 meets or exceeds such threshold values.

[0010] FIG. 3 is a cross-sectional top view of a portion of one BOP 40 with a first ram 50 and a second ram 52 in an open position 54. In the open position 54, the first ram 50 and the second ram 52 are withdrawn or retracted from the bore 25, do not contact the tubular string 24, and/or do not contact the corresponding opposing ram 50, 52. As shown, the BOP 40 includes a body 56 (e.g., housing) surrounding the bore 25. The body 56 is generally rectangular in the illustrated embodiment, although the body 56 may have any cross-sectional shape, including any polygonal shape or an annular shape. A bonnet assembly 60 is mounted to the body 56 (e.g., via threaded fasteners). The bonnet assembly 60 may support the actuators 42, which each include a piston 62 and a connecting rod 63. As shown in the illustrated embodiment, when in the open position 54, the first ram 50 is generally adjacent to a first end 64 of the body 56 and the second ram 52 is generally adjacent to a second end 65 opposite the first end 64 of the body 56. The actuators 42 may drive the first and second rams 50, 52 toward and away from one another along the longitudinal axis 32 and through the bore 25 to shear the tubular string 24 and/or to seal the bore 25 (e.g., the annulus about the tubular string 24).

[0011] The first ram 50 may include a first shearing portion 66, and the second ram 52 may include a second shearing portion 68. The first shearing portion 66 may include a first width 70 that is greater than a diameter 72 of the tubular string 24, such that the first shearing portion

66 may cut through the entire tubular string 24. Similarly, the second shearing portion 68 may include a second width 74 that is greater than the diameter 72 of the tubular string 24. Accordingly, when the first and second shearing portions 66, 68 are aligned with the tubular string 24 and are directed toward one another, the tubular string 24 may be completely cut to seal the bore 25. However, in certain embodiments, the first and second shearing portions 66, 68 may not extend across an entire diameter 76 of the bore 25. For example, the bore 25 may include an annular opening 78 that surrounds the tubular string 24. Although the first and second shearing portions 66, 68 may not extend across the entire diameter 76 of the bore 25, the first and second rams 50, 52 may include non-shearing portions 80, 82, respectively, that are configured to cover portions of the bore 25 that may be left uncovered by the shearing portions 66, 68. Accordingly, during blowout conditions, the first and second rams 50, 52 may be moved along the longitudinal axis 32 toward one another to seal the bore 25. To completely seal the bore 25, the first and second rams 50, 52 may cut through the tubular string 24.

[0012] In some embodiments, the shearing portions 66, 68 may include different geometries. For example, as shown in the illustrated embodiment of FIG. 3, the first shearing portion 66 may include a substantially linear (e.g., a generally straight line) geometry. The second shearing portion 68 may include an indented (e.g., two lines forming an obtuse angle with respect to a joint 83) geometry. It should be noted that in other embodiments, the first and second shearing portions 66, 68 may include any suitable geometry for cutting the tubular string 24 and sealing the bore 25. In some embodiments, the first shearing portion 66 and the second shearing portion 68 may be offset with respect to the axial axis 30 (see FIG. 5). For example, the first shearing portion 66 may be at a first position along the axial axis 30 such that the second shearing portion 68 may be configured to be positioned above or below (e.g., with respect to the axial axis 30) the first shearing portion 66 (e.g., the first and second shearing portions 66, 68 may not directly contact one another) when both the first and second shearing portions 66, 68 are in a second position (see FIG. 6). Such a configuration may enable both the first and second shearing portions 66, 68 to completely pass through the tubular string 24 when blowout conditions exist.

[0013] As shown in the illustrated embodiment of FIG. 3, the tubular string 24 may not be positioned in a center of the bore 25 with respect to the rams 50, 52. In other words, the tubular string 24 may not be aligned with the first shearing portion 66 of the first ram 50 and/or the second shearing portion 68 of the second ram 52. Accordingly, driving the first and second rams 50, 52 toward one another along the longitudinal axis 32 simultaneously may not enable both the first shearing portion 66 and the second shearing portion 68 to contact a complete circumference 84 (e.g., outer surface) of the tubular string 24. As the first and second rams 50, 52 are driven toward the tubular string 24, the first ram 50 may apply a first force to the tubular string 24 in a first direction 86, and the second ram 52 may apply a second force to the tubular string 24 in a second direction 88 opposite the first direction 86. In some embodiments, the first force and the second force applied in opposing directions 86, 88 may be substantially equal, such that the tubular string 24 may remain substantially stationary when the first and second rams 50, 52 are simultaneously driven toward the tubular string 24 and contact the tubular string 24 at approximately the same time.

[0014] The tubular string 24 may be cut as the first and second shearing portions 66, 68 contact the circumference 84 of the tubular string 24. However, because the first shearing portion 66 and/or the second shearing portion 68 may not be aligned with the entire circumference 84 of the tubular string 24, a portion 90 of the tubular string 24 may not be cut by the rams 50, 52. The portion 90 of the tubular string 24 left uncut may block the rams 50, 52 (e.g., the non-shearing portions 80, 82) from completely contacting one another, such that the bore 25 includes a gap or opening that may enable fluid to flow from the wellbore 26 (e.g., wellhead) and into the drilling riser 22 when blowout conditions occur. Accordingly, the bore 25 may not be completely sealed by the BOP 40 as a result of the uncut portion 90 of the tubular string 24. Therefore, it is now recognized that an enhanced sequence of actuating the rams 50, 52 is desired to enhance the seal of the bore 25.

[0015] For example, FIG. 4 is a cross-sectional top view of a portion of the BOP 40 of the BOP stack 38, illustrating the first ram 50 in a second position 100 and the second ram 52 in the open position 54. Accordingly, FIG. 4 illustrates the BOP 40 operating with an enhanced sequence that includes driving the first ram 50 into the second position 100 before driving the second ram 52 toward the tubular string 24 (and the first ram 50). It should be noted that in other embodiments, the second ram 52 may be actuated before the first ram 50 to align the tubular string 24, and then the first ram 50 may be actuated to cut the tubular string 24.

[0016] As shown in the illustrated embodiment of FIG. 4, as the first ram 50 is driven into the second position 100, the first ram 50 aligns the tubular string 24, the first shearing portion 66, and the second shearing portion 68 of the second ram 52 along an axis 101. In some embodiments, the first ram 50 may align the tubular string 24 by contacting the tubular string 24 and directing the tubular string 24 in the first direction 86. As the tubular string 24 moves in the direction 86, it may be guided along an inner diameter 102 of the bore 25 (e.g., in a direction 104 about the axial axis 30). Accordingly, when the first ram 50 is in the second position 100, the tubular string 24 may contact a portion 106 of the inner diameter 102 closest to the second shearing portion 68 of the second ram 52, and thus be substantially aligned with the second shearing portion 68 along the axis 101.

[0017] Therefore, the position of the tubular string 24 within the bore 25 may be adjusted by the first ram 50 and/or the second ram 52 (e.g., the tubular string 24 is not substantially fixed with respect to the bore 25). Therefore, actuating the first ram 50 before the second ram 52 (or vice versa) enables the tubular string 24 to be guided along the inner diameter 102 of the bore 25 to a position that substantially aligns the entire diameter 72 of the tubular string 24 with the first shearing portion 66 and the second shearing portion 68 along the axis 101.

[0018] In some embodiments, to actuate the first ram 50 without actuating the second ram 52, a sequencing valve 120 may be utilized. For example, FIG. 5 is a schematic of the of a portion of the BOP 40, illustrating the first ram 50 in the second position 100 and the second ram 52 in the open position 54. The illustrated embodiment of FIG. 5 shows a hydraulic circuit 122 that may direct hydraulic fluid 124 from one or more of the hydraulic accumulators 45 to the actuators 42 via a first pump 125. It should be noted that in other embodiments, the actuators 42 may be pneumatic such that the BOP 40 includes a pneumatic circuit (e.g., that includes a compressor) instead of the hydraulic circuit 122. In some embodiments, the hydraulic circuit 122 may include the sequencing valve 120 to perform the enhanced shearing sequence. For example, the sequencing valve 120 may be configured to direct the hydraulic fluid 124 toward a first hydraulic chamber 126 of a first actuator 127 that drives the first ram 50 along the longitudinal axis 32 (e.g., the hydraulic fluid 124 directs the first actuator 127 along the longitudinal axis 32 by increasing the pressure in the first hydraulic chamber 126 to drive the first actuator in the direction 86). Additionally, the sequencing valve 120 may be configured to block the hydraulic fluid 124 from flowing toward a first hydraulic chamber 128 of a second actuator 129 configured to drive the second ram 52 along the longitudinal axis 32. Therefore, the sequencing valve 120 enables the first ram 50 to be actuated along the longitudinal axis 32, while generally maintaining the second ram 52 in the open position 54.

[0019] As the hydraulic fluid 124 enters the first hydraulic chamber 126 and directs the first actuator 127 in the direction 86, a second hydraulic fluid 130 may flow from a second hydraulic chamber 131 of the first actuator 127 toward one or more of the hydraulic accumulators 45. In some embodiments, pressure may increase in the second hydraulic chamber 131 as the first actuator 127 moves in the direction 86 (e.g., as a result of a reduction of a volume of the second hydraulic chamber 131 caused by the piston 62). Accordingly, the pressure within the second hydraulic chamber 131 may urge the second hydraulic fluid 130 through an outlet 132 of the second hydraulic chamber 131 and toward one or more of the hydraulic accumulators 45.

[0020] In some embodiments, the sequencing valve 120 may include a mechanism (e.g., a spring or other biasing member) that blocks an outlet 134 of the sequencing valve 120 coupled to the second actuator 129 until a threshold pressure of the hydraulic fluid 124 is reached. Accordingly, the sequencing valve 120 may direct hydraulic fluid 124 toward the first actuator 127 and block the hydraulic fluid 124 from flowing toward the second actuator 129 until the first ram 50 is in the second position 100. The threshold pressure of the sequencing valve 120 may be set (e.g., manually or electronically via the controller 46) at a pressure corresponding to the hydraulic fluid 124 when the first ram 50 is in second position 100. When the threshold pressure is met and/or exceeded, the outlet 134 of the sequencing valve 120 may be configured to open such that the hydraulic fluid 124 is directed toward the second actuator 129.

[0021] When the sequencing valve 120 is triggered (e.g., the threshold pressure is met and/or exceeded to open the outlet 134), the second ram 52 may be directed toward the first ram 50 (and the tubular string 24) by the second actuator 129. For example, FIG. 6 is a cross-sectional top view of the BOP 40, illustrating the first ram 50 in the second position 100 and the second ram 52 in a second position 140. As shown in the illustrated embodiments, the second ram 52 contacts the tubular string 24 as it moves toward the second position 140 and applies a force in the direction 88 such that the tubular string 24 is cut. The first ram 50 remains substantially stationary in the second position 100 and may apply an opposing force (e.g., reactive force) to the tubular string 24 in the direction 86 to keep the tubular string 24 substantially stationary with respect to the bore 25 as the second ram 52 moves toward the second position 140. Accordingly, as the second ram 52 moves toward the second position 140, the second shearing portion 68 and/or the first shearing portion 66 of the first ram 50 may cut through the tubular string 24, thereby sealing the bore 25.

[0022] To actuate the second ram 52, the outlet 134 of the sequencing valve 120 coupled to the second actuator 129 may be opened. For example, FIG. 7 is a schematic of the portion of the BOP 40, illustrating the first ram 50 in the second position 100 and the second ram 52 in the second position 140. As shown in the illustrated embodiment of FIG. 7, the hydraulic fluid 124 flows toward the second actuator 129, thereby driving the second ram 52 in the second direction 88 toward the tubular string 24 and the first ram 50.

[0023] When the second ram 52 moves in the direction 88, the second shearing portion 68 may contact the tubular string 24 and cut the tubular string 24, thereby sealing the bore 25. As discussed above, the first shearing portion 66 and the second shearing portion 68 may be offset from one another with respect to the axial axis 30. For example, the first shearing portion 66 may form a ledge 160 at a first distance 162 from a bottom surface 164 of the BOP 40. Additionally, the second shearing portion 68 may include a surface 166 that is a second distance 168 from the bottom surface 164 of the BOP 40. In some embodiments, the second distance 168 is slightly larger than the first distance 162 such that a gap 170 is formed between the surface 166 of the second shearing portion 68 and the ledge 160 of the first shearing portion 66. Accordingly, the first ram 50 and the second ram 52 may each extend through the tubular string 24 to completely cut the tubular string 24, and thus seal the bore 25.

[0024] Similar to movement of the first ram 50, as the hydraulic fluid 124 enters the first hydraulic chamber 128 and directs the second actuator 129 in the direction 88, the second hydraulic fluid 130 may flow from a second hydraulic chamber 142 of the second actuator 129 toward one or more of the hydraulic accumulators 45. In some embodiments, a pressure may increase in the second hydraulic chamber 142 as the second actuator 129 moves in the direction 88 (e.g., as a result of a reduction in volume of the second hydraulic chamber 142 caused by the piston 62). Accordingly, the pressure within the second hydraulic chamber 142 may urge the second hydraulic fluid 130 through an outlet 144 of the second hydraulic chamber 142 and toward one or more of the hydraulic accumulators 45.

[0025] In some embodiments, the hydraulic fluid 124 flows toward the first hydraulic chamber 128 of the second actuator 129 through a piloted check valve 172. The piloted check valve 172 may include a default position 174 configured to enable the hydraulic fluid 124 to flow in a first direction 176 toward the second actuator 129. The piloted check valve 172 may additionally block flow of the hydraulic fluid 124 in a second direction 178 (e.g., from the second actuator 129 toward the piloted check valve 172 and/or the sequencing valve 120). As shown in the illustrated embodiment of FIG. 7, the piloted check valve 172 may be fluidly coupled to the second hydraulic chamber 142 of the second actuator 129. When the pressure within the second hydraulic chamber 142 of the second actuator 129 increases to a value that meets or exceeds a threshold pressure (e.g., as a result of a reduction in volume of the second hydraulic chamber 142 as the second actuator 129 moves in the direction 88), the piloted check valve 172 may be configured to trigger, thereby enabling flow of the hydraulic fluid 124 in the second direction 178 and blocking flow of the hydraulic fluid in the first direction 176. In some embodiments, when the hydraulic fluid 124 flows in the second direction 178, the second ram 52 may be driven toward the open position 54 by the second actuator 129 (e.g., via the second hydraulic fluid 130 being pumped into the second hydraulic chamber 142 via a second pump 180).

[0026] When blowout conditions subside (e.g., the pressure of fluid in the well decreases below a threshold pressure), the rams 50, 52 may both be driven to the open position 54 to unseal the bore 25. For example, it may be desirable to open the bore 25 and enable fluid to flow toward the platform 12 when blowout conditions no longer exist. FIG. 8 is a schematic of a portion of the BOP 40, illustrating the hydraulic circuit 122 directing the hydraulic fluid 124 such that the rams 50, 52 are driven to the open position 54. As shown in the illustrated embodiment, the piloted check valve 172 is triggered, thereby enabling flow of the hydraulic fluid 124 in the second direction 178 (e.g., from the second actuator 129 toward the sequencing valve 120). Accordingly, the hydraulic fluid 124 may drain from both the first hydraulic chamber 126 of the first actuator 127 and the first hydraulic chamber 128 of the second actuator 129 toward a hydraulic fluid reservoir (e.g., one or more of the hydraulic accumulators 45).

[0027] For example, the second pump 180 may direct the second hydraulic fluid 130 from one or more of the hydraulic accumulators 45 toward the second hydraulic chamber 131 of the first actuator 127 and toward the second hydraulic chamber 142 of the second actuator 129. Therefore, pressures within the second hydraulic chambers 131, 142 may increase, thereby driving the first and second actuators 127, 129 toward the open position 54 (e.g., the first actuator 127 is driven in the direction 88 and the second actuator is driven in the direction 86).

[0028] In some embodiments, the first pump 125 and/or the second pump 180 may be coupled to the controller 46, which may be configured to adjust a speed of the first and second pumps 125, 180 to control movement of the actuators 127, 129. For example, the controller 46 may be communicatively coupled to motors of the first and second pumps 125, 180 such that the controller 46 may adjust the speed of the motors, and thus, the amount of the hydraulic fluid 124, 139 directed toward the actuators 127, 129.

[0029] Moving the rams 50, 52 to the second positions 100, 140, respectively, may be performed in the sequence described above (e.g., driving the first ram 50 to the second position 100 before driving the second ram 52 into the second position 140). However, directing the rams 50, 52 to the open position 54 (e.g., from the second positions 100, 140) may occur simultaneously or sequentially. Therefore, the bore 25 may be opened in a single step, whereas sealing the bore 25 may occur utilizing the multi-step, enhanced shearing sequence.

[0030] It should be noted that, in other embodiments, other components (e.g., instead of the sequencing valve 120 and the piloted check valve 172) may be utilized to perform the enhanced shearing sequence. For example, any suitable combination of valves and conduits may be utilized to direct the first ram 50 to the second position 100, while leaving the second ram 52 substantially stationary as a first step, and then directing the second ram 52 to the second position 140 after the first ram 50 reaches the second position 100 as a second step.

[0031] FIG. 9 is a block diagram 200 of a process for performing the enhanced shearing sequence to enhance a seal of the bore 25 when blowout conditions exist. At block 202, the controller 46 may be configured to actuate the first ram 50 toward the tubular string 24 disposed in the bore 25 of the riser 22. As discussed above, the first ram 50 may be positioned adjacent to the first end 64 of the body 56 of the BOP 40 (e.g., on a first side of the bore 25). In some embodiments, the first ram may be actuated toward the tubular string 24 by directing the hydraulic fluid 124 through the sequencing valve 120 toward the first hydraulic chamber 126 of the first actuator 127. Additionally, the hydraulic fluid 124 may be blocked from flowing toward the second actuator 129 by the sequencing valve 120 when the pressure of the hydraulic fluid 120 is below the threshold pressure, thereby maintaining the second ram 52 in the open position 54.

[0032] At block 204, the first ram 50 may guide the tubular string 24 along the inner diameter 102 of the bore 25 such that the tubular string 24 is generally aligned with the first shearing portion 66 and the second shearing portion 68 of the first and second rams 50, 52 along the axis 101. As discussed above, the second ram 50 may be positioned adjacent to the second end 65 of the body 56 of the BOP 40 (e.g., on a second side of the bore 25 opposite the first side).

[0033] At block 206, the controller 46 may be configured to actuate the second ram 52 toward the tubular string 24 and toward the first ram 52. As discussed above, the sequencing valve 120 may trigger when the pressure of the hydraulic fluid 124 meets or exceeds the threshold pressure, thereby opening the outlet 134 coupled to the second actuator 129. Therefore, the second ram 52 may be directed toward the tubular string 24 and the first ram 50 as the hydraulic fluid 124 flows toward the first hydraulic chamber 128 of the second actuator 129. Additionally, the first ram 52 may remain substantially stationary such that opposing forces are applied to the tubular string 24 by the first ram 50 and the second ram 52. Accordingly, the first ram 50 and the second ram 52 may cut through the entire tubular string 24 such that the bore 25 may be sealed when blowout conditions are experienced at the wellhead.

[0034] While the present 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 present disclosure is not intended to be limited to the particular forms disclosed. Rather, the present disclosure is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure as defined by the following appended claims.

Claims

1. A blowout preventer system, comprising:

a body surrounding a bore configured to enable fluid flow between a wellhead and a drilling riser;
a first ram disposed adjacent a first end of the body, wherein the first ram is coupled to a first actuator;
a second ram disposed adjacent to a second end opposite the first end of the body, wherein the second ram is coupled to a second actuator; and
a controller communicatively coupled to the first actuator and the second actuator, wherein the controller is configured to actuate the first actuator to direct the first ram toward a tubular string disposed in the bore, such that the first ram aligns the tubular string with a first shearing portion of the second ram when the first ram is in an actuated position, and wherein the controller is configured to actuate the second actuator, after actuating the first actuator, to direct the second ram toward the tubular string such that the first ram and the second ram completely cut the tubular string to seal the bore.

2. The blowout prevention system of claim 1, comprising a sequencing valve configured to direct hydraulic fluid toward the first actuator and configured to block a flow of hydraulic fluid toward the second actuator when a first pressure of the hydraulic fluid in the first actuator is below a first threshold pressure.

3. The blowout prevention system of claim 2, wherein the first threshold pressure corresponds to a second pressure of the hydraulic fluid in the first actuator when the first actuator is in the actuated position.

4. The blowout prevention system of claim 2, comprising a piloted check valve configured to direct the hydraulic fluid from the sequencing valve toward the second actuator and configured to block the hydraulic fluid from flowing toward the sequencing valve from the second actuator when a third pressure of the hydraulic fluid in the first actuator meets or exceeds the first threshold pressure.

5. The blowout prevention system of claim 4, wherein the piloted check valve is configured to direct the hydraulic fluid from the second actuator toward the sequencing valve when a fourth pressure of the hydraulic fluid in the second actuator reaches a second threshold pressure.

6. The blowout prevention system of claim 2, comprising a pump configured to drive the hydraulic fluid through the sequencing valve.

7. The blowout prevention system of claim 1, comprising a sensor configured to send feedback to the controller pertaining to a pressure of a fluid at the wellhead, wherein the controller is configured to compare the feedback to a threshold value.

8. The blowout prevention system of claim 7, wherein the controller is configured to actuate one or both of the first and second actuators only when the feedback meets or exceeds the threshold value.

9. The blowout prevention system of claim 1, wherein the first ram comprises a second shearing portion comprising a linear geometry and the first shearing portion of the second ram comprises an indented geometry.

10. A system, comprising:

a bore extending between a wellhead and a drilling riser;
a tubular string disposed in the bore and configured to direct a fluid between the wellhead and the drilling riser;
a blowout preventer coupled to the wellhead, wherein the blowout preventer comprises a body surrounding the bore and the tubular string;
a first ram of the blowout preventer positioned on a first side of the bore, wherein the first ram comprises a first shearing portion and is coupled to a first actuator;
a second ram of the blowout preventer positioned on a second side of the bore opposite the first side, wherein the second ram comprises a second shearing portion and is coupled to a second actuator; and
a controller coupled to the first actuator and the second actuator, wherein the controller is configured to actuate the first actuator to direct the first ram toward the tubular string and configured to actuate the second actuator to direct the second ram toward the tubular string after actuating the first actuator.

11. The system of claim 10, comprising a hydraulic circuit configured to flow a hydraulic fluid to and from a hydraulic accumulator, the first actuator, and the second actuator.

12. The system of claim 11, wherein the hydraulic circuit comprises a sequencing valve configured to direct hydraulic fluid toward the first actuator and to block a flow of the hydraulic fluid toward the second actuator when a first pressure of the hydraulic fluid in the first actuator is below a first threshold pressure.

13. The system of claim 12, comprising a piloted check valve configured to direct the hydraulic fluid from the sequencing valve toward the second actuator and block the hydraulic fluid from flowing toward the sequencing valve from the second actuator when a second pressure of the hydraulic fluid in the first actuator meets or exceeds the first threshold pressure.

14. The system of claim 13, wherein the piloted check valve is configured to direct the hydraulic fluid from the second actuator toward the sequencing valve when a third pressure of the hydraulic fluid in the second actuator reaches a second threshold pressure.

15. The system of claim 10, wherein the first shearing portion of the first ram comprises a linear geometry and the second shearing portion of the second ram comprises an indented geometry.

16. A method, comprising:

actuating a first ram of a blowout preventer toward a tubular string disposed in a bore of the blowout preventer, wherein the first ram is disposed on a first side of the bore;
aligning the tubular string with a first shearing portion of a second ram disposed on a second side of the bore opposite the first side; and
actuating the second ram toward the tubular string and the first ram, such that the first ram and the second ram cut the tubular string to seal the bore.

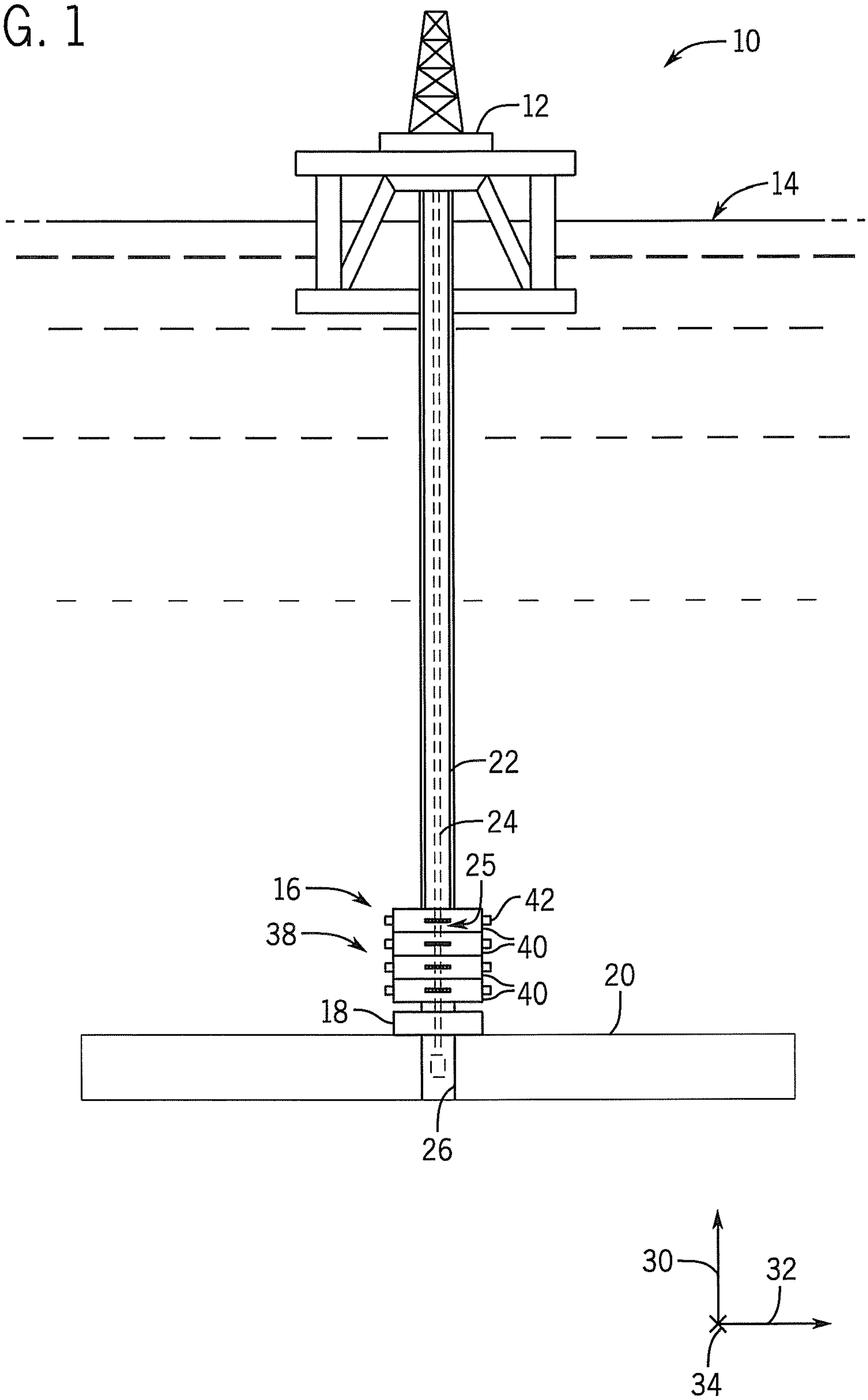
17. The method of claim 16, wherein actuating the first ram of the blowout preventer toward a tubular string disposed in the bore of the drilling riser comprises directing hydraulic fluid through a sequencing valve and toward a first actuator coupled to the first ram.

18. The method of claim 17, wherein directing the hydraulic fluid through the first sequencing valve and toward the first actuator coupled to the first ram comprises blocking the hydraulic fluid from flowing toward a second actuator coupled to the second ram when a pressure of the hydraulic fluid in the first actuator is below a threshold pressure.

19. The method of claim 18, wherein actuating the second ram toward the tubular string and the first ram such that the first ram and the second ram completely cut the tubular string to seal the bore comprises directing the hydraulic fluid through the sequencing valve toward the second actuator coupled to the second ram when the pressure of the hydraulic fluid in the first actuator meets or exceeds the threshold pressure.

20. The method of claim 16, wherein aligning the tubular string with the first shearing portion of the second ram disposed on the second side of the bore opposite the first side comprises guiding the tubular string along an inner diameter of the bore, such that the tubular string is aligned with the first shearing portion and a second shearing portion of the first ram with respect to a longitudinal axis.

FIG. 1



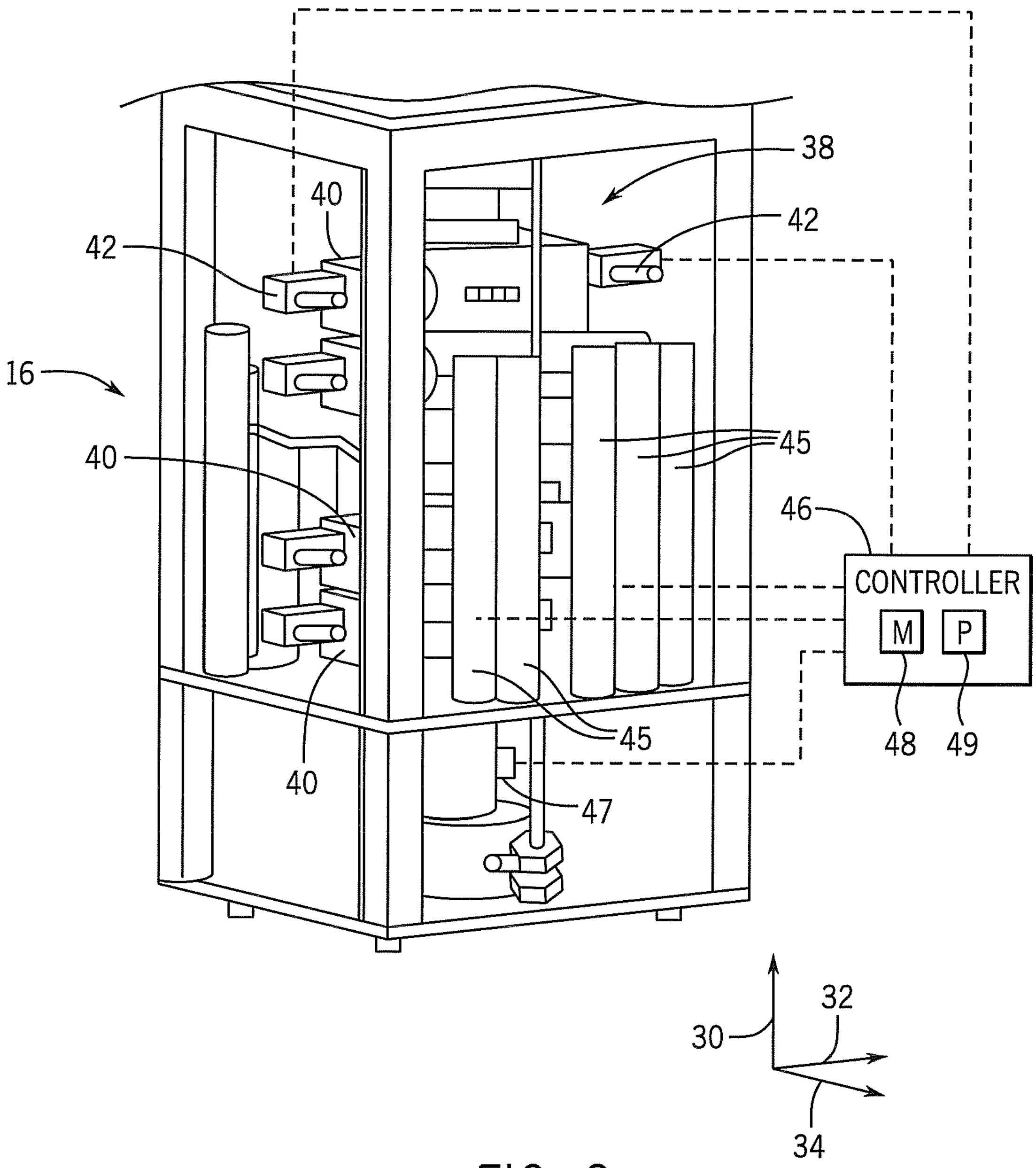


FIG. 2

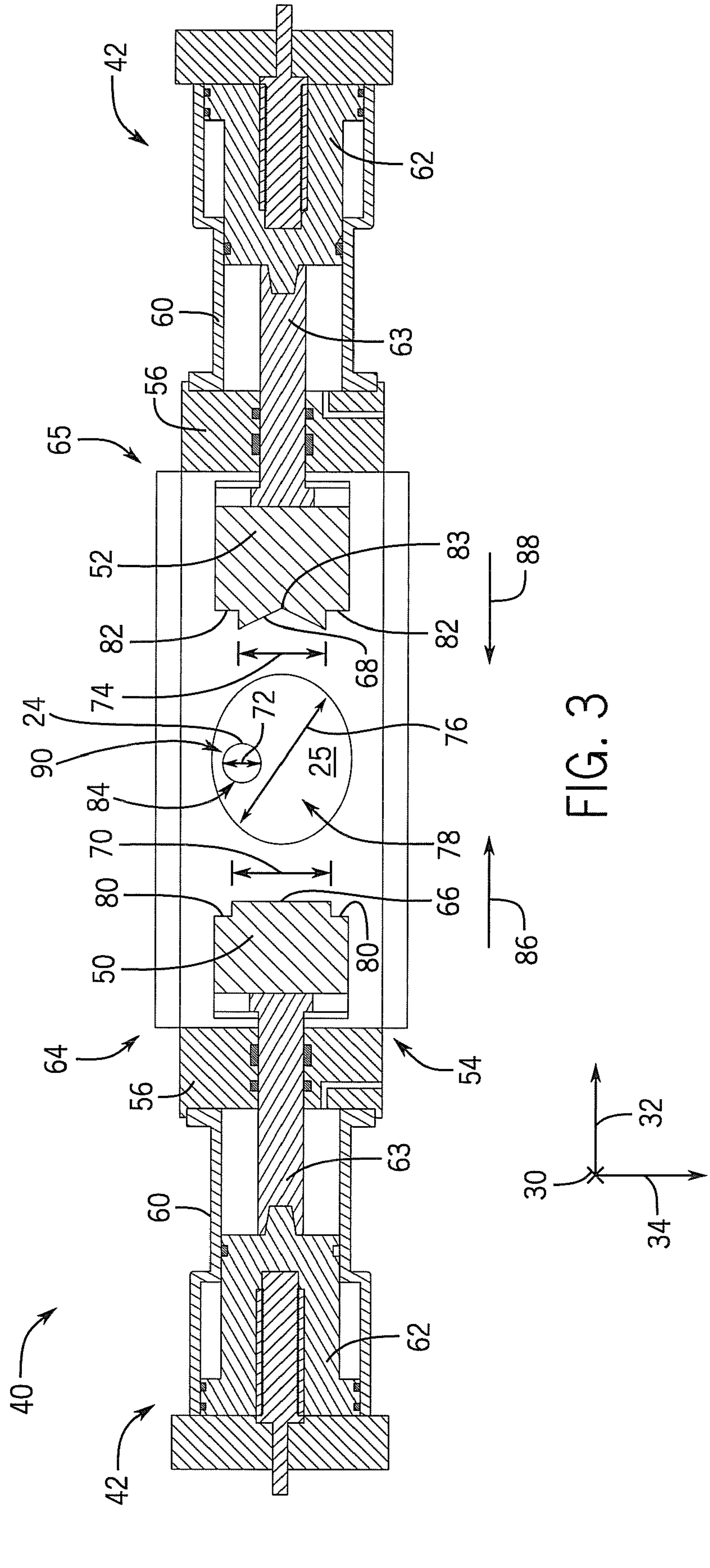

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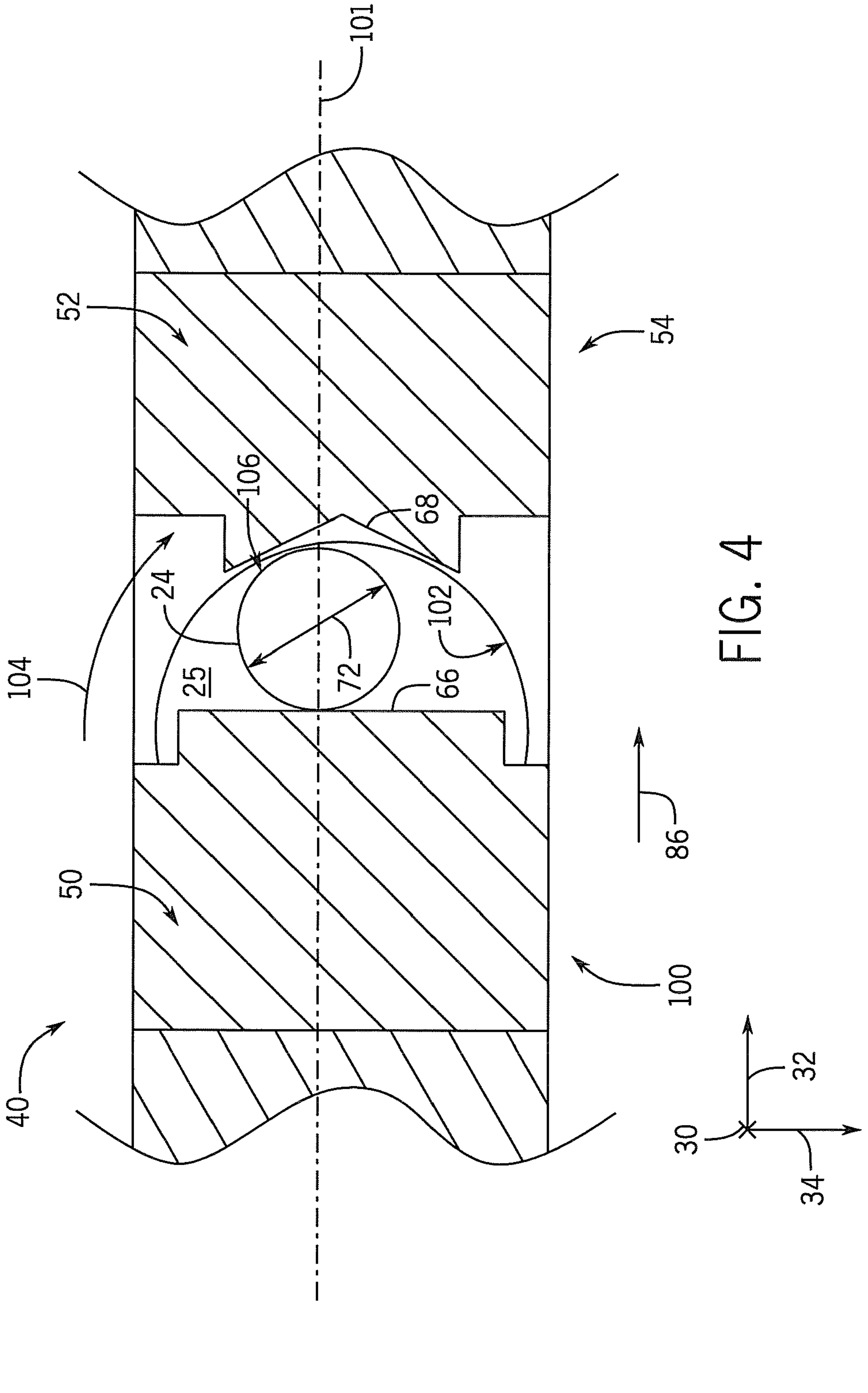
FIG. 3



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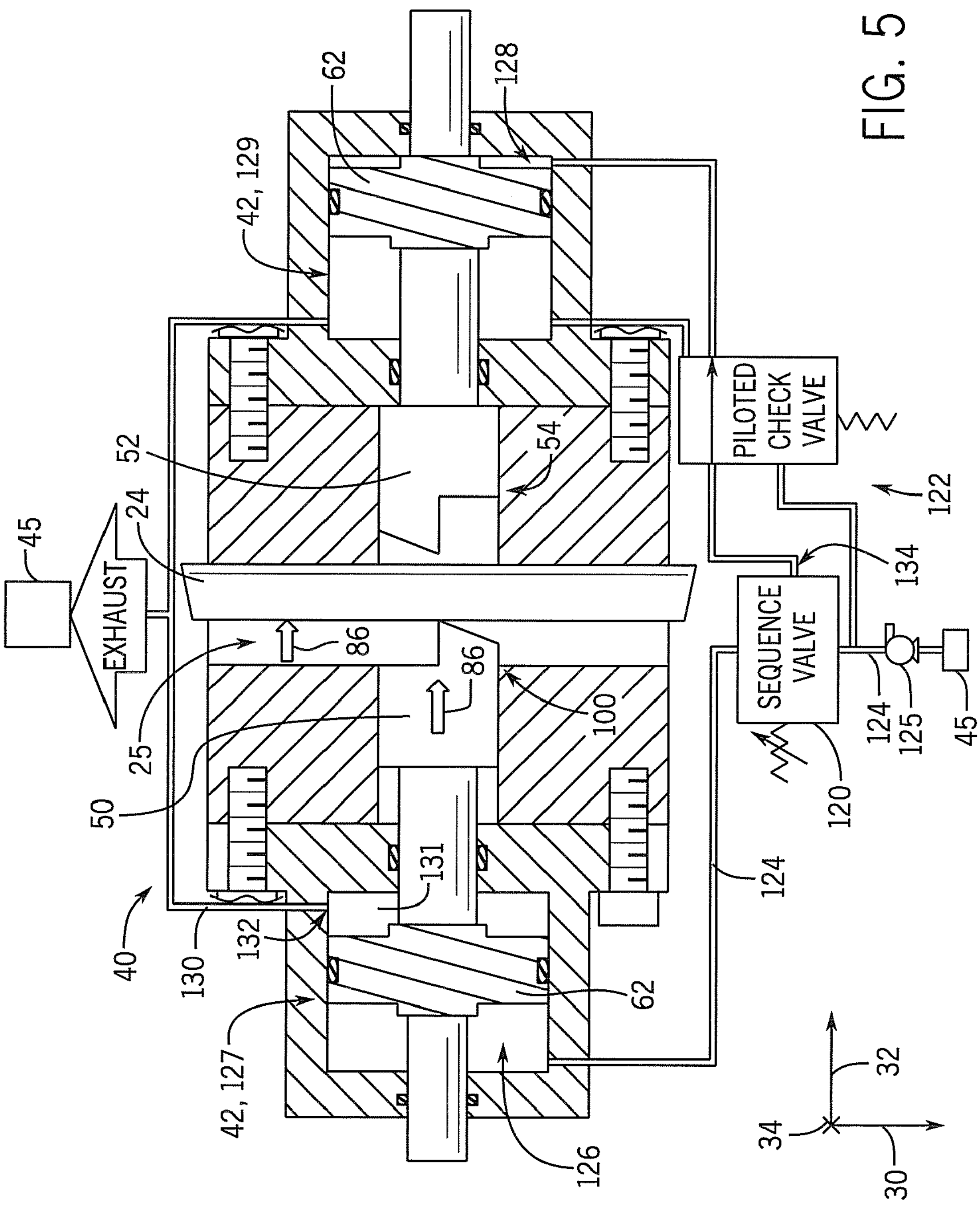
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FIG. 5

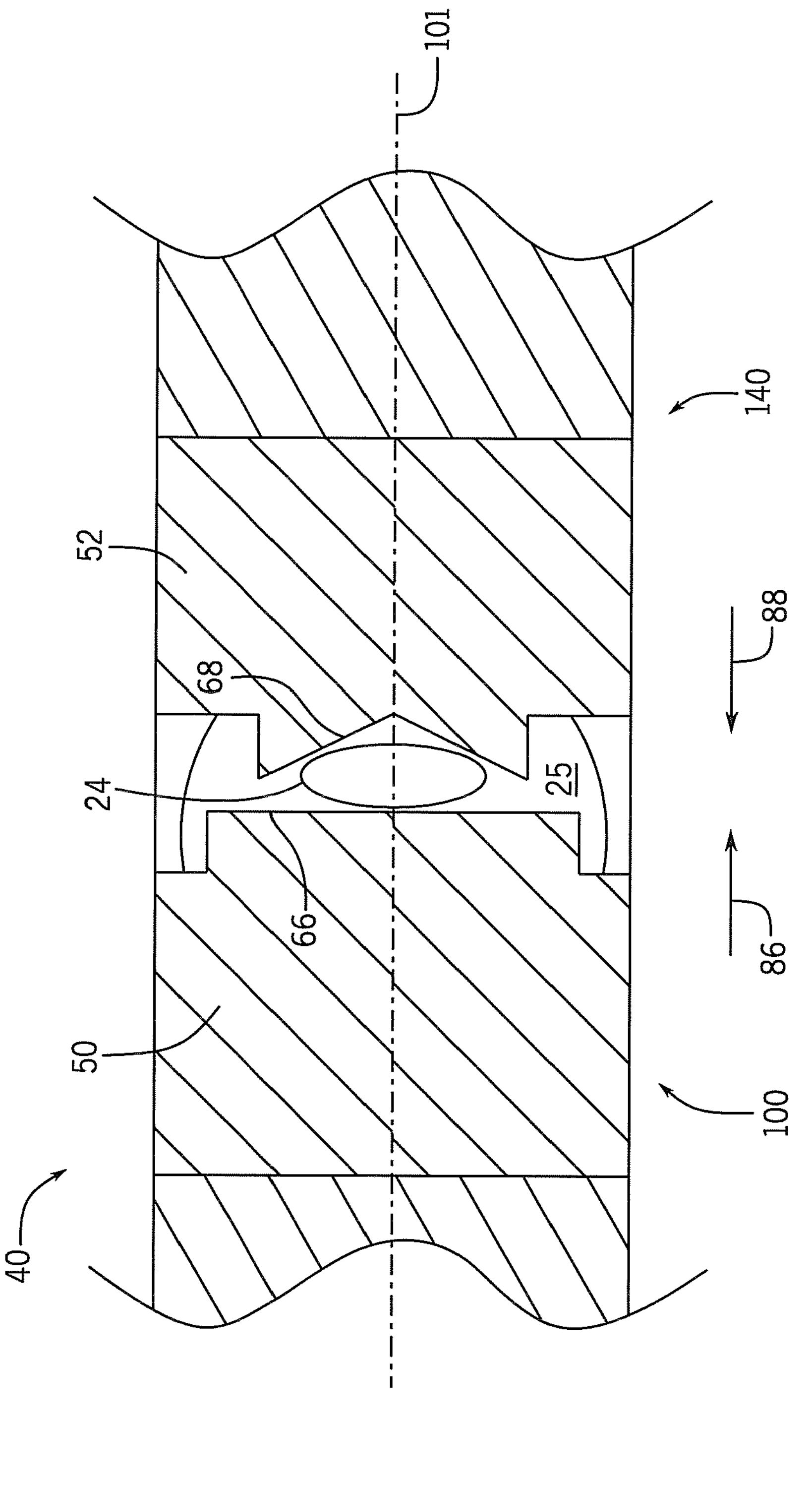

FIG. 6

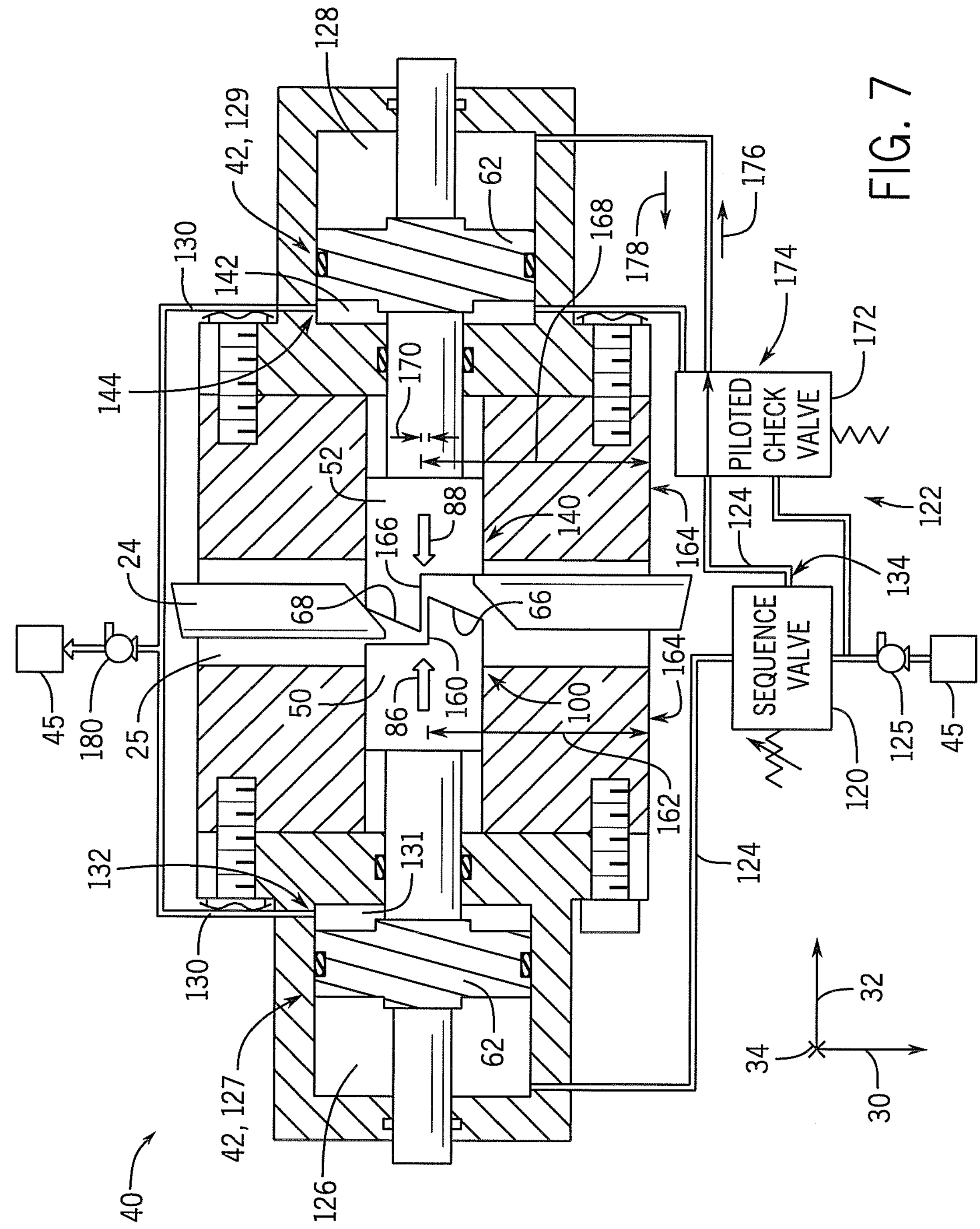
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FIG. 7

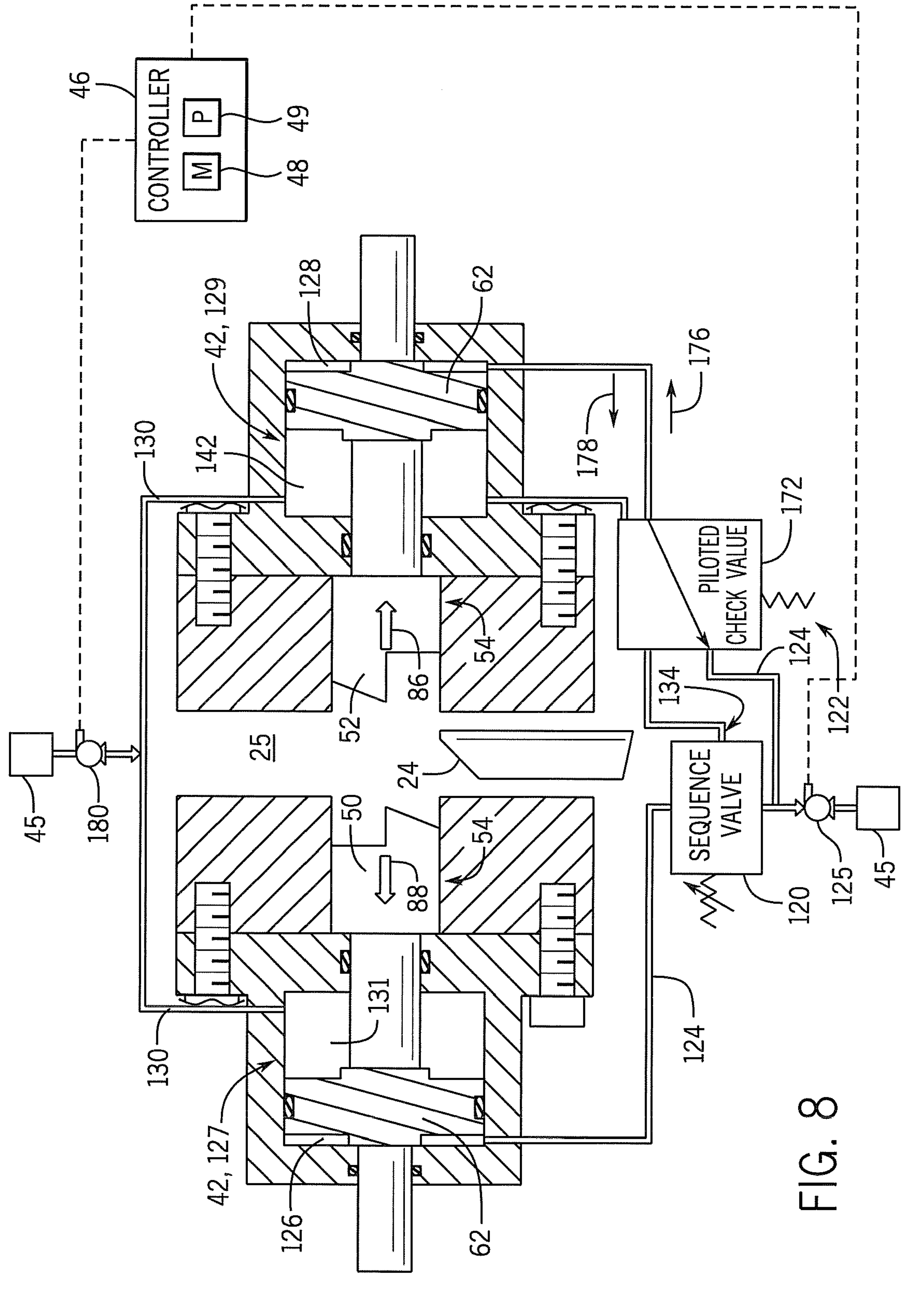
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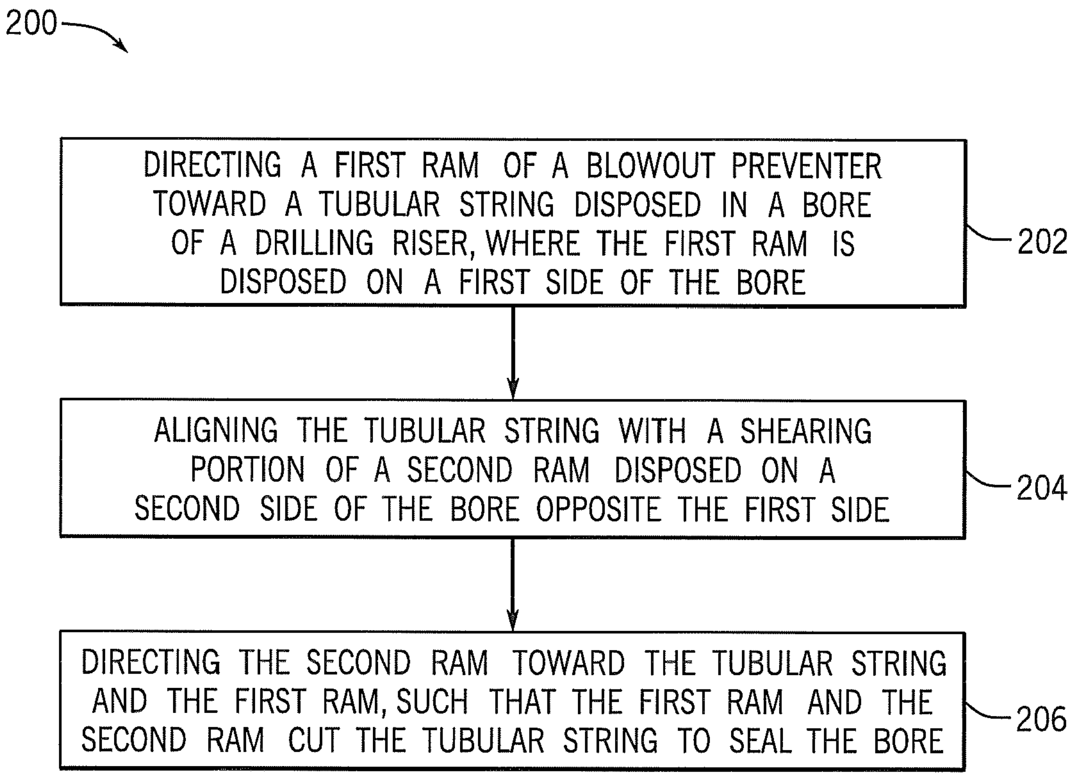
FIG. 8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DIRECTING A FIRST RAM OF A BLOWOUT PREVENTER TOWARD A TUBULAR STRING DISPOSED IN A BORE OF A DRILLING RISER, WHERE THE FIRST RAM IS DISPOSED ON A FIRST SIDE OF THE BORE
202
ALIGNING THE TUBULAR STRING WITH A SHEARING PORTION OF A SECOND RAM DISPOSED ON A SECOND SIDE OF THE BORE OPPOSITE THE FIRST SIDE
204
DIRECTING THE SECOND RAM TOWARD THE TUBULAR STRING AND THE FIRST RAM, SUCH THAT THE FIRST RAM AND THE SECOND RAM CUT THE TUBULAR STRING TO SEAL THE BORE
206

FIG. 9

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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 15 30 7172

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 2010/155086 A1 (BERCKENHOFF MICHAEL WAYNE [US] ET AL) 24 June 2010 (2010-06-24) * paragraphs [0060], [0061]; figure 16 * -----	1,2,6-9, 16-19	INV. E21B33/06 E21B34/16
Y	US 6 006 647 A (VAN WINKLE DENZAL WAYNE [US]) 28 December 1999 (1999-12-28) * column 3, line 34 - column 5, line 62; figures 1,2,3 * -----	1,2,16	
Y	US 5 062 349 A (KHAN FAROOQ A [US]) 5 November 1991 (1991-11-05) * column 4, line 64 - column 11, line 31 * -----	1,2,6-8, 16-19	
Y	US 3 955 622 A (JONES HOWARD W) 11 May 1976 (1976-05-11)	9	
A	* column 5, line 49 - column 7, line 57 * -----	1-8, 16-20	
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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	18 July 2016	Beran, Jiri

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

EPO FORM 1503 03.82 (P04E07)

page 1 of 2

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PARTIAL EUROPEAN SEARCH REPORT

Application Number
EP 15 30 7172

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	WO 2008/096174 A1 (NAT OILWELL VARCO LP [US]; LUCAS BRIAN [GB]; SPRINGETT FRANK BENJAMIN) 14 August 2008 (2008-08-14) * the whole document * -----	1-9, 16-20	

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EPO FORM 1503 03.82 (P04C10)

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INCOMPLETE SEARCH SHEET C

Application Number
EP 15 30 7172

Claim(s) completely searchable:
1-9, 16-20

Claim(s) not searched:
10-15

Reason for the limitation of the search:

Upon invitation dated on 02/05/2016 to clarify, upon which of the groups of the independent claims of the same category the search should be based, the applicant has indicated that the search shall be based upon the group with the independent claim 1.
Hence claims 1-9 and 16-20 are to be searched.
It is further noted that the subject-matter excluded from search according to Rule 62a(1) EPC cannot be used to amend the present application during examination (Rule 62a(2) EPC).

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 30 7172

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
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18-07-2016

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