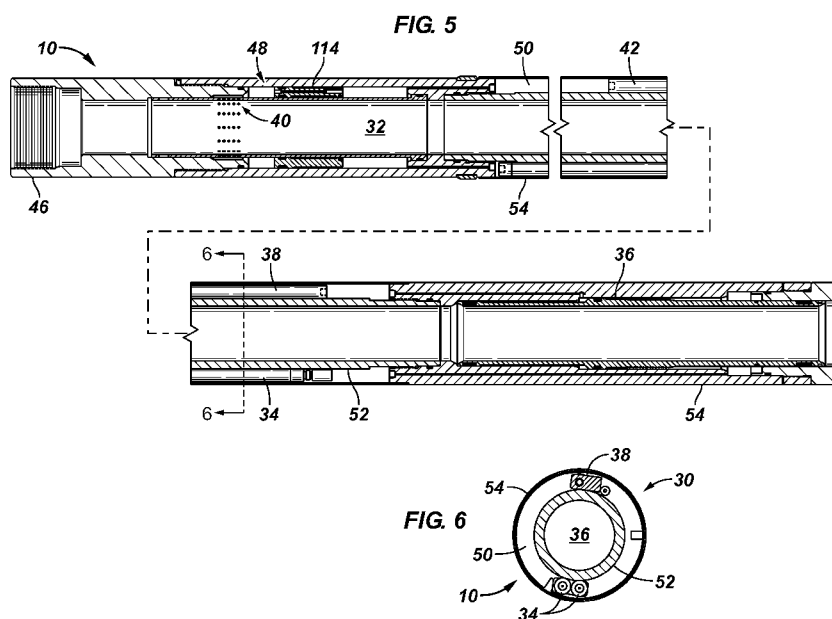




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[Continued on next page]

(54) **Title:** ACTUATING DEVICE AND METHOD

(57) **Abstract:** An actuating method includes applying an input pressure to a first side of a tool operator and to a second side of the tool operator and moving the tool operator from a first position to a second position in response to depleting the input pressure applied to the second side. A state of a tool element can be changed in response to moving the tool operator from the first position to the second position. The input pressure may be depleted from the second side of the tool operator by transferring hydraulic fluid to a confined diameter container disposed in an annular region of the actuating device or to the first side of the tool operator.



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ACTUATING DEVICE AND METHOD

BACKGROUND

[0001] This section provides background information to facilitate a better understanding of the various aspects of the disclosure. It should be understood that the statements in this section of this document are to be read in this light, and not as admissions of prior art.

[0002] Many downhole tools are actuated by stored mechanical energy sources such as springs or compressed gases. The energy is used to do work on a movable element of the tool, such as a piston or a sliding sleeve. When such tools are operated at great depths, the hydrostatic pressure of the wellbore fluid may apply pressures on the movable element that are comparable to or even greater than the pressure applied by the stored energy.

SUMMARY

[0003] An example of a method of changing the state of a tool disposed in a well in accordance with an embodiment includes applying differential pressure cycles to an actuating device disposed in a wellbore, the actuating device comprising a tool operator having a first side open to a first chamber and a second side open to a second chamber; moving the tool operator to a first position in response to applying the differential pressure cycles; actuating the tool operator from the first position to a second position in response to depleting pressure in the second chamber; and changing the state of a tool element in response to actuating the tool operator to the second position.

[0004] An example of an actuating device according to one or more embodiments includes a tubular body comprising an axial bore and an annular region, a confined diameter container disposed within the annular region, a tool operator having a first side open to a first chamber and a second side open to a second chamber, the tool operator moveable from a first position to a second position in response to a pressure differential between the first chamber and the second chamber, a trigger valve having a valve piston operable from a closed position to an open position, an input pressure port in hydraulic communication with the first chamber and the

second chamber through the trigger valve, and an exhaust port in hydraulic communication with the second chamber and the confined diameter container when the trigger valve piston is in the open position.

[0005] An example of an actuating method according to one or more embodiments includes applying an input pressure to a first side of a tool operator and to a second side of the tool operator; depleting the input pressure applied to the second side while maintaining the input pressure applied to the first side, moving the tool operator from a first position to a second position in response to depleting the input pressure applied to the second side, and changing the state of a tool element in response to moving the tool operator to the second position.

[0006] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Embodiments of actuating devices and methods are described with reference to the following figures. The same numbers are used throughout the figures to reference like features and components. It is emphasized that, in accordance with standard practice in the industry, various features are not necessarily drawn to scale. In fact, the dimensions of various features may be arbitrarily increased or reduced for clarity of discussion.

[0008] **Figure 1** illustrates an example system in which embodiments of the actuating device and method can be implemented.

[0009] **Figure 2** illustrates an example of an actuating device in accordance with one or more embodiments.

[0010] **Figure 3** illustrates an example of a tool that can implement embodiments of the actuating device and method.

[0011] **Figure 4** illustrates a sectional view of an actuating device along the line 4-4 of Figure 2 in accordance to one or more embodiments.

[0012] **Figure 5** illustrates an example of an actuating device in accordance with one or more embodiments.

[0013] **Figure 6** illustrates a sectional view of an actuating device along the line 6-6 of Figure 5 in accordance to one or more embodiments.

[0014] **Figure 7** illustrates an example of an actuating device tool operator in accordance to one or more embodiments.

[0015] **Figure 8** illustrates an example of an actuating device trigger valve according to one or more embodiments.

[0016] **Figure 9** schematically illustrates an example of an actuating device in a static position in accordance with one or more embodiments.

[0017] **Figure 10** schematically illustrates an example of an actuating device in a second position in accordance with one or more embodiments.

[0018] **Figure 11** schematically illustrates an example of a tool implementing an actuating device in accordance with an embodiment.

[0019] **Figure 12** illustrates a tool implementing an actuating device in accordance with an embodiment.

[0020] **Figure 13** illustrates an actuating device utilized with a tool in accordance with an embodiment.

[0021] **Figure 14** illustrates an expanded portion of a tool operator in isolation in accordance with an embodiment.

DETAILED DESCRIPTION

[0022] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

[0023] As used herein, the terms "up" and "down"; "upper" and "lower"; "top" and "bottom"; and other like terms indicating relative positions to a given point or element are utilized to more clearly describe some elements. Commonly, these terms relate to a reference point as the surface from which drilling operations are initiated as being the top point and the total depth of the well being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal or slanted relative to the surface.

[0024] Figure 1 illustrates an example of a well 5 in which embodiments of an actuating device and method, generally denoted by the numeral 10, can be implemented. Actuating device 10 is operationally connected with a tool element 12 to form a tool 14. In this embodiment, tool 14 is disposed downhole (i.e., subsurface) in wellbore 16 on a tubular string 18. In a non-limiting example, tool 14 is described as a valve, for example a formation isolation valve, and tool element 12 is a controllable barrier across the axial bore of tool 14. As examples, tool element 12 may be a ball-type valve control element or a flapper-type valve control element. Other types of tool elements and valve control elements are contemplated and considered within the scope of the appended claims.

[0025] Wellbore 16 is depicted extending from a surface 20 into the subterranean earthen formations 22. Wellbore 16 may or may not be cased, for example via a casing string 24. Although tool 14 is depicted as being disposed in a vertical wellbore 16, tool 14 may be disposed in a lateral or deviated section of wellbore 16 without departing from the scope of the disclosure. An annulus 26 is located between an exterior surface of the tool 14 and the interior surface of wellbore 16. The pressure in annulus 26 may be referred to in some embodiments as a casing pressure and the pressure in the bore 17 of tubular string 18 as tubing pressure. Casing pressure is associated with the hydrostatic column of the fluid in annulus 26 and the formation pressures communicated to annulus 26. The tubing pressure can be manipulated via pumps 28 located for example at surface 20.

[0026] In the embodiment depicted in Figure 1, actuating device 10 operates tool element 12 for controlling the state, open or closed, of tool 14. Actuating device 10 is an interventionless apparatus facilitating remote actuation of tool element 12, for example from surface 20. In an intervention, a tool (e.g., shifting tool) is conveyed downhole through bore 17 of tubular string 18 and through tool 14 to engage tool element 12 and actuate it to a different state.

[0027] Figure 3 illustrates an example of a tool 14 with which embodiments of actuating device 10 may be implemented. In the embodiment depicted in Figure 3, tool 14 is a valve, such as a formation isolation valve, adapted to be connected within a tubular string and disposed in a wellbore. Tool 14 comprises actuating device 10, illustrated for example in Figures 2 and 5.

[0028] With reference to Figures 2-10, an example of an actuating device 10 comprises a tubular body 30 having an axial bore 32; a confined diameter container 34 (i.e., atmospheric container); a tool operator 36 movable in response to a pressure differential between a first side 70 and a second side 72 of tool operator 36; and a hydraulic system 7 (Figures 9, 10) to selectively actuate tool operator 36. According to one or more embodiments, hydraulic system 7 comprises a trigger valve, generally denoted by the numeral 38, which is moveable from a closed position to an open position. Hydraulic system 7 communicates pressure at input pressure port 40 to first side 70 and second side 72 of tool operator 36 via tubing compensator 48 and trigger valve 38. Pressure is depleted from second side 72 by opening hydraulic communication between second side 72 of tool operator 36 and confined diameter container 34 via an exhaust port 94 when

trigger valve 38 is in the open position. In accordance with one or more embodiments of the disclosure, actuating device 10 includes a trigger 42 operationally connected to trigger valve 38 to selectively actuate trigger valve 38 from the closed position to the open position.

[0029] Refer now to Figure 7 illustrating an example of a tool operator 36 in accordance with one or more embodiments. A chamber 62 is defined between tool operator 36 and a housing generally denoted by the numeral 54. In accordance with one or more embodiments, chamber 62 may be filled with hydraulic fluid 116 (Figures 9, 10). A seal 64 is provided between tool operator 36 and housing 54, dividing chamber 62 into a first chamber 66 and a second chamber 68. First chamber 66 is in hydraulic communication with the first side 70 of tool operator 36. Second chamber 68 is in hydraulic communication with the second side 72 of tool operator 36. First side 70 is illustrated as an exterior surface of tool operator 36 on one side of seal 64 and second side 72 is illustrated as the exterior surface of tool operator 36 on the opposite side of seal 64 from first side 70. Tool operator 36 moves axially in response to a pressure differential between first side 70 and second side 72. A first passage 74 provides a flow path to first chamber 66 and first side 70. A second passage 76 provides a flow path to second chamber 68 and second side 72. Additional seals, generally denoted by the numeral 3, may be provided in actuating device 10.

[0030] Tool operator 36 is operationally connected to tool element 12, such that movement of tool operator 36 causes tool element 12 to actuate thereby changing the state of tool element 12 and tool 14. In the depicted embodiment, tool operator 36 is operationally connected to tool element 12 (Figures 1, 3) through a mechanical latch 44 (Figure 3). In this embodiment, movement of tool operator 36 from the first position to the second position causes ball-type tool element 12 to rotate from a closed position to an open position.

[0031] Actuating device 10 may be connected within tubular string 18 (Figure 1), for example at end 46, such that bore 17 of tubular string 18 and bore 32 of tool 14 form a substantially continuous axial bore. Input pressure port 40 is provided by compensator 48 (e.g., tubing compensator). Input pressure port 40 is illustrated as being opened to bore 32, thereby hydraulically communicating tubing pressure, which may be provided by pump 28 (Figure 1) for example, to trigger valve 38 and first side 70 and second side 72 of tool operator 36. Pressure

across tool operator 36 is independent of the reservoir pressure (i.e., pressure of the formation 22 penetrated by the wellbore). Pressure on the first side 70 (i.e., the pressure in first chamber 66) and the pressure on the second side 72 (i.e., the pressure in second chamber 68) is balanced when trigger valve 38 is in the closed position. When tool 14 is suspended in the well, the pressure across tool operator 36 is balanced and the pressure in first chamber 66 and second chamber 68 are balanced with the wellbore pressure. A sequence of pressure differentials are created by increasing the tubing pressure over the annulus 26 pressure and the sequence of pressure differentials are applied to trigger 42 to actuate trigger valve 38 to the open position. When trigger valve 38 opens a pressure differential is created across tool operator 36 by the transfer of hydraulic fluid from second chamber 68 to confined diameter container 34 through open trigger valve 38. The input hydraulic pressure applied to tool operator 36 prior to the trigger differential pressure sequence is maintained on first side 70 when trigger valve 38 is actuated to the open position. The differential pressure created across tool operator 36 by bleeding pressure from second side 72 causes tool operator 36 to move axially from the first position.

[0032] When actuating device 10 is suspended in the wellbore, the out of balance pressure situation exists in trigger 42 and not across tool operator 36 which may provide for longer suspension times than available with conventional actuating devices. Locating the pressure differential (i.e., the energy to actuate tool operator 36) in trigger 42 may reduce the seal area utilized at tool operator 36 relative to some contemporary actuating devices thereby reducing the leakage across the seals and increasing the available suspension time of the tool in the wellbore relative to the suspension time of some contemporary wellbore tools.

[0033] Tubular body 30 forms an annular region 50 between a mandrel 52 defining a portion of axial bore 32 and a housing 54. In accordance with one or more embodiments, confined diameter container 34 and trigger valve 38 are disposed in annular region 50 as illustrated for example in Figures 4 and 6.

[0034] In Figures 2 and 4, confined diameter container 34 is illustrated as a helical coil that is concentrically disposed about mandrel 52. In Figures 5 and 6, confined diameter container 34 is depicted as a bottle, e.g., a sample bottle. Confined diameter container 34 is initially set at atmospheric pressure, for example the pressure at surface 20, and evacuated to provide a

reservoir into which hydraulic fluid from the second side of tool operator 36 is transferred when trigger valve 38 is operated to the open position creating hydraulic communication between the second side of tool operator 36 and confined diameter container 34. With reference to Figures 1 and 9, when tool 14 is suspended in the wellbore the pressure differential between the internal volume of confined diameter container 34 and the wellbore is located in trigger valve 38 across first seal 84 and second seal 88 and not across the seal 64 of tool operator 36.

[0035] In accordance with one or more embodiments, actuating device 10 is adapted for use in high pressure wells. Confined diameter container 34 is at atmospheric pressure internally and high external pressure acts on the exterior surface of confined diameter container 34, thus confined diameter container 34 is configured with a small internal diameter and corresponding small external surface area to resist crushing in high pressure environments. For example, the internal diameter and the external surface area of confined diameter container 34 is smaller than the respective internal diameter of annular region 50 and the external surface area of tubular body 30 in which confined diameter container 34 is disposed. It is noted that when actuating device 10 is disposed in a wellbore, annular region 50 may be in hydraulic communication with the wellbore and not subject to a differential pressure.

[0036] Figure 4 illustrates a sectional view of device 10 along the line 4-4 of Figure 2 and Figure 6 illustrates a sectional view of actuating device 10 along the line 6-6 of Figure 5. Annular region 50 is formed between housing 54 and mandrel 52 of tubular body 30. Confined diameter container 34 is located in annular region 50. The volume of confined diameter container 34 can be modified to accommodate the volume of hydraulic fluid 116 (Figures 9, 10) that is to be transferred from the second side 72 to allow tool operator 36 to move to the second position and change the state of tool element 12. For example, with reference to Figures 2 and 4, the length of confined diameter container 34 (i.e., helical coil) and the number of turns around mandrel 52 may be varied to accommodate the desired volume of hydraulic fluid. With reference to Figures 5 and 6, the length of confined diameter container 34 and/or the number of confined diameter containers 34 (i.e., bottles) utilized can be varied to accommodate the desired volume of hydraulic fluid for tool operator 36 to shift. For example, Figure 6 illustrates two confined diameter containers 34, in the form of bottles, disposed in annular region 50.

[0037] The configuration of the confined diameter container 34 may be selected for operational characteristics. For example, the actuation of tool operator 36 may be controlled differently by a coiled embodiment of confined diameter container 34 relative to the same internal volume bottle embodiment of a confined diameter container 34. For example, a bottle configuration of confined diameter container 34 may provide an accelerated transfer of hydraulic fluid 116 from second chamber 68 and corresponding accelerated actuation of tool operator 36 upon opening of trigger valve 38 relative to a same volume helical coil embodiment. In a helical coil configuration, the curvature of the coil governs the centrifugal force and the pitch (e.g., helix angle) influences the torsion to which the hydraulic fluid 116 is subjected while flowing. While the total force on the hydraulic fluid 116 flowing into the bottle and the helical coil may be the same, the force is distributed over a longer period of time in the helical coil configuration which may create a longer duration axial movement of tool operator 36 and corresponding longer duration pull on tool element 12. A longer duration actuation may be beneficial in opening a tool element 12 that is stuck relative to a more instantaneous actuation force which may be provided with a bottle configuration.

[0038] Figures 4 and 6 illustrate trigger valve 38 disposed in annular region 50. As further described below, depicted trigger valve 38 comprises a first side port 58 in hydraulic communication with first side 70 of tool operator 36 via first passage 74 (Figures 9, 10) and a second side port 60 in hydraulic communication with the second side of tool operator 36 via second passage 76 (Figures 9, 10).

[0039] Figure 8 illustrates an example of a trigger valve 38 in accordance to one or more embodiments this disclosure. Trigger valve 38 comprises a valve body 78 having a cylinder 80, a valve piston 82 disposed in cylinder 80, and ports providing hydraulic communication to cylinder 80. In the depicted embodiment, an inlet port 92 is located proximate to a first end 77 of valve body 78. First side port 58 and second side port 60 are located proximate to a second end 79 of valve body 78. An exhaust port 94 is formed through valve body 78 between first end 77 and second end 79.

[0040] Valve piston 82 comprises a first seal 84 spaced apart from a second seal 88 to form a sealed section 96. Valve piston 82 has a first seal surface 86 proximate first seal 84 upon which

hydraulic pressure acts and a second seal surface 90 proximate second seal 88 upon which hydraulic pressure acts. In accordance with one or more embodiments, first seal surface 86 has a larger surface area than second seal surface 90.

[0041] Valve piston 82 and trigger valve 38 are illustrated in Figure 8 in the closed position, or static position, as further described below. In the closed position, valve piston 82 blocks hydraulic communication between confined diameter container 34 and second side 72 of tool operator 36. Valve piston 82 is held by trigger 42 to prevent movement of valve piston 82 from the closed position to the open position until trigger 42 is actuated to release valve piston 82 for movement. In accordance with one or more embodiments, actuating trigger valve 38 to the open position may include actuating trigger 42 to release valve piston 82 for movement.

[0042] Trigger 42 is illustrated in Figure 8 as a counter mechanism in accordance with one or more embodiments. In accordance with one or more embodiments, trigger 42 is actuated to release valve piston 82 in response to a pressure differential, or force differential, created a determined number of times across trigger 42. In the embodiment of Figure 8, the pressure differential across trigger 42 is created by applying an input pressure (e.g., tubing pressure) via tubing compensator 48 to trigger 42 that exceeds the opposing casing pressure applied to trigger 42 via annulus compensator 106.

[0043] The depicted trigger 42 includes a cycling piston 98 that is in fluid communication with input pressure port 40 via tubing compensator 48 (Figures 2, 5). Cycling piston 98 is connected through a mechanical indexer 100 to a rod 102 which is connected to valve piston 82 via holding collet 104. Trigger 42 includes an annulus compensator 106 that has an input pressure port 108 in hydraulic communication with annulus 26 (Figure 1). Annulus compensator 106 communicates the reference pressure, casing pressure in this embodiment, from annulus 26 to cycling piston 98.

[0044] Cycling piston 98 is cycled up and down in response to cycling the tubing pressure which is applied to cycling piston 98 through tubing compensator 48. Tubing pressure is communicated through tubing compensator 48 and port 110 urging cycling piston 98 downward and against the counter-force of the annulus 26 pressure communicated to cycling piston 98 via

annulus compensator 106 and, in this embodiment, the force of spring 112. After a determined number of cycles, indexing mechanism 100 reaches a position that permits rod 102 to move upward disconnecting from collet 104 thereby releasing valve piston 82 so that it can move from the closed position to the open position as further described below with reference to Figures 9 and 10.

[0045] Figure 9 schematically illustrates an example of an actuating device 10 in a static position in accordance with one or more embodiments. Hydraulic system 7 comprises hydraulic fluid 116 disposed in first passage 74, second passage 76, first chamber 66, and second chamber 68. In the static position, trigger valve 38 is in the closed position and tool operator 36 is in the first position. Actuating device 10 can be conveyed downhole into a wellbore 16 as illustrated in Figure 1, and remain in the static position until trigger 42 is operated to free valve piston 82 to move from the closed position. In the static position, the pressure across tool operator 36 is balanced.

[0046] Pressure applied at input pressure port 40 acts on floating piston 114 of compensator 48 and hydraulic fluid 116 communicating the pressure at input pressure port 40 to first seal surface 86 of valve piston 82. When actuating device 10 is in the static position, for example disposed in wellbore 16, trigger 42 maintains valve piston 82 in the closed position. In the closed position, first seal 84 and second seal 88 straddle exhaust port 94, thereby blocking exhaust port 94 and sealing hydraulic communication to confined diameter container 34.

[0047] Figure 10 schematically illustrates actuating device 10 in a second position in accordance with one or more embodiments of the disclosure. After trigger 42 has been actuated, valve piston 82 of trigger valve 38 is released to move from the closed position of Figure 9 to the open position illustrated in Figure 10. Upon release of valve piston 82, input pressure from tubular string 18 is communicated via tubing compensator 48 to act on first seal surface 86 of valve piston 82 which communicates the same pressure to both first side 70 and second side 72 of tool operator 36 via hydraulic fluid 116 in first passage 74 and second passage 76 being in communication with second seal surface 90.

[0048] Valve piston 82 moves downward, shifting from the closed position to the open position in response to the downward force on valve piston 82 overcoming the upward force on valve piston 82. First seal surface 86 has a larger surface area than the surface area of second seal surface 90 to provide the force differential for movement of valve piston 82 in response to an equal hydraulic pressure on both sides of valve piston 82. Movement of valve piston 82 to the open position opens hydraulic communication between second side 72 and confined diameter container 34 permitting the flow of hydraulic fluid 116 from second chamber 68 to confined diameter container 34. In the second position, sealed section 96 is positioned across second side port 60 and exhaust port 94 opening the flow path between passage 95 and second passage 76. Input pressure is maintained on first side 70 of tool operator 36 while tool operator 36 moves toward the second position and hydraulic fluid 116 is bled from second chamber 68 into confined diameter container 34.

[0049] An example of an actuating method 10 in accordance with an embodiment is now described with reference to Figures 1-10. Actuating method 10 comprises applying an input pressure to first side 70 and to second side 72 when tool operator is in a first position; depleting the input pressure applied to second side 72 while maintaining the input pressure applied to first side 70; moving the tool operator 36 from the first position to the second position in response to depleting the input pressure applied to second side 72; and changing the state of tool element 12 in response to moving tool operator 36 to the second position. Depleting the input pressure applied to second side 72 may comprise transferring hydraulic fluid 116 from the second side 72 to an atmospheric container such as confined diameter container 34.

[0050] Referring to Figures 1 and 11-14, an example of a tool 14 implementing an actuating device and method 10 according to one or more embodiments is described. Actuating device 10 comprises a tool operator 36 that is axially moveable in response to a pressure differential between a first chamber 66 and a second chamber 68. In a tool 14, actuating device 10 is operationally connected to a tool element 12, for example via a latch 44, to actuate and change the state of tool element 12 in response to movement of tool operator 36 from a first position to a second position. In the illustrated embodiment, latch 44 comprises an operator connector 122 of tool operator 36 and a latch connector 123. According to one or more embodiments, actuating

device 10 is selectively operated from the first position to the second position by a time counter depleting a hydraulic pressure applied to the second chamber 68.

[0051] With reference to Figure 12, actuating device 10 is implemented in a tool 14 connected to a tubular string 18. Actuating device 10 comprises a tubular body 30 having an axial bore 32 and an annular region 50 defined between a mandrel 52 and a housing 54. In this embodiment, a tubing compensator 48 and annulus compensator 106 are disposed in annular region 50. Input pressure port 40 is in communication with co-axial bores 17, 32 and tubing compensator 48. Annulus compensator 106 is in hydraulic communication with annulus 26 of Figure 1 through input pressure port 108.

[0052] Referring to Figure 14, an expanded view of an example of a tool operator 36 is illustrated. Tool operator 36 is movably positioned within a housing 54 and an axial bore 32 extends through tool operator 36. First chamber 66 is defined between an exterior surface of tool operator 36 and housing 54 and between a first seal 117 and a second seal 119. The second chamber 68 is defined between the exterior surface of tool operator 36 and housing 54 and between a third seal 118 and a fourth seal 120. A third chamber 124, referred to herein as a vacuum chamber, is defined between second seal 119 and third seal 118 and between the exterior surface of tool operator 36 and housing 54. The exterior surface of tool operator 36 that is open to first chamber 66 is referred to as the first side 70 of tool operator 36. Similarly, the exterior surface of tool operator 36 that is open to second chamber 68 is referred to as the second side 72 of tool operator 36. A first passage 74 is depicted extending through housing 54 to first chamber 66 and a second passage 76 extending through housing 54 to second chamber 68. Hydraulic pressure in first chamber 66 acts on first side 70, urging tool operator 36 down in this embodiment against the counter force of the hydraulic pressure in second chamber 68 acting on second side 72. Additional seals, generally denoted by the numeral 3, may be provided in actuating device 10. As more clearly illustrated in Figure 13, first passage 74, first chamber 66, second passage 76, and second chamber 68 may contain hydraulic fluid 116.

[0053] Referring to Figures 11-14, actuating device 10 comprises a hydraulic system 7 to selectively actuate tool operator 36 and tool element 12. Hydraulic system 7 comprises tubing compensator 48, annulus compensator 106, and a trigger valve, generally denoted by the numeral

38. Hydraulic system 7 forms a closed loop of clean hydraulic fluid 116 with first chamber 66 and second chamber 68. According to one or more embodiments, trigger valve 38 comprises a first check valve 128 permitting one-way flow of hydraulic fluid 116 from tubing compensator 48 to second chamber 68, a second check valve 130 permitting one-way flow of hydraulic fluid 116 from annulus compensator 106 to tubing compensator 48, and a flow restrictor 126 providing hydraulic communication between second chamber 68 and first chamber 66. Flow restrictor 126 can act as a time counter with respect to actuating tool element 12 in response to actuation of tool operator 36 from the first position to the second position. Flow restrictor 126 can be sized to control the flow of hydraulic fluid 116 from the second chamber 68 in accordance with a desired time delay for movement of tool operator 36 from the first position to the second position.

[0054] An example of an actuating device and method 10 is now described with reference to Figures 1 and 11-14. Tool 14, illustrated as a downhole wellbore tool, is disposed in wellbore 16 on tubular string 18 where it can remain in a static position until it is desired to operate tool element 12 of tool 14 to a different state. For example, tool element 12 may comprise a valve moveable between an open state and a closed state blocking the continuous axial bore formed through tubular string 18 and tool 14.

[0055] In accordance to one or more embodiments, casing pressure, the pressure in annulus 26, acts through input pressure port 108 on floating piston 114 of annulus compensator 106 communicating annulus 26 pressure via first passage 74 to first chamber 66 and first side 70 of tool operator 36. Tubing pressure, the pressure in tubular string 18 (bores 17, 32), acts on the floating piston 114 of tubing compensator 48 and is communicated via second passage 76 to second chamber 68 and second side 72.

[0056] In this embodiment, well 5 is underbalanced and the pressure in annulus 26 (casing pressure, reservoir pressure) is greater than the tubing pressure (pressure in bore 17 of tubular string 18). In the static position, hydraulic fluid 116 has flowed from second chamber 68 to first chamber 66 through flow restrictor 126 permitting tool operator 36 to move to the static position wherein either the force across tool operator 36 is equal or tool operator is physically stopped for example by a shoulder of tool operator 36 contacting a shoulder of housing 54. An example of a

tool shoulder 138 and corresponding housing shoulder 139 are illustrated in Figure 14 relative to second chamber 68.

[0057] When it is desired to change the state of tool 14, tool operator 36 is actuated from the static position to a first position by increasing the volume and pressure in second chamber 68. The volume and pressure of second chamber 68 is increased in response to applying differential pressure cycles to actuating device 10, in particular to hydraulic system 7. In an example, a differential pressure cycle includes applying a first tubing pressure in excess of the casing pressure, for example by operation of pump 28, and then reducing the tubing pressure back below the annulus 26 pressure. When the tubing pressure is increased above the casing pressure, the upward force on tubular operator 36 from second side 72 overcomes the downward force from first side 70 causing tool operator 36 to move uphole as hydraulic fluid 116 is pumped into second chamber 68. A vacuum may be created in third chamber 124 between second seal 119 and third seal 118 as tool operator 36 is urged upward. In accordance to one or more embodiments, seals 117, 118, 119 and 120 are high pressure seals. Tool operator 36 is subsequently actuated from the first position to the second position in response to depleting the pressure in second chamber 68. Annulus 26 pressure acts on first side 70 when the pressure in second chamber 68 is depleted. The vacuum created in third chamber 124 may act on tool operator 36, urging it downward from the first position toward the second position. Actuation of tool operator 36 from the first position to the second position changes the state of operationally coupled tool element 12. Tool operator 36 may be located in substantially the same location when it is in the static position and when it is in the second position.

[0058] Each differential pressure cycle creates an incremental upward movement, or stroke, of tool operator 36 when the tubing pressure exceeds the casing pressure. The reduction of tubing pressure below the casing pressure portion of the differential pressure cycle facilitates the next differential pressure induced incremental upward stroke. For example, when the tubing pressure exceeds the casing pressure, hydraulic fluid 116 and pressure are communicated from tubing compensator 48 through second passage 76 and first check valve 128 into second chamber 68 increasing the volume of second chamber 68. First check valve 128 blocks the backflow of hydraulic fluid 116 from second chamber 68 to tubing compensator 48 and second check valve

130 blocks the flow of hydraulic fluid 116 from tubing compensator 48 into annulus compensator 106. The volume and pressure of second chamber 68 remains substantially unchanged during the second portion of the differential pressure cycle when the casing pressure exceeds the tubing pressure and hydraulic fluid 116 can flow from annulus compensator 106 to tubing compensator 48 through second check valve 130.

[0059] From the first position tool operator 36 is actuated to the second position, for example downhole, through the controlled leakage of the pressure build-up in second chamber 68 as hydraulic fluid 116 flows from second chamber 68 through flow restrictor 126 to first chamber 66. Flow restrictor 126 serves as a time counter for actuation of tool operator 36 from the first position to the second position. Annulus 26 pressure acts on first side 66 urging tool operator 36 toward the second position against the upward force of tubular string 18 pressure acting on second side 68. According to some embodiments, the vacuum created in third chamber 124 may act to urge tool operator toward the second position.

[0060] In accordance with embodiments, actuating device 10 and tool element 12 are operationally connected, or coupled, to permit movement of tool operator 36 from the static position to the first position without changing the state of tool element 12 and to translate movement of tool operator 36 from the first position to the second position to change the state of tool element 12. Actuating device 10 is illustrated in the static position in Figure 11-13, with operator connector 122 of tool operator 36 located below latch connector 123. Operator connector 122 is positioned below latch connector 123 a distance 140 when actuating device 10 is in the static position. As will be further described, operator latch 122 may be located in substantially the same location, generally denoted by the numeral 152 in Figure 13, when actuating device 10 is in the static position and when actuating device 10 is in the second position. When actuating device 10 is in the first position, operator latch 122 is positioned above latch connector 123 at a location generally denoted by the numeral 150 in Figure 13. According to one or more embodiments, operator connector 122 may comprise collet fingers. As tool operator 36 moves uphole from the static position to the first position, operator connector 122 travels substantially the distance 140 and then engages latch connector 123 and carries latch connector 123 uphole to an intermediate position generally denoted by the numeral 132.

Distance 140 is described as the distance operator connector 122 extends below latch connector 123 in the static position. A pocket 134 having a shoulder 136 is formed in housing 54 proximate to intermediate position 132. As tool operator 36 moves uphole, operator connector 122 expands into pocket 134 releasing latch connector 123. When tool operator 36 is in the first position, operator connector 122 is located proximate to location 150 and positioned above latch connector 123. In accordance with one or more embodiments, latch connector 123 may expand outward at pocket 134 and hang on shoulder 136 when released from operator connector 122. It is repeated that the movement of latch connector 123 from the static position to intermediate position 132 does not actuate the tool element in this embodiment. When tool operator 36 is actuated downhole from the first position, operator connector 122 contacts latch connector 123 and pushes latch 44 downhole until tool operator 36 is in the second position. In the second position, tool connector 122 is located proximate to location 152 and latch connector 123 is located below tool connector 122. Thus, when actuating device 10 is in the second position, latch connector 123 is positioned approximately the distance 140 below where latch connector 123 was positioned when actuating device 10 was in the static position. Tool element 12 is actuated to change states in response to movement of tool operator 36 from the first position to the second position.

[0061] An example of a method 10 of changing the state of a tool 14 disposed in a well 5 is now described with reference to Figures 1 and 11-14. Method 10 in accordance with one or more embodiments, comprises applying differential pressure cycles to an actuating device 10 disposed in a wellbore 16, the actuating device 10 comprising a tool operator 36 having a first side 70 open to a first chamber 66 and a second side 72 open to a second chamber 68; moving the tool operator 36 to a first position in response to applying the differential pressure cycles; actuating the tool operator from the first position to a second position in response to depleting pressure in the second chamber 68 of the tool operator 36; and changing the state of a tool element 12 in response to actuating the tool operator 36 to the second position.

[0062] Tool operator 36 may be moved to the first position, for example from a static position, by increasing the volume of the second chamber 68. According to one or more embodiments, the pressure may be depleted from second chamber 68 by communicating hydraulic fluid 116

from second chamber 68 to first chamber 66. For example, hydraulic fluid 116 may flow from second chamber 68 through a flow restrictor 126 to first chamber 66.

[0063] In accordance to one or more embodiments of the disclosure, first chamber 66 is defined between tool operator 36 and housing 54 and between first seal 117 and second seal 119; second chamber 68 is defined between tool operator 36 and housing 54 and between third seal 118 and forth seal 120, and a third chamber 124 is defined between tool operator 36 and housing 54 and between second seal 119 and third seal 118. A vacuum may be created in third chamber 124 in response to moving tool operator 36 to the first position. The created vacuum may urge tool operator 36 toward the second position from the first position.

[0064] According to one or more embodiments, actuating device 10 may comprise a first compensator 106 in communication with the first chamber 66 through a first passage 74 containing hydraulic fluid 116, wherein the first compensator 106 is acted on by a first well pressure; a second compensator 48 in communication in with the second chamber 68 via a second passage 76 containing hydraulic fluid 116, wherein the second compensator 48 is acted on by a second well pressure; a first one-way valve 128 permitting flow of the hydraulic fluid 116 from the second compensator 48 to the second chamber 68; and a flow restrictor 126 communicating hydraulic fluid 116 from the second chamber 68 to the first chamber 66. The first well pressure may be one of a tubing pressure or a casing pressure for example, and the second well pressure the other of the tubing pressure and the casing pressure. In the depicted embodiments, the first well pressure is described as annulus 26 pressure and the second well pressure is described as the pressure in tubular string 18.

[0065] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from this invention. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employees a cylindrical surface to secure wooden parts together, whereas they screw employees

a helical surface, in the environment unfastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words "means for" together with an associated function. The term "comprising" within the claims is intended to mean "including at least" such that the recited listing of elements in a claim are an open group. The terms "a," "an" and other singular terms are intended to include the plural forms thereof unless specifically excluded.

WHAT IS CLAIMED IS:

1. An actuating method (10), comprising:
applying an input pressure to a first side (70) of a tool operator (36) and to a second side (72) of the tool operator (36);
depleting the input pressure applied to the second side (72) while maintaining the input pressure applied to the first side (70);
moving the tool operator (36) from a first position to a second position in response to depleting the input pressure applied to the second side (72); and
changing the state of a tool element (12) in response to moving the tool operator (36) to the second position.
2. The method of claim 1, wherein depleting the input pressure applied to the second side comprises transferring hydraulic fluid from the second side to a confined diameter container.
3. The method of claim 1, wherein the depleting the input pressure applied to the second side comprises opening a passage between the second side and a confined diameter container in response to actuating a valve piston from a closed position to an open position.
4. The method of claim 1, wherein the input pressure is applied to the first side of the tool operator and to the second side of the tool operator through a valve, the valve comprising:

- a cylinder disposing a valve piston, the valve piston comprising a sealed section between
a first seal surface and a second seal surface;
- an inlet port in hydraulic communication with an input pressure port and the first seal
surface;
- a first side port in hydraulic communication with the first side and the second seal
surface;
- an exhaust port in hydraulic communication with the sealed section of the valve piston
and a confined diameter container; and
- a second side port in hydraulic communication with the second side and the second seal
surface when the valve piston is in the closed position and in hydraulic
communication with the sealed section and the exhaust port when the valve piston
is in the open position.
5. The method of claim 4, wherein the confined diameter container comprises a helical coil.
6. An actuating device (10), comprising:
- a tubular body (30) comprising an axial bore (32) and an annular region (50);
- a confined diameter container (34) disposed within the annular region (50);
- a tool operator (36) having a first side (70) open to a first chamber (66) and a second side
(72) open to a second chamber (68), the tool operator (36) moveable from a first
position to a second position in response to a pressure differential between the
first chamber (66) and the second chamber (68);

a valve (38) having a valve piston (82) operable from a closed position to an open position;

an input pressure port (40) in hydraulic communication with the first chamber (66) and the second chamber (68) through the valve (38); and

an exhaust port (94) in hydraulic communication with the second chamber (68) and the confined diameter container (34) when the valve piston (82) is in the open position.

7. The device of claim 6, wherein the confined diameter container comprises a helical coil.

8. The device of claim 6, wherein the confined diameter container comprises a bottle.

9. The device of claim 6, wherein the valve comprises:

a valve body having a cylinder disposing the valve piston;

the valve piston comprising a sealed section between a first seal surface and a second seal surface;

an inlet port providing hydraulic communication with the input pressure port and the first seal surface;

a first side port in hydraulic communication with the first chamber and the second seal surface;

the exhaust port in hydraulic communication with the sealed section of the valve piston;
and

- a second side port in hydraulic communication with the second chamber and the second seal surface when the valve piston is in the closed position and with the sealed section and the exhaust port when the valve piston is in the open position.
10. The device of claim 9, wherein the first seal surface has a surface area greater than a surface area of the second seal surface.
11. A method (10) of changing the state of a tool (14) disposed in a well (5), comprising:
applying differential pressure cycles an actuating device (10) disposed in a wellbore (16),
the actuating device (10) comprising a tool operator (36) having a first side (70) open to a first chamber (66) and a second side (72) open to a second chamber (68);
moving the tool operator (36) to a first position in response to applying the differential pressure cycles;
actuating the tool operator (36) from the first position to a second position in response to depleting pressure in the second chamber (68); and
changing the state of a tool element (12) in response to actuating the tool operator (36) to the second position.
12. The method of claim 11, wherein the moving the tool operator to the first position comprises increasing the volume of the second chamber.

13. The method of claim 11, wherein the depleting the pressure in the second chamber comprises communicating hydraulic fluid from the second chamber to the first chamber.
14. The method of claim 11, wherein:
the first chamber is defined between the tool operator and a housing and between a first seal and a second seal;
the second chamber is defined between the tool operator and the housing and between a third seal and a forth seal; and
a third chamber is defined between the tool operator and the housing and between the second seal and the third seal.
15. The method of claim 14, further comprising creating a vacuum in the third chamber in response to moving the tool operator to the first position.
16. The method of claim 11, wherein the actuating device comprises:
a first compensator in communication with the first chamber through a first passage containing hydraulic fluid, the first compensator acted on by a first well pressure;
a second compensator in communication in with the second chamber via a second passage containing hydraulic fluid, the second compensator acted on by a second well pressure;
a first one-way valve permitting flow of the hydraulic fluid from the second compensator to the second chamber; and

a flow restrictor communicating hydraulic fluid from the second chamber to the first chamber.

17. The method of claim 16, wherein the moving the tool operator to the first position comprises increasing the volume of the second chamber.
18. The method of claim 16, wherein the depleting the pressure in the second chamber comprises communicating hydraulic fluid from the second chamber through the flow restrictor to the first chamber.
19. The method of claim 16, wherein:
the first chamber is defined between the tool operator and a housing and between a first seal and a second seal;
the second chamber is defined between the tool operator and the housing and between a third seal and a forth seal; and
a third chamber is defined between the tool operator and the housing and between the second seal and the third seal.
20. The method of claim 17, further comprising creating a vacuum in the third chamber in response to moving the tool operator to the first position.

FIG. 1

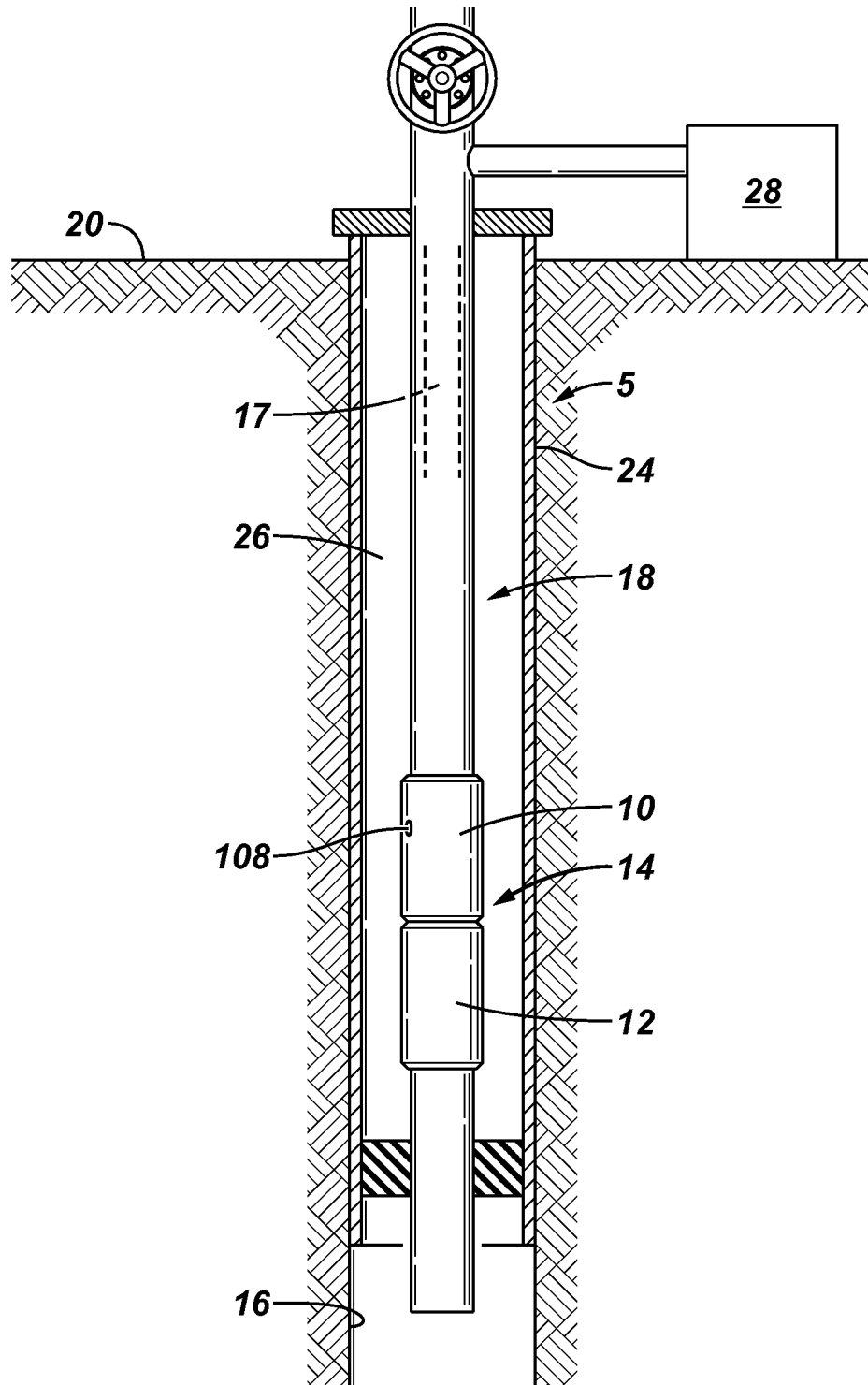


FIG. 2

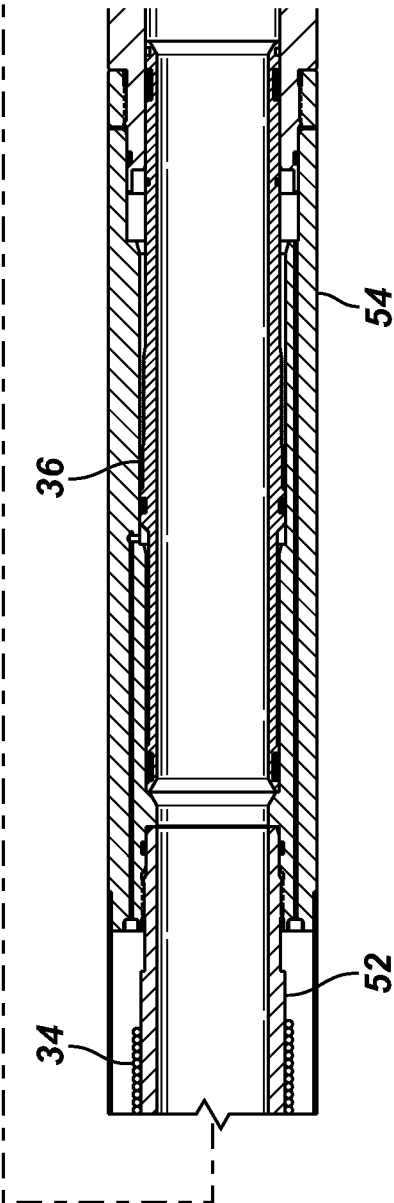
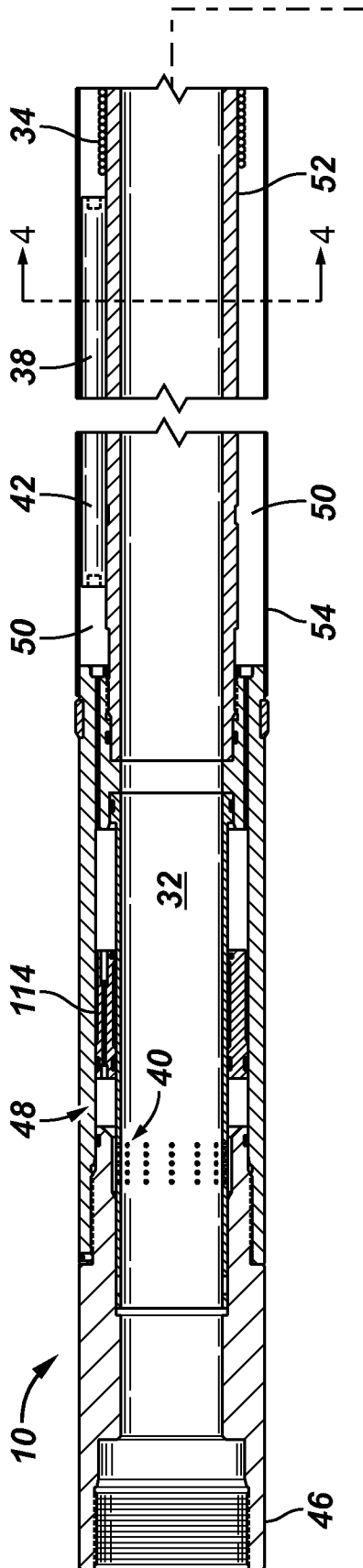


FIG. 4

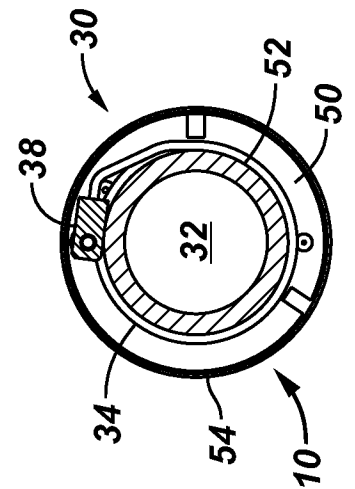


FIG. 3

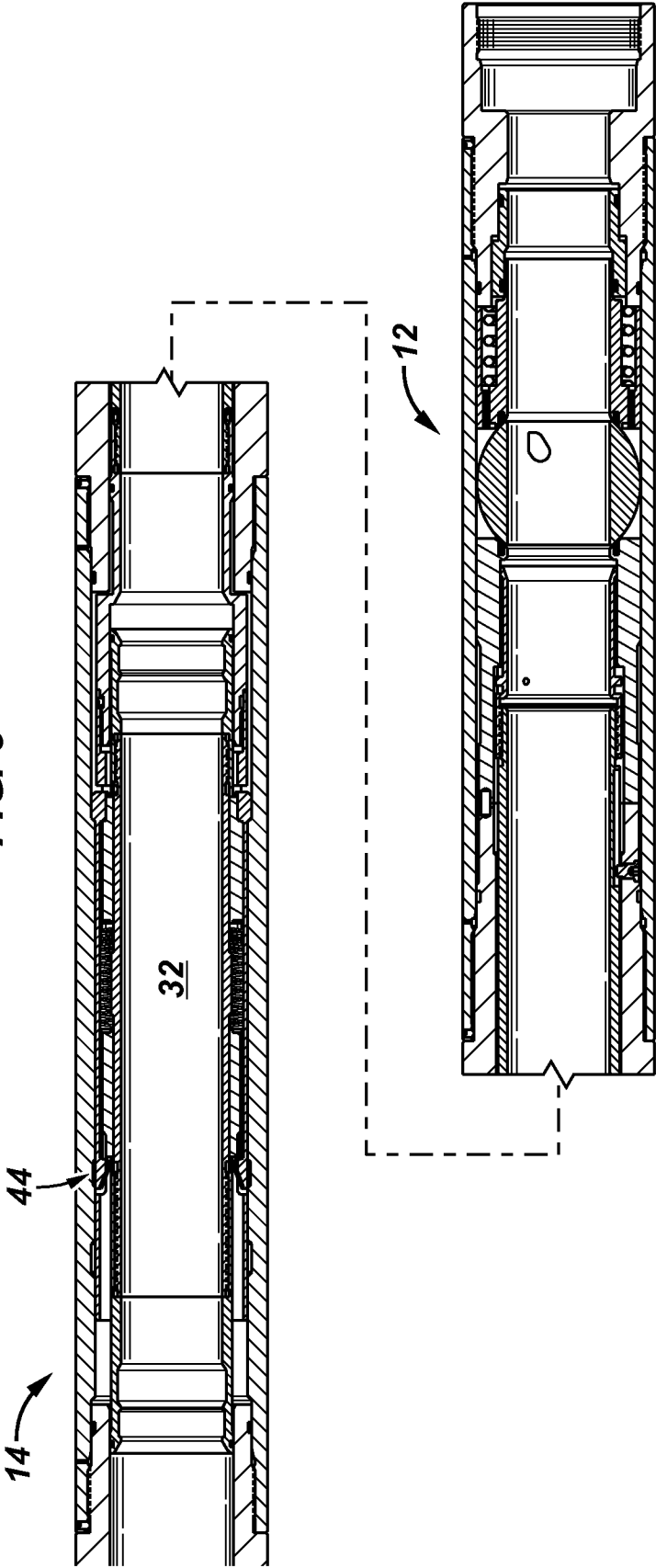


FIG. 5

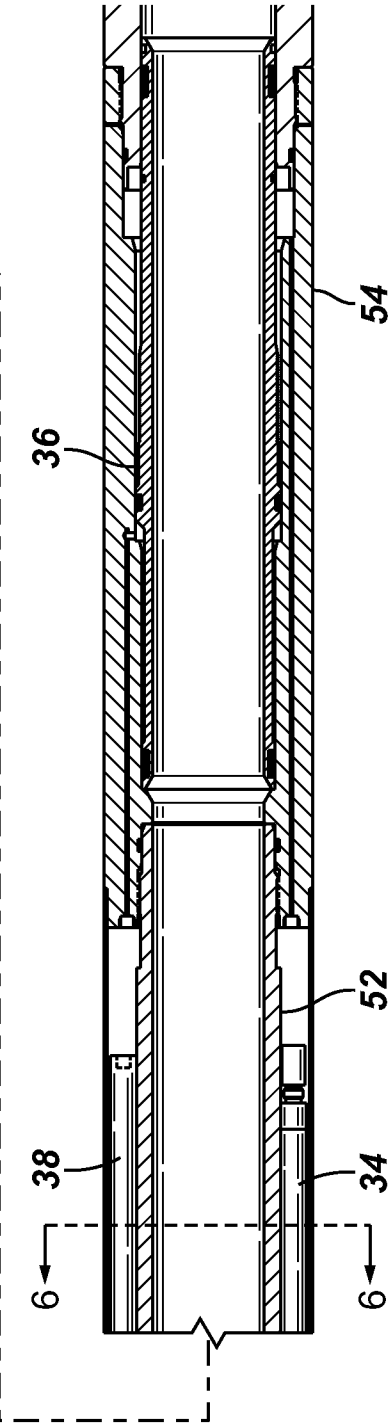
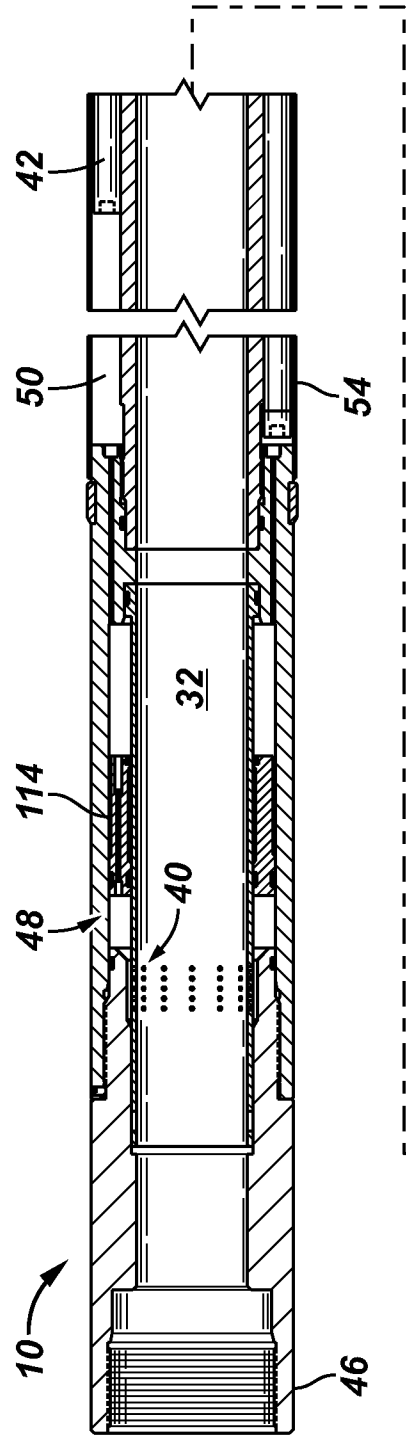


FIG. 6

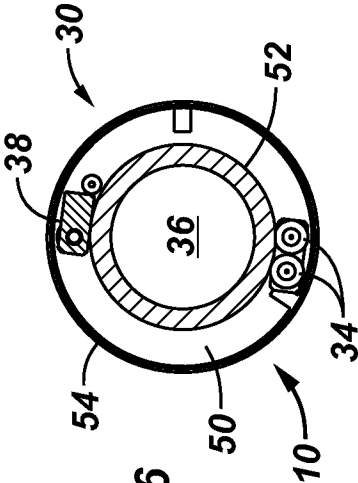


FIG. 7

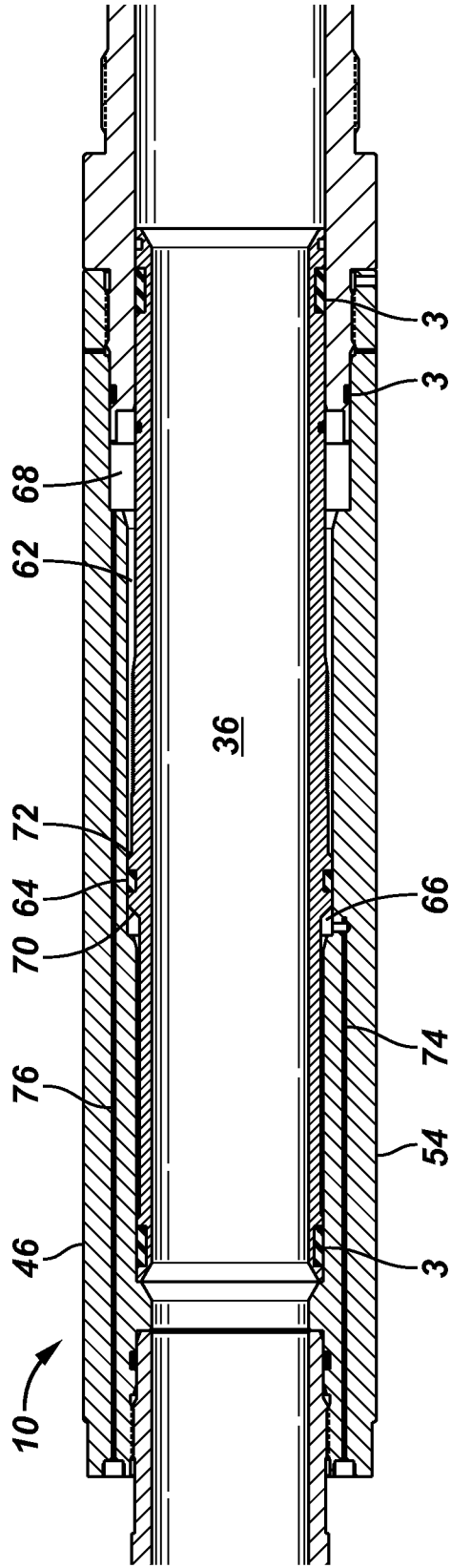


FIG. 8

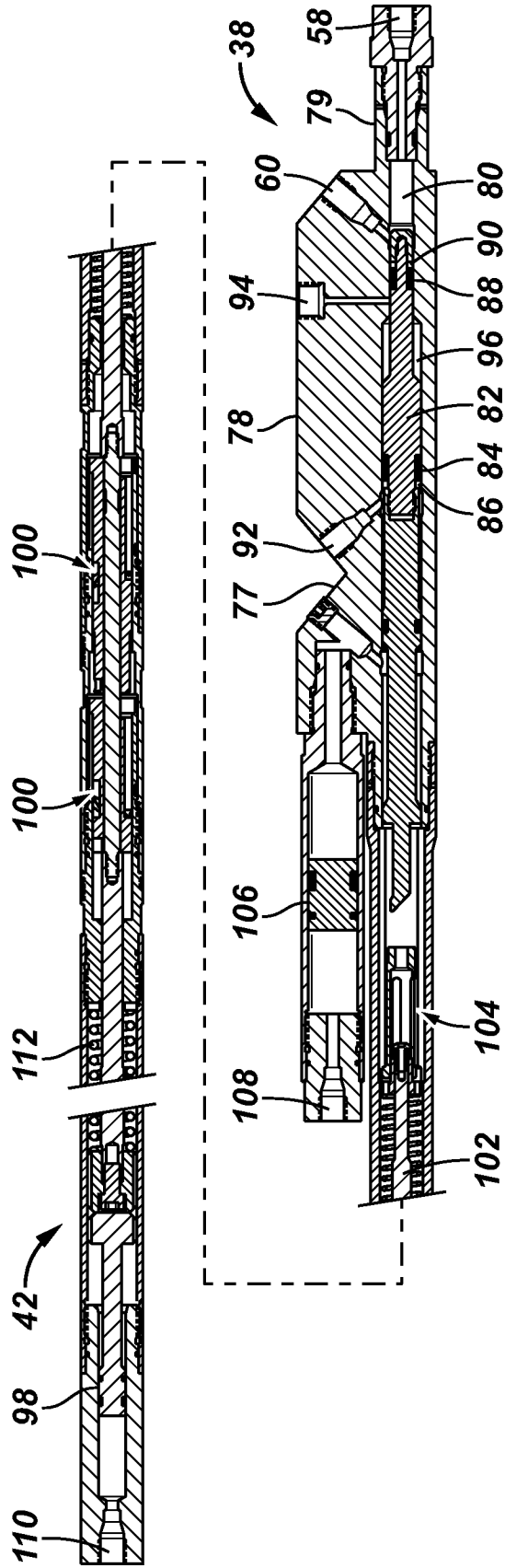


FIG. 9

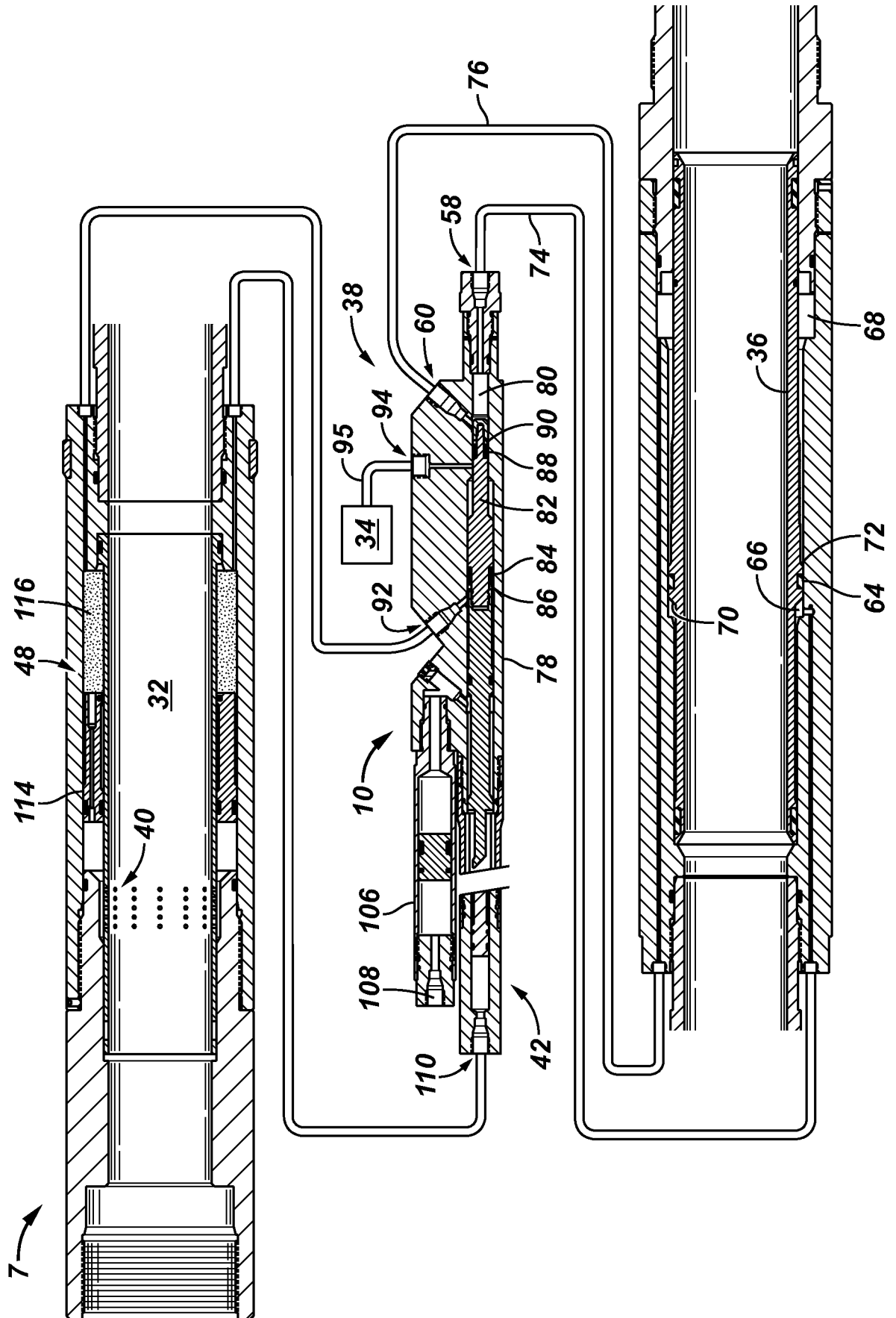


FIG. 10

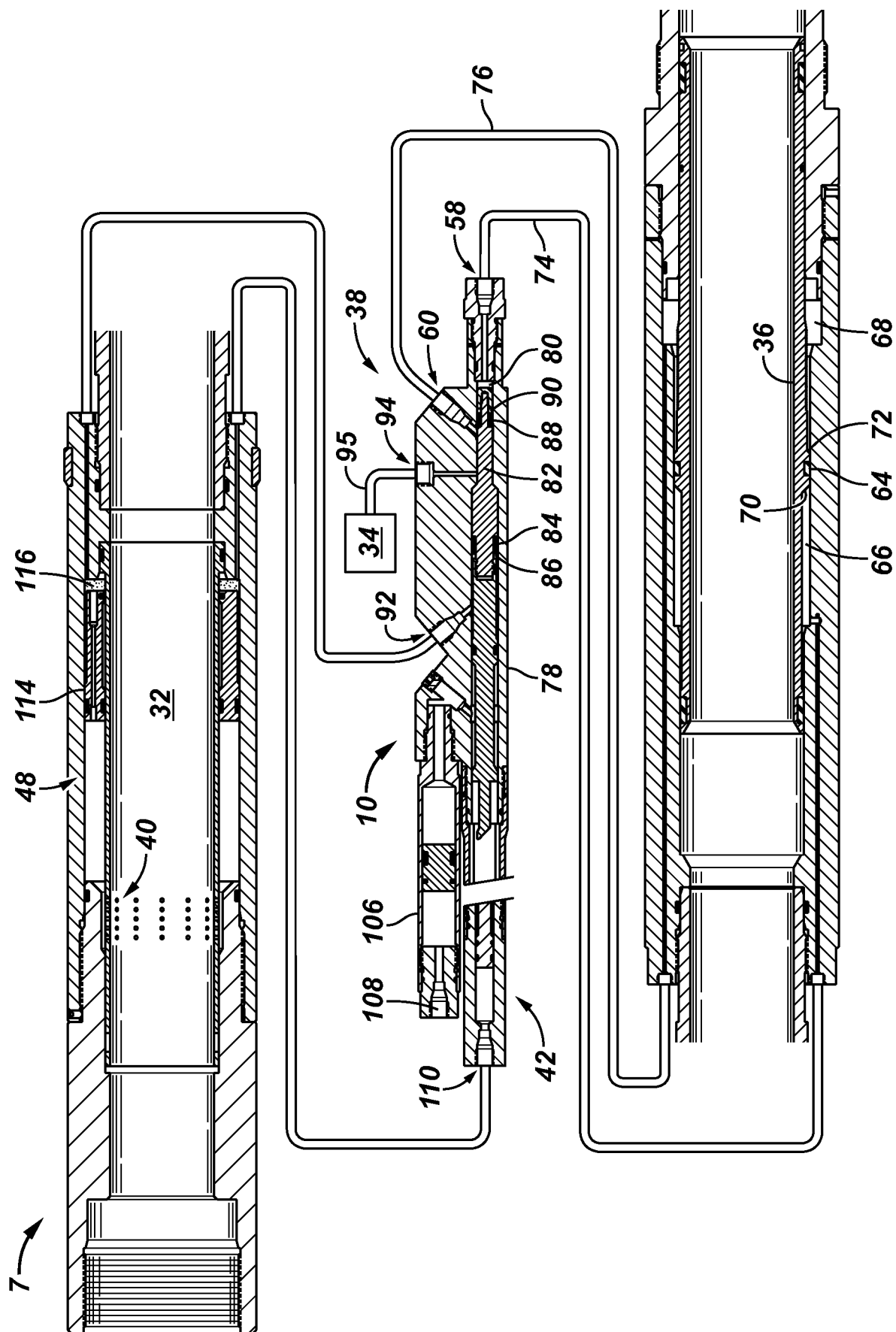


FIG. 11

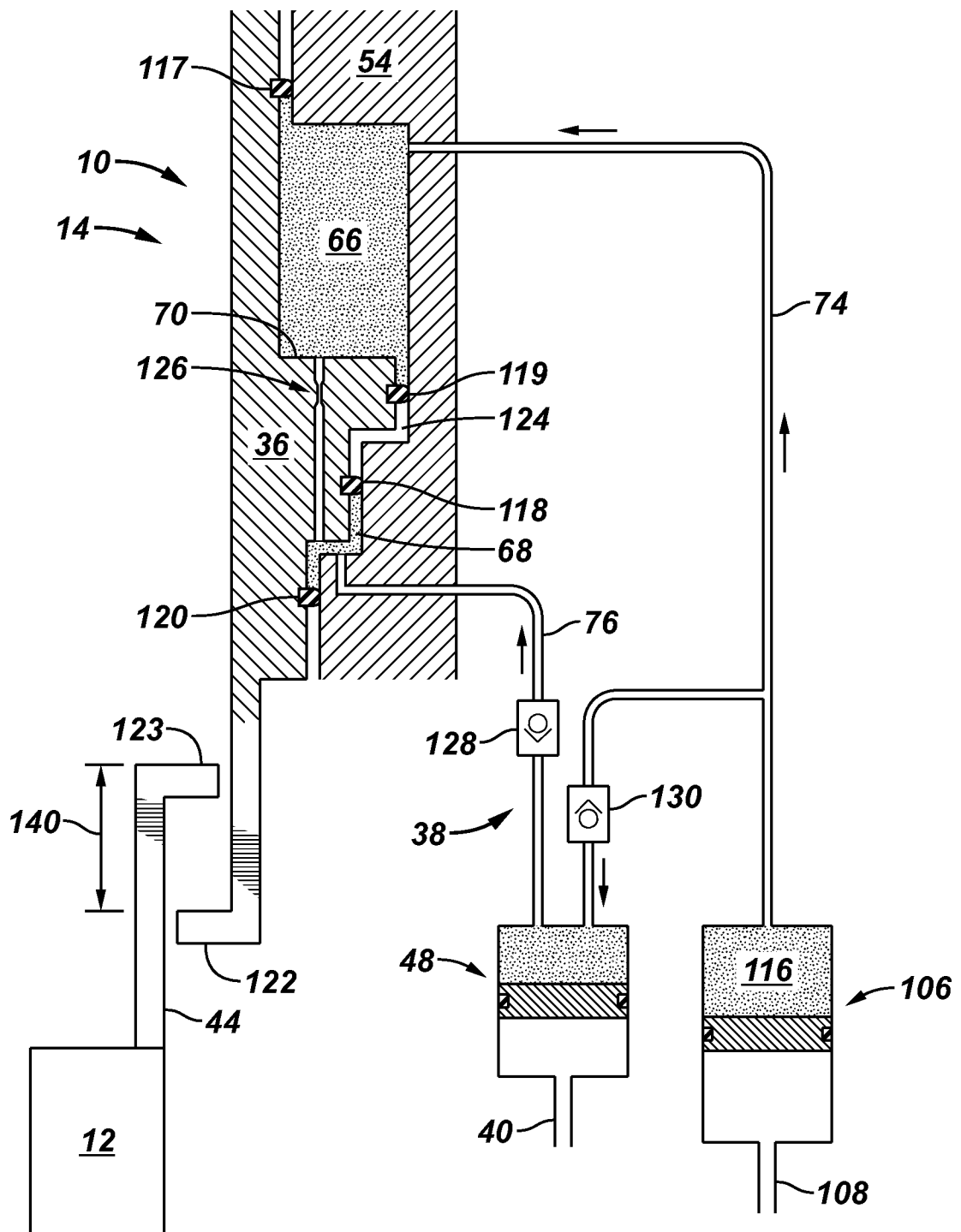


FIG. 12

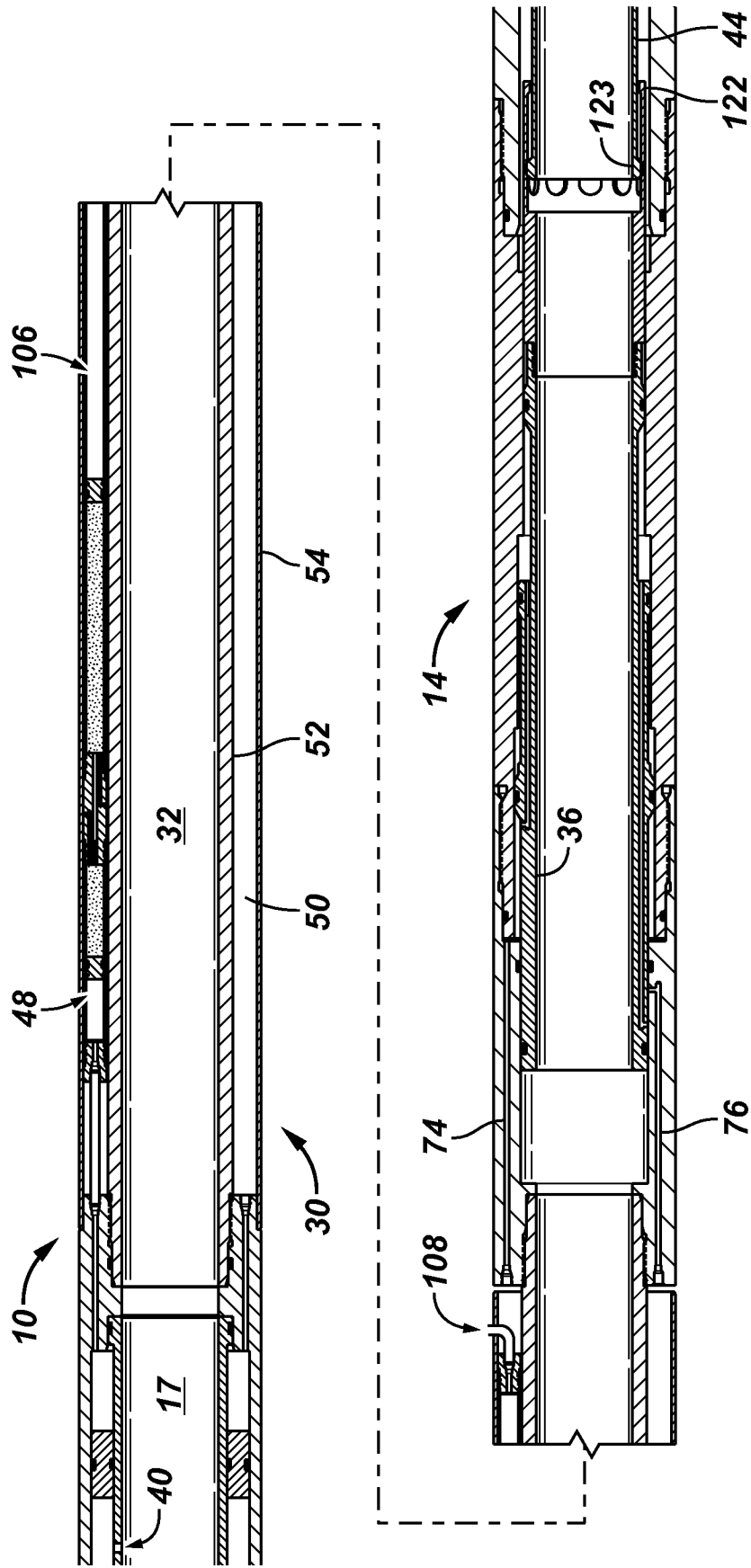
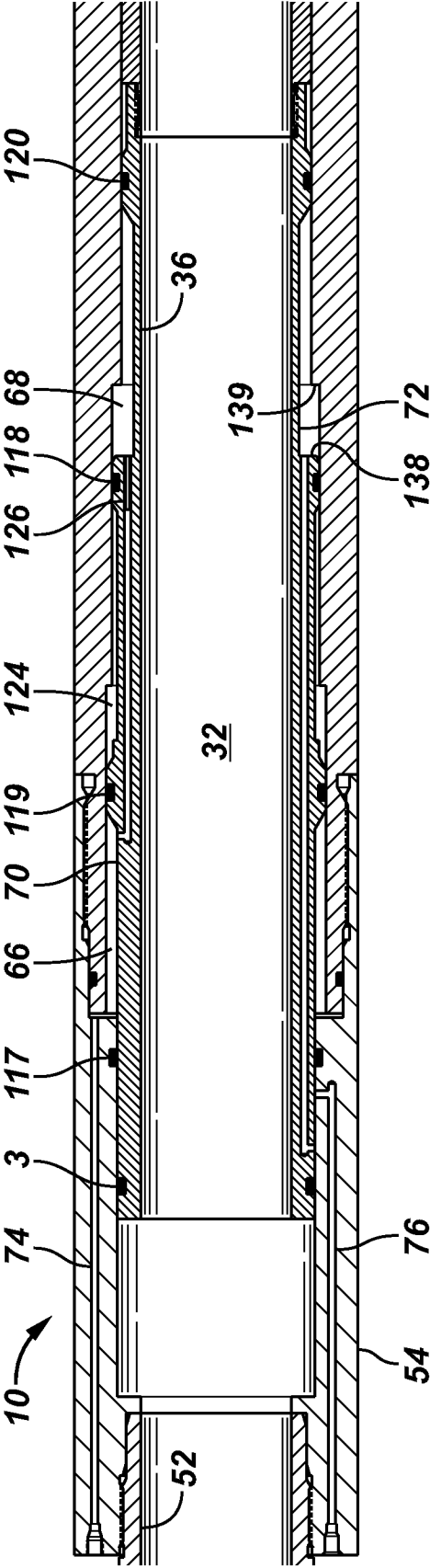


FIG. 14



A. CLASSIFICATION OF SUBJECT MATTER**E21B 34/14(2006.01)i, E21B 23/08(2006.01)i, E21B 43/00(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 34/14; E21B 23/04; E21B 34/06; E21B 34/00; G01V 3/00; E21B 23/00; E21B 29/00; E21B 34/10; E21B 23/08; E21B 43/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: downhole tool, tubular, tool operator, pressure differential, input pressure, chamber, confined diameter container, and valve

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0038093 A1 (PATEL, DINESH R.) 18 February 2010 See paragraphs [0031]-[0032], [0035] and figures 6-7.	1
A		2-20
A	US 2011-0061875 A1 (TIPS, TIMOTHY R. et al.) 17 March 2011 See paragraphs [0068]-[0070] and figure 4.	1-20
A	US 2010-0175871 A1 (WRIGHT, ADAM D. et al.) 15 July 2010 See paragraphs [0023]-[0025], [0028]-[0029] and figures 2-3C.	1-20
A	US 2006-0090900 A1 (MULLEN, BRYON D. et al.) 04 May 2006 See paragraphs [0080]-[0082] and figure 6.	1-20
A	US 2003-0048197 A1 (PURKIS, DANIEL G. et al.) 13 March 2003 See paragraphs [0034]-[0036] and figure 2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

26 August 2013 (26.08.2013)

Date of mailing of the international search report

27 August 2013 (27.08.2013)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/046105

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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		WO 01-63089 A1	30/08/2001