(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 840 228 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
25.02.2015 Bulletin 2015/09

(51) Int Cl.:
E21B 33/129 (2006.01) ***E21B 34/10*** (2006.01)
E21B 43/12 (2006.01)

(21) Application number: **14181208.1**

(22) Date of filing: **17.08.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **22.08.2013 US 201313973686**

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  Designated Contracting States:
  AL AT BE BG CH CY CZ DE DK EE ES FI GR HR HU IE IS IT LI LT LU LV MC MK MT NO PL PT RO RS SE SI SK SM TR

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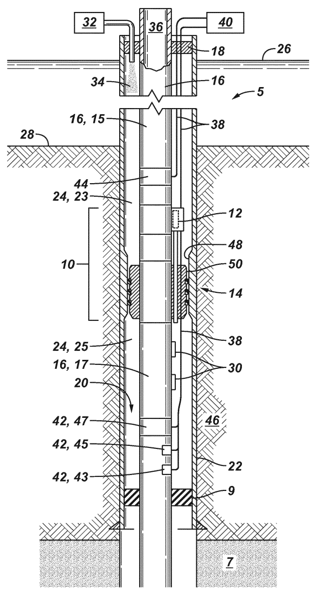
(54) **Wellbore Annular Safety Valve and Method**

(57) A well system includes an annular barrier separating the tubing-casing annulus into an upper annulus (23) and a lower annulus (25) and a barrier valve(12) coupled with the annular barrier, the barrier valve permitting one-way fluid communication from the upper annulus to the lower annulus. The annular barrier may include a female polished bore receptacle(48) integrated in the casing and a male seal assembly (50) integrated in the tubing. The tubing bore and an annular fluid conduit extend through the male seal assembly substantially parallel to one another and the barrier valve is connected in the annular fluid conduit.

FIG. 1



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Description

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] Hydrocarbon fluids such as oil and natural gas are obtained from a subterranean geological formation, referred to as a reservoir, by drilling a well that penetrates the hydrocarbon-bearing formation. Forms of well completion components may be installed in the wellbore to control and enhance efficiency of producing fluids from the reservoir.

SUMMARY

[0003] A well system in accordance to one or more embodiments includes an annular barrier disposed in a tubing-casing annulus of a wellbore separating the tubing-casing annulus into an upper annulus and a lower annulus and a barrier valve coupled with the annular barrier, the barrier valve permitting one-way fluid communication from the upper annulus to the lower annulus. An annular safety valve in accordance with an embodiment includes a male seal assembly integrated in a tubing, a tubing bore and a fluid conduit extending through the body substantially parallel to one another, a female polished bore receptacle integrated in a casing to receive the male seal assembly and form an annular barrier between the tubing and the casing, and a barrier valve in connection with the fluid conduit to permit one-way fluid flow through the fluid conduit. A method includes setting casing having a female polished bore receptacle in a wellbore, deploying tubing having a male seal assembly landed in the female polished bore receptacle forming an annular barrier separating the tubing-casing annulus into an upper annulus and a lower annulus, communicating fluid from the upper annulus through a barrier valve in connection with a fluid conduit through the male seal assembly and closing the barrier valve in response to pressure in the upper annulus being lower than the pressure in the lower annulus.

[0004] The foregoing has outlined some of the features and technical advantages in order that the detailed description of the annular safety valves, systems, and methods that follow may be better understood. Additional features and advantages of the annular safety valve system and method will be described hereinafter which form the subject of the claims of the invention. 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

[0005] Embodiments of annular safety valves 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.

Figure 1 illustrates a well system in which an annular safety valve in accordance to one or more embodiments is incorporated.

Figure 2 illustrates an annular safety valve in accordance to one or more embodiments.

Figure 3 illustrates a male polished bore receptacle seal assembly in accordance to one or more embodiments.

Figure 4 is a top view illustration of a male polished bore receptacle seal assembly in accordance to one or more embodiments.

Figure 5 illustrates a side pocket mandrel in accordance to one or more embodiments.

Figure 6 illustrates a side pocket mandrel along the line I-I of Figure 5.

Figure 7 illustrates a barrier valve in accordance to one or more embodiments.

DETAILED DESCRIPTION

[0006] 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.

[0007] As used herein, the terms "connect," "connection," "connected," "in connection with," and "connecting" are used to mean "in direct connection with" or "in connection with via one or more elements"; and the term "set" is used to mean "one element" or "more than one element." Further, the terms "couple," "coupling," "coupled," "coupled together," and "coupled with" are used to mean "directly coupled together" or "coupled together via one or more elements." 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 being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal or slanted relative to the surface.

[0008] Generally, a well consists of a wellbore drilled through one or more reservoir production zones. Conductor casing serves as support during drilling operations and provides support for a wellhead and Christmas tree. In offshore wells, a riser may extend the wellbore from the sea floor to the surface platform. One or more strings of casing with diminishing inside diameters will be run inside of the conductor. The well may then be completed with a tubing string extending to the one or more reservoir production zones. The annulus between the tubing and the smallest diameter casing, i.e., the A-annulus, extends from the producing zones to the surface. The surface barrier seals the tubing-casing annulus from the environment. The tubing may be landed for example in a production packer located above the upper most production zone to isolate the annulus from the producing zones. The tubing-casing annulus may extend thousands of feet from the surface to the production packer. The tubing-casing annulus may be utilized for example for gas-injection into the tubing to reduce the density of the fluid in the tubing to facilitate production to the surface. The tubing-casing annulus may be exposed to the surrounding formations via perforations or loss of casing integrity. In the case of failure of the surface annular barrier, for example located at the wellhead, wellbore fluid in the tubing-casing annulus will be in communication with the environment.

[0009] In accordance to one or more embodiments, an annular safety valve is integrated in the completion to provide an annular safety barrier in the upper completion. In accordance with embodiments, the annular safety valve provides one-way fluid flow from the upper annulus to the lower annulus. In accordance to one or more embodiments, the annular safety valve provides one or more control line bypasses to operationally connect devices in the lower completion below the annular safety valve to surface control systems at the surface or in the upper completion above the annular safety valve. In accordance to one or more embodiments, the annular safety valve is not surface controlled.

[0010] Figure 1 illustrates a well system 5 in which a polished bore receptacle ("PBR") based subsurface annular safety valve ("ASV"), generally denoted by the numeral 10, may be incorporated and utilized. Annular safety valve 10 includes a one-way barrier valve 12 coupled with an annular barrier 14. In accordance with embodiments, annular barrier 14 is referred to as a polished bore receptacle ("PBR") barrier 14. PBR 14 provides a sealed annular barrier between the tubing and casing. Barrier valve 12 is illustrated as being located above PBR 14 in Figure 1, however, as will be understood by those skilled in the art with benefit of this disclosure, barrier valve 12 may be locate below PBR 14. Barrier valve 12 provides one-way fluid flow in the direction from the upper completion or upper annulus across PBR 14 to the lower completion or lower annulus. In accordance to one or more embodiments, barrier valve 12 is normally closed and actuated to the open position in response to pressure in the upper annulus being greater than pressure in the lower annulus. Similarly, barrier valve 12 is actuated to the closed position in response to pressure in the lower annulus exceeding pressure in the upper annulus.

[0011] Well system 5 is illustrated as a gas lift completion that includes tubing 16 that extends from an upper or surface barrier 18 into a wellbore 20. A portion of wellbore 20 is completed with casing 22. The tubing-casing annulus, generally denoted by the numeral 24, between tubing 16 and casing 22 may be referred to as the A-annulus. Surface barrier 18, for example a tubing hanger, is depicted in Figure 1 located at a water surface 26, for example at a platform, e.g., tension leg platform, or ship, positioned above a sea floor 28. Surface barrier 18 may be located in the wellhead area. Reference to the surface of the well is not limited to the sea surface or sea floor. Annular safety valve 10 is set in the upper completion and separates tubing-casing annulus 24 into an upper annulus 23 and a lower annulus 25. Lower annulus 25 may be isolated from a production zone 7, i.e., reservoir formation, by a production packer 9.

[0012] Tubing 16 incorporates one or more gas lift valves 30 which are located in the lower tubing section 17 below annular safety valve 10 in wellbore 20. For purposes of gas injection, well system 5 includes a gas compressor 32 located at the surface to pressurize gas that is communicated to tubing-casing annulus 24. The pressurized gas 34 is communicated from upper annulus 23 through annular safety valve 10 to lower annulus 25. The pressurized gas 34 is communicated from lower annulus 25 into tubing bore 36 through gas lift valves 30.

[0013] One or more control lines 38 may extend from a surface system 40, for example an electronic controller and or pressurized fluid source, to downhole devices, generally denoted by the numeral 42, located below annular safety valve 10. Downhole devices 42 may include devices such as, and without limitation to, pressure, temperature, and flow rate sensors 43, chemical injection valves 45, and flow control valves 47. In accordance to one or more embodiments, annular safety valve 10 provides control line bypasses from the upper completion or surface to the lower completion while maintaining an annular barrier. Control lines 38 may include, without limitation, electrical and optic cables as well as hydraulic and chemical conduits.

[0014] Together, annular safety valve 10 and tubing 16 can serve as a primary barrier to maintain well integrity. In the depicted embodiment, a downhole safety valve

44 is located in the upper section 15 of tubing 16 to provide a vertical barrier through tubing bore 36. In this example, downhole safety valve 44 is a surface controlled subsurface safety valve ("SCSSV") connected to the surface via a control line 38. Annular safety valve 10 serves as a safety barrier in A-annulus 24 in the event that surface barrier 18 is lost. Lower annulus 25 although located above production packer 9 in Figure 1, may be in communication with formation fluids and pressure. For example, perforations or loss integrity of casing 22 may expose annulus 25 to the surrounding formation 46. In Figure 1, gas lift injection through lower annulus 25 may temporarily supercharge formation 46.

[0015] With additional reference to Figure 2 to 4, polished bore receptacle 14 includes a female PBR 48 integrated in casing 22 and a male PBR 50 integrated in tubing 16. Female PBR 48 includes a smooth or honed bore formed on the inner surface of casing 22 and has a predetermined diameter for sealing or mating with male PBR 50. Female PBR 48 is depicted disposed above casing cross-over 27. Female PBR 48 may be constructed as portion of casing cross-over 27. Tubing 16 may be anchored to casing 22 for example proximate to female PBR 48.

[0016] Depicted male PBR 50 (e.g., seal assembly) is an eccentric member having one or more seal elements 52. Male seal assembly 50 is integrated with tubing 16 so that the tubing bore 36 extends through male seal assembly 50. Bypass ports, generally denoted by the reference number 60, are formed longitudinally through male PBR 50, for example substantially parallel to tubing bore 36, to pass or form a portion of annular fluid conduit 54 and control lines 38 in the depicted embodiment. Barrier valve 12 is coupled with fluid conduit 54 to provide one-way fluid communication across PBR 14, i.e., upper annulus to lower annulus fluid flow. For example, ports 60 are formed through the thicker body portion 58 of male PBR 50 between tubing bore 36 and seal elements 52. As will be understood by those skilled in the art with benefit of this disclosure, annular safety valve 10 may be utilized in well systems 5 that do not have gas injection.

[0017] With reference in particular to Figures 1-2 and 5-6, barrier valve 12 is a one-way valve providing fluid connection across polished bore receptacle 14 from upper annulus 23 to lower annulus 25 through passage or conduit 54. Although barrier valve 12 is illustrated located above PBR 14 in Figures 1 and 2, it will be understood by those skilled in the art with benefit of this disclosure that barrier valve 12 can be located below PBR 14 to provide fluid communication in the direction from upper annulus 23 to lower annulus 25.

[0018] In accordance to one or more embodiments, barrier valve 12 is located in a side pocket mandrel 56 integrated, i.e., connected, with tubing 16. Barrier valve 12 is disposed in pocket 62 (Figure 6) to provide annulus to annulus fluid communication. Fluid, such as gas 34, flows from upper annulus 23 through port(s) 64 into pocket 62 and through barrier valve 12 into conduit 54 and lower annulus 25. Side pocket mandrel 56 may not include a port between tubing-casing annulus 24 and tubing bore 36 or the tubing bore may not be in communication with tubing-casing annulus 24 through barrier valve 12. Side pocket mandrel 56 may be a single or a dual pocket mandrel.

[0019] Figure 7 illustrates a gas lift type barrier valve 12 in accordance to one or more embodiments. Barrier valve 12 includes a reverse flow check valve 66 suited for barrier applications. For example, barrier valve 12 is a barrier-qualified, reverse flow check valve that provides positive seal between the lower annulus side and the upper annulus side. In accordance to one or more embodiments, barrier valve 12 has metal-to-meal seal surfaces without elastomers. Some embodiments may have elastomer seal surfaces. A non-limiting example of barrier valve 12 is a NOVA 15-B type of gas lift valve available from Schlumberger.

[0020] In accordance to one or more embodiments, a surface control system is not required for operation of annular safety valve 10. Barrier valve 12 may be retrieved, for example via wireline or slickline, eliminating the need to retrieve the completion to maintain the well integrity. If the pressure in lower annulus 25 exceeds the pressure in upper annulus 23, barrier valve 12 closes. Accordingly, barrier valve 12 fails safe closed if the surface barrier is lost. Annular safety valve 10 is insensitive to setting depth. In accordance with one or more embodiments, barrier valve 12 may be eliminated for example by eliminating or plugging conduit 54. For example, a dummy valve may be landed in pocket 62 to plug conduit 54.

[0021] A method in accordance to one or more embodiments is now described with reference to Figures 1-7. Casing 22 having a female polished bore receptacle 48 is set in wellbore 20. Tubing 16 is deployed landing integrated male seal assembly 50 in the female polished bore receptacle forming an annular barrier 14 across a tubing-casing annulus 24, the annular barrier separating the tubing-casing annulus into an upper annulus 23 and a lower annulus 25. Male seal assembly 50 includes a fluid conduit 54 extending substantially parallel to tubing bore 36. Barrier valve 12 is coupled with the fluid conduit to permit fluid, for example gas 34, to flow from the upper annulus to the lower annulus. Fluid 34 is communicated from the upper annulus through the barrier valve and across the annular barrier in response to pressure in the upper annulus being greater than pressure in the lower annulus. The barrier valve is closed in response to the pressure in the upper annulus being less than the pressure in the lower annulus.

[0022] The foregoing outlines features of several embodiments of annular safety valves, systems, and methods so that those skilled in the art may better understand the aspects of the disclosure. Those skilled in the art should appreciate that they may readily use the disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the disclosure. The scope of the invention should be determined only by the language of the claims that follow. 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.

Claims

1. A well system, comprising:

a wellbore extending downward from a surface, the wellbore comprising a tubing deployed in a casing;
an annular barrier disposed in a tubing-casing annulus of a wellbore separating the tubing-casing annulus into an upper annulus and a lower annulus; and
a barrier valve coupled with the annular barrier, the barrier valve permitting one-way fluid communication from the upper annulus to the lower annulus.

2. The well system of claim 1, wherein the annular barrier is a polished bore receptacle.

3. The well system of claim 1, wherein the annular barrier comprises:

a female polished bore receptacle integrated in the casing; and
a male seal assembly integrated in the tubing.

4. The well system of claim 1, further comprising a control line passing through the annular barrier.

5. The well system of claim 1, wherein the barrier valve is disposed in a side pocket mandrel integrated in the tubing.

6. The well system of claim 1, wherein the barrier valve is located above the annular barrier.

7. The well system of claim 1, wherein the barrier valve is operated to an open position in response to pressure in the upper annulus being greater than pressure in the lower annulus.

8. The well system of claim 1, wherein the barrier valve is located in a side pocket mandrel integrated in the tubing; and
the polished bore receptacle comprises:

a female polished bore receptacle integrated in the casing; and
a male seal assembly integrated in the tubing.

9. The well system of claim 8, further comprising gas lift valves located in the tubing below the annular barrier.

10. The well system of claim 9, further comprising a control line extending from above the annular barrier through the annular barrier to a device located below the annular barrier.

11. A method, comprising:

setting a casing in a wellbore, the casing comprising a female polished bore receptacle;
deploying a tubing in the casing, the tubing comprising a male seal assembly landed in the female polished bore receptacle forming an annular barrier across a tubing-casing annulus separating the tubing-casing annulus into an upper annulus and a lower annulus, wherein the male seal assembly comprises a fluid conduit extending substantially parallel to a tubing bore, and a barrier valve coupled with the fluid conduit to permit fluid flow from the upper annulus to the lower annulus;
communicating a fluid from the upper annulus through the barrier valve to the lower annulus; and
closing the barrier valve in response to pressure in the upper annulus being less than pressure in the lower annulus.

12. The method of claim 11, wherein the fluid is a pressurized gas and further comprising injecting the pressurized gas from the lower annulus through a gas lift valve into the tubing.

13. The method of claim 11, further comprising a control line extending from the upper annulus through a body of the male seal assembly to a device located below the annular barrier.

14. The method of claim 11, wherein the barrier valve is located in a side pocket mandrel integrated in the tubing.

15. The method of claim 11, wherein the barrier valve is normally closed and the barrier valve is opened in response to pressure in the upper annulus being greater than pressure in the lower annulus.

16. The method of claim 13, wherein:

the barrier valve is located in a side pocket mandrel integrated in the tubing;
the fluid is a pressurized gas; and
further comprising injecting the pressurized gas from the lower annulus through a gas lift valve into the tubing.

FIG. 1

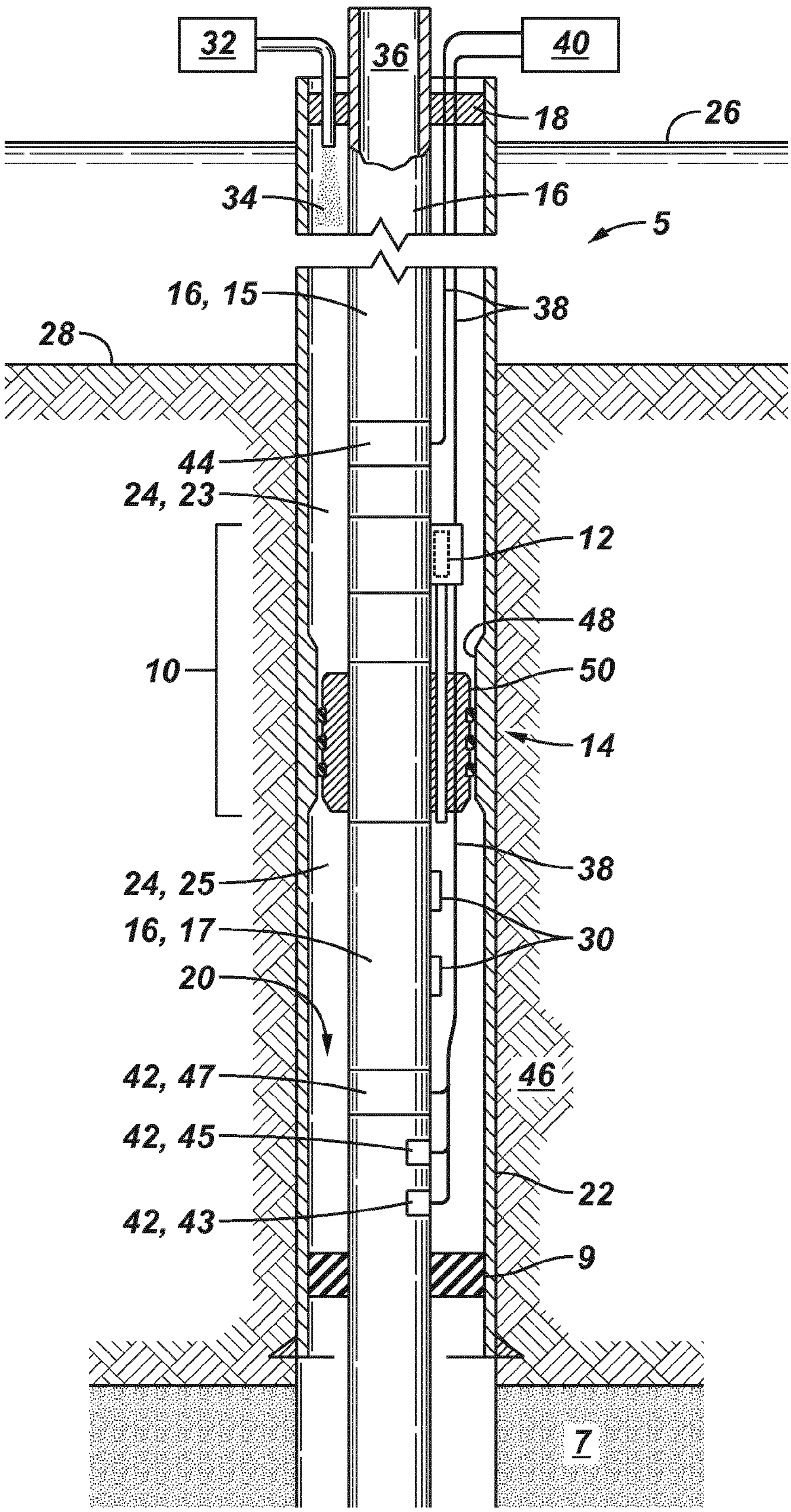
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FIG. 2

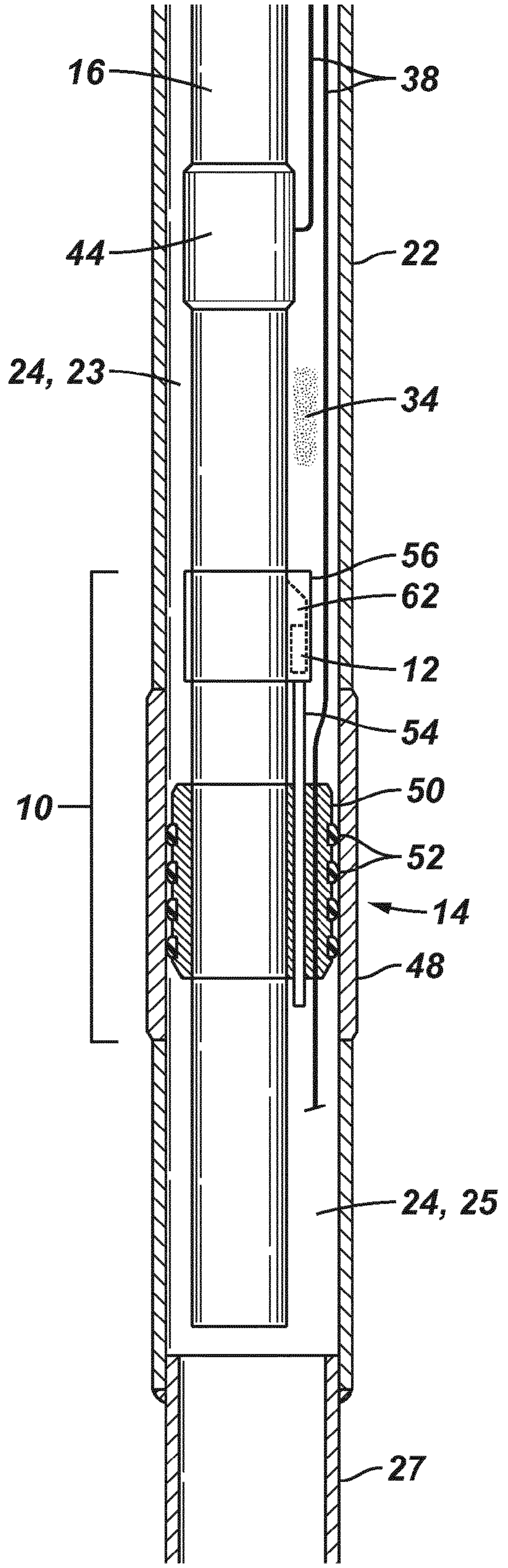

FIG. 3

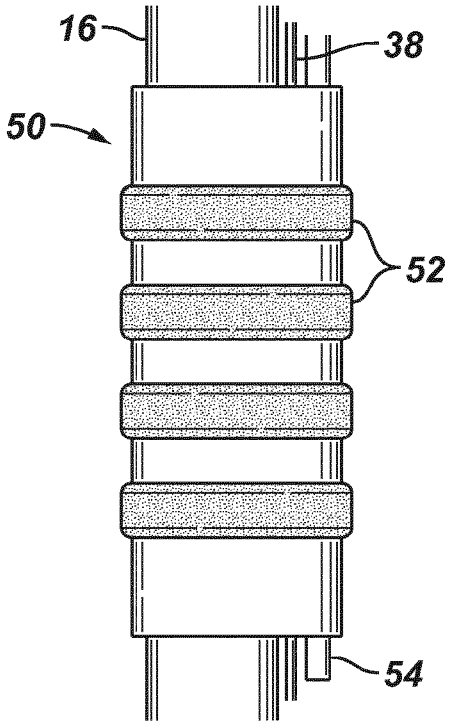

FIG. 4

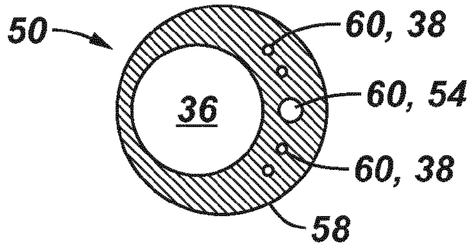

FIG. 5

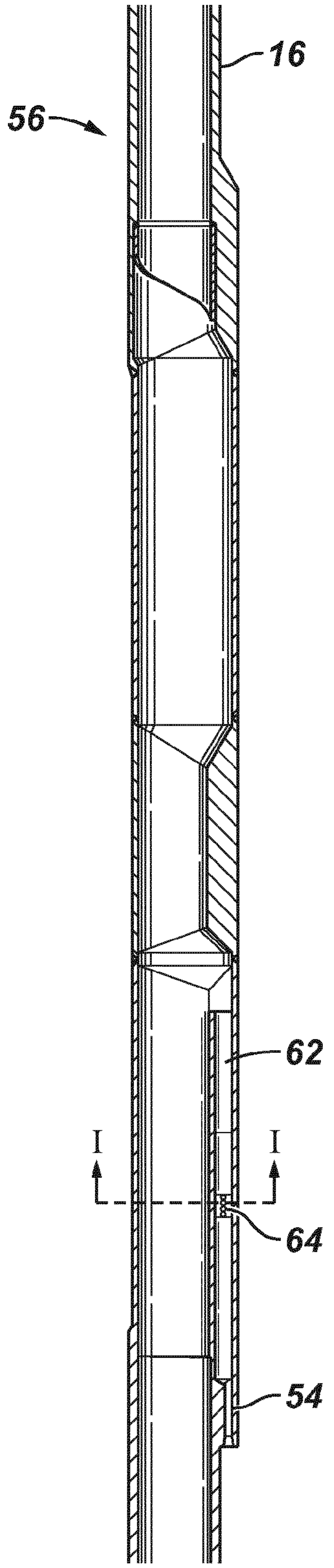

FIG. 6

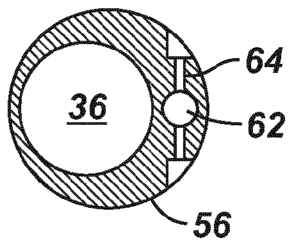

FIG. 7