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- (71) Applicant (for all designated States except US): **TENDEKA B.V.** [GB/GB]; 12a Peterseat Park, Altens, Aberdeen AB12 3HT (GB).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **ANDERSON, Neil** [GB/GB]; Todearth Croft, Holmsbum, Leslie, Insch, Aberdeenshire AB52 6NQ (GB). **PITMAN, Malcolm** [GB/GB]; 41 Culterhouse Road, Milltimber, Aberdeen AB13 0EN (GB).
- (74) Agent: **DOCHERTY, Andrew**; MARKS & CLERK LLP, Aurora, 120 Bothwell Street, Glasgow, G2 7JS (GB).
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(54) Title: DOWNHOLE PRESSURE RELIEF APPARATUS

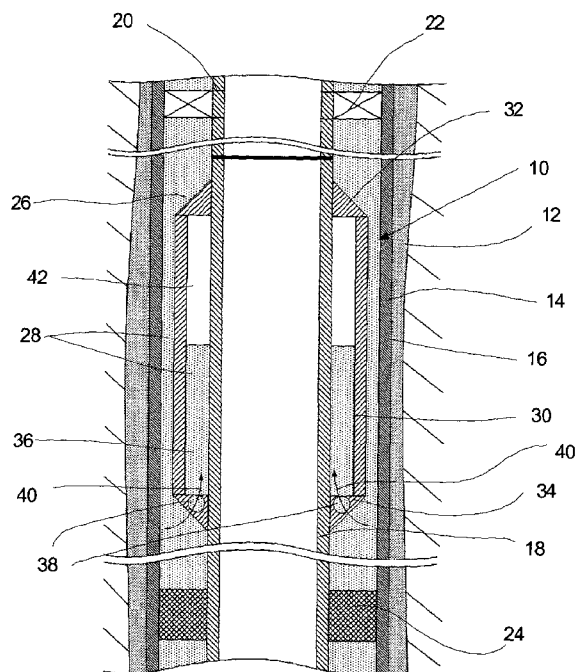


FIGURE 2

(57) Abstract: A downhole pressure relief apparatus (10) comprises a tubular member (18) configured to be located within a wellbore (12) to at least partially define a wellbore annulus (26), wherein the annulus (26) is subject to varying fluid pressure, and a chamber (36) associated with the tubular member (18). A valve arrangement (38) associated with the chamber (36) is provided and is configurable from a closed state to an open state in response to a pressure event, wherein, in use, in the closed state the chamber (36) is isolated from the wellbore annulus (26), and in the open state fluid (28) is permitted to flow into the chamber (36) from the wellbore annulus (26) to relieve pressure within said annulus.



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DOWNHOLE PRESSURE RELIEF APPARATUS

FIELD OF THE INVENTION

5 The present invention relates to a downhole pressure relief apparatus, and in particular, but not exclusively, to a downhole pressure relief apparatus for relieving pressure within a wellbore annulus.

BACKGROUND TO THE INVENTION

10 Typical wellbore architecture, such as for use in the extraction of hydrocarbons from subterranean formations, involves the use of multiple tubulars which extend into a drilled bore. Such tubulars may include casing for use in supporting and sealing the drilled bore, production tubing, injection tubing, completion strings, tool strings and the like. Multiple tubulars are usually installed within a wellbore in a substantially coaxially manner which creates one or more
15 annuli. Some of these annuli may be completely filled with cement, such as an annulus formed between the rock face of a drilled bore and a casing string. However, some applications may not permit all annuli to be filled with cement, and in such circumstances these annuli will normally remain filled with fluid, such as a completion fluid. Furthermore, it may be desirable, or a requirement, to isolate a fluid
20 filled annulus, for example by use of upper and lower seals, such as packers and the like. In this situation, however, the fluid isolated or trapped within the annulus will be subject to the downhole thermal environment, which may cause thermal expansion of the trapped fluid, causing an increase in volume, which will be manifested as an increase in pressure. This increase in pressure may be sufficient to cause
25 mechanical failure of an exposed tubular, such as bursting of an outer tubular or collapse of an inner tubular.

Proposals have been made in the art for relieving pressure within isolated annuli. For example, US 6,675,898 discloses the use of a burst disk assembly which is mounted within the wall of an inner tubular. Upon reaching a predetermined
30 annulus pressure the burst disk assembly ruptures to permit bleeding of the fluid from the annulus and into the inner tubular. However, this arrangement may not be suitable where the annulus fluid must remain completely isolated from any fluid within the inner tubular, such as when the inner tubular is used to support production flow.

35 SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a downhole pressure relief apparatus, comprising:

a tubular member configured to be located within a wellbore to at least partially define a wellbore annulus, wherein the annulus is subject to varying fluid pressure;

a chamber associated with the tubular member; and

5 a valve arrangement associated with the chamber and configurable from a closed state to an open state in response to a pressure event, wherein, in use, in the closed state the chamber is isolated from the wellbore annulus, and in the open state fluid is permitted to flow into the chamber from the wellbore annulus to relieve pressure within said annulus.

10 The pressure event may comprise a pressure event within the wellbore annulus. The pressure event may be established by thermal expansion of fluid within the wellbore annulus. The pressure event may comprise reaching a predetermined pressure within the wellbore annulus. The pressure event may comprise a predetermined pressure differential between the wellbore annulus and the chamber.
15 Accordingly, in use, pressure relief within the annulus may be provided which may function to protect a downhole component, such as the tubular member. Such pressure relief, by being accommodated within the chamber, may be achieved while avoiding interfering with the function of the tubular member, for example by avoiding introducing annulus fluid into the tubular.

20 The chamber may be annular, for example at least partially annular.

The chamber may be mounted on the tubular member. In such an arrangement the chamber may encroach into the wellbore annulus. This may assist to displace fluids from the wellbore annulus during running in of the tubular member and chamber. This may therefore permit a greater recovery of the fluids from the
25 wellbore annulus, which may include expensive completion fluids or the like. Furthermore, mounting the chamber on the tubular member may permit a centraliser functionality to be achieved, for example by assisting to centralise the tubular member within a larger bore, or to assist to centralise another component running through the tubular member.

30 The chamber may be at least partially defined by the tubular member. The chamber may be at least partially defined by a wall surface of the tubular member. The chamber may be at least partially defined within a wall of the tubular member.

The chamber may be defined separately from the tubular member. The chamber may be defined within a chamber module which is mounted on the tubular
35 member.

The chamber may be fixed relative to the tubular member. Alternatively, the chamber may be moveable relative to the tubular member. For example, in some

embodiments the chamber may be slidably mounted on or relative to the tubular member.

5 The chamber may be defined externally of the tubular member. In such an arrangement the tubular member may define an inner periphery of the wellbore annulus. An outer wall surface of the tubular member may define a wall surface of the chamber.

10 The chamber may be defined internally of the tubular member. In such an arrangement the tubular member may define an outer periphery of the wellbore annulus. An inner wall surface of the tubular member may define a wall surface of the chamber.

15 The chamber may be defined by a pipe mounted on the tubular member, for example mounted externally or internally of the tubular member. The chamber may be at least partially defined between the pipe and the tubular member. The chamber may be at least partially defined between the pipe and a further component, such as a further pipe. The pipe may be secured to the tubular member. The pipe may be secured to the tubular member in any suitable manner, for example by threaded coupling, interference fitting, welding or the like.

20 The chamber may comprise a gas, such as air, an inert gas, for example nitrogen or the like. The chamber may comprise a gas at atmospheric pressure. This arrangement may permit a pressure differential to be established between the wellbore annulus and the chamber, when in use.

The chamber may be at least partially evacuated.

The chamber may be substantially liquid free prior to configuration of the valve assembly to the open state.

25 The chamber may be formed during a process of running the tubular member into a wellbore. For example, the chamber may be formed on the tubular member at a topside location, such as on a drilling rig or the like. The chamber may be formed during manufacture of the tubular member.

30 The valve arrangement may comprise a passive valve arrangement configurable between closed and open states by action of fluid pressure within the annulus. The valve arrangement may comprise an active valve arrangement configurable between closed and open states by a powered actuator, such as a motor, piston arrangement or the like.

35 The valve arrangement may be only configured from the closed state to the open state. Such an arrangement may be defined as a "one-shot" valve arrangement.

The valve arrangement may be reconfigurable between closed and open states. In such an arrangement the valve arrangement may be configured to be closed, for example in response to a pressure event.

The valve arrangement may comprise a burst disk arrangement.

5 The valve arrangement may be mounted relative to a lower region of the chamber. This arrangement may assist to prevent or minimise release of a fluid, such as a gas, contained within the chamber, for example when the valve arrangement is configured to an open state. This may, for example, prevent or minimise the risk of such fluid from the chamber interfering with other wellbore
10 apparatus or operations. In this case the lower region may be defined as that region of the chamber which sits lowermost when located within a wellbore. In many embodiments and uses of the present invention the lower region may be defined as a vertically lower region. However, this need not always be the case, for example in deviated or horizontal wellbores.

15 The apparatus may comprise a sensing arrangement configured to sense a downhole property, such as pressure, temperature or the like. The sensing arrangement may be configured to generate an activation signal addressed to the valve arrangement, for example upon sensing a predetermined event. For example, the sensor arrangement may sense a pressure event (or a thermal event which will
20 be recognised to create a pressure event), and instruct the valve arrangement to reconfigure to the open state.

The chamber may be sized in accordance with a desired level of pressure relief.

25 The apparatus may comprise a plurality of chambers associated with one or more tubular members. In such an arrangement the number of chambers may be selected in accordance with a desired level of pressure relief.

The tubular member may be configured for use in a production well.

The tubular member may be configured for use in an injection well.

The tubular member may be configured for use in an evaluation well.

30 The tubular member may comprise wellbore casing tubing, liner tubing, production tubing, injection tubing or the like.

The tubular member may be configured to form part of a tubing string.

The tubular member may comprise coiled tubing.

35 The tubular member, or a tubing string to which the tubular member is attached, may be sealed within a wellbore to provide an isolated wellbore annulus. Sealing may be achieved by use of a packer arrangement, such as a swellable packer, mechanical packer, inflatable packer or the like.

According to a second aspect of the present invention there is provided a method of providing pressure relief within a wellbore annulus, such as a closed or isolated wellbore annulus, defined at least in part by a tubular member, comprising:

5 providing a chamber associated with the tubular member, and a valve arrangement associated with the chamber;

maintaining the valve arrangement in a closed state to isolate the wellbore annulus from the chamber;

10 reconfiguring the valve arrangement to an open state in response to a pressure event to permit fluid to flow into the chamber from the wellbore annulus to relieve pressure within said annulus.

The method may comprise passively reconfiguring the valve arrangement to an open state, for example by the effects of pressure within the wellbore annulus.

The apparatus according to the first aspect may be used in the method according to the second aspect.

15 According to a third aspect of the present invention there is provided a method of installing a pressure relief apparatus within a wellbore, comprising:

securing a pipe concentrically on a tubing string to define a chamber;

forming a valve arrangement associated with the chamber; and

20 running the tubing string carrying the chamber into the wellbore to a desired depth.

The method may comprise running a tubing string into the wellbore, and then ceasing running of the tubing string to secure the pipe to the tubing string.

According to a fourth aspect of the present invention there is provided a downhole pressure relief apparatus, comprising:

25 a chamber configured to be located within a fluid filled wellbore region subject to varying fluid pressure;

a valve arrangement configurable from a closed state to an open state in response to a pressure event within the wellbore region, wherein in the closed state the chamber is isolated from the wellbore region, and in the open state fluid is permitted to flow into the chamber from the wellbore region to relieve pressure within the wellbore region.

The wellbore region may comprise a wellbore annulus, such as an annulus at least partially defined by the tubular member.

35 According to a fifth aspect of the present invention there is provided a method of providing pressure relief within a wellbore region, such as a closed or isolated wellbore region, comprising:

providing an initially sealed void within the wellbore region; and

opening the void to provide fluid communication with the wellbore region in response to a pressure event to permit fluid to flow into the void from the wellbore region to relieve pressure within said region.

5 The void may be initially sealed and subsequently opened by use of a valve arrangement.

The void may be initially sealed and subsequently opened by use of a burst disk arrangement.

The void may be filled with a gas.

The void may be at least partially evacuated.

10 Other aspects of the present invention may relate to methods of manufacturing an apparatus according to at least one of the first and fourth aspects.

The invention includes one or more corresponding aspects, embodiments or features in isolation or in various combinations whether or not specifically stated (including claimed) in that combination or in isolation. For example, it will readily be appreciated that features recited as optional with respect to one aspect may be additionally applicable with respect to any other aspect, without the need to explicitly and unnecessarily list those various combinations and permutations here.

BRIEF DESCRIPTION OF THE DRAWINGS

20 These and other aspects of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a pressure relief apparatus in accordance with an embodiment of the present invention, wherein the apparatus is shown located within a wellbore under conditions in which pressure relief is not required;

Figure 2 is a cross sectional view of the pressure relief apparatus of Figure 1, shown in a configuration to provide pressure relief;

Figure 3 diagrammatically illustrates the formation of a pressure relief apparatus in accordance with an embodiment of one or more aspects of the present invention;

Figure 4 illustrates the a tubing string comprising a plurality of pressure relief apparatuses in accordance with an embodiment of the present invention; and

Figure 5 illustrates a pressure relief apparatus in accordance with a further embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

A pressure relief apparatus, generally identified by reference numeral 10, in accordance with an embodiment of the present invention is shown in Figure 1 located within a wellbore 12. More specifically, the apparatus 10 is located within a casing string 14 which is positioned and sealed within a drilled wellbore 12 with cement 16. The apparatus 10 includes a tubular member 18 which forms part of a tubing string 20, wherein the tubing string 20 is sealed within the casing 14 via upper and lower seal assemblies 22, 24, defining an isolated annulus region 26. The upper and lower seal assemblies 22, 24 may be provided by packers, such as swellables packers. In some embodiments the upper seal assembly 22 may be provided by a wellhead seal assembly, such as within a tubing hanger or the like. Upon activation of the upper and lower seal assemblies 22, 24 wellbore fluids, such as completion fluids 28, present within the annulus region 26 become trapped, or "locked-in". During typical wellbore operations, such as production of hydrocarbons, this trapped fluid 28 will become heated and will be subject to thermal volumetric expansion. As the annulus region 26 is isolated by the seal assemblies 22, 24 this fluid expansion will be manifested as an increase in pressure, which could be of such a degree as to cause mechanical failure and collapse of the tubing string 20. As will be discussed in further detail below, the apparatus 10 of the present invention is configured to accommodate such increases in annulus pressure to thus protect the tubing string 20 from damage.

The apparatus 10 includes a pipe section 30 which is sealably mounted on the outer surface of the tubular member 18 via upper and lower adaptors or connectors 32, 34 so as to define an annular chamber or void 36. In the present embodiment the chamber 36 is filled with a gas, such as air, at atmospheric pressure. In alternative embodiments the chamber 36 may be at least partially evacuated. As illustrated in Figure 3, the pipe section 30 and upper and lower connectors 32, 34 may be mounted on the tubular member by sliding over an upper end of the tubular member 18 while located on a rig floor 50. Following this the upper and lower connectors 32, 34 may be welded or otherwise secured to the tubular member 18 to create the chamber 36. In this way, the chamber 36 may be formed during the process of running the tubular 18 into the wellbore 12. Alternatively, the chamber 36 may be formed on the tubular member 18 remotely from a rig.

The apparatus 10 further comprises a valve arrangement in the form of one or more burst disks assemblies 38 provided in the lower connector 34. The burst disk assemblies 38 initially seal the chamber 36 to prevent fluid communication between

the chamber 36 and the annulus region 26. The burst disk assemblies 38 are configured to rupture upon exposure to a predetermined pressure differential between the annulus region 26 and the chamber 36 to establish fluid communication therebetween. Accordingly, when the fluid 28 within the annulus region 26 reaches a predetermined pressure the disks 38 will rupture to permit the fluid 28 to enter the chamber 36, as illustrated in Figure 2 by arrows 40, thus relieving pressure from the annulus region 26 and protecting the tubing string 20.

As noted above, the burst disk assemblies 38 are located within the lower connector 34, and thus in a lower region of the chamber 36. This arrangement advantageously assists to prevent escape of the gas from the chamber 36, which could otherwise interfere with other wellbore equipment and/or operations. As illustrated in Figure 2, upon entry of the fluid 28 into the chamber 36, the gas 42 becomes compressed and trapped within an upper region of the chamber 36.

The chamber 36 may be sized, for example by using a desired length of pipe section 30, to accommodate a desired, for example known or estimated, pressure increase/thermal expansion of the wellbore fluid 28. Alternatively, or additionally, multiple chambers 36a, 36b, 36c may be formed along the length of a tubing string 20, as illustrated in Figure 4.

In the embodiment described above the chamber 36 is formed between an outer surface of the tubular member 18 and an inner surface of the pipe section 30. However, in alternative embodiments a suitable chamber may be formed independently of the tubular member. Such an embodiment is shown in Figure 5, in which a chamber module 60 is provided which includes a chamber 61 formed between inner and outer pipe sections 62, 64 which extend between upper and lower connectors 64, 68, wherein the lower connector 68 includes one or more burst disk assemblies 70. In such an embodiment the chamber module 60 may be rigidly fixed to the tubular member 18. Alternatively, the chamber module 60 may be freely mounted on the tubular member, which may permit relative movement between the tubular member 18 and module 60. Operation of the embodiment shown in Figure 5 is similar to that first shown in Figure 1 and as such no further description will be given.

It should be understood that the embodiments described herein are merely exemplary and that various modifications may be made thereto without departing from the scope of the invention. For example, a chamber may be provided internally of a tubular member. Further, the chambers in the embodiments described above are annular in form. However, in alternative embodiments chambers of different profiles may be utilised, such as cylindrical, part annular or the like. Furthermore,

one or more canisters may be provided which each defines a chamber. Such canisters may be circumferentially mounted around a tubular member, axially along the length of a tubular member, or a suitable combination thereof.

CLAIMS

1. A downhole pressure relief apparatus, comprising:
a tubular member configured to be located within a wellbore to at least
5 partially define a wellbore annulus, wherein the annulus is subject to varying fluid
pressure;
a chamber associated with the tubular member; and
a valve arrangement associated with the chamber and configurable from a
closed state to an open state in response to a pressure event, wherein, in use, in the
10 closed state the chamber is isolated from the wellbore annulus, and in the open state
fluid is permitted to flow into the chamber from the wellbore annulus to relieve
pressure within said annulus.
2. The apparatus according to claim 1, wherein the pressure event comprises a
15 pressure event within the wellbore annulus established by thermal expansion of fluid
within the wellbore annulus.
3. The apparatus according to claim 1 or 2, wherein the chamber is at least
20 partially annular.
4. The apparatus according to claim 1, 2 or 3, wherein the chamber is mounted
on the tubular member.
5. The apparatus according to any preceding claim, wherein the chamber is at
25 least partially defined by the tubular member.
6. The apparatus according to any preceding claim, wherein the chamber is at
least partially defined by a wall surface of the tubular member.
- 30 7. The apparatus according to any one of claims 1 to 4, wherein the chamber is
defined separately from the tubular member within a chamber module which is
mounted on the tubular member.
- 35 8. The apparatus according to any preceding claim, wherein the chamber is
defined externally of the tubular member.

9. The apparatus according to any one of claims 1 to 7, wherein the chamber is defined internally of the tubular member.
10. The apparatus according to any preceding claim, wherein the chamber is defined by a pipe mounted on the tubular member.
11. The apparatus according to any preceding claim, wherein the chamber comprises a gas.
12. The apparatus according to claim 11, wherein the gas is provided at atmospheric pressure.
13. The apparatus according to any one of claims 1 to 10, wherein the chamber is at least partially evacuated.
14. The apparatus according to any preceding claim, wherein the chamber is substantially liquid free prior to configuration of the valve assembly to the open state.
15. The apparatus according to any preceding claim, wherein the chamber is formed during a process of running the tubular member into a wellbore.
16. The apparatus according to any preceding claim, wherein the valve arrangement comprises a passive valve arrangement configurable between closed and open states by action of fluid pressure within the annulus.
17. The apparatus according to any preceding claim, wherein the valve arrangement comprises an active valve arrangement configurable between closed and open states by a powered actuator.
18. The apparatus according to any preceding claim, wherein the valve arrangement is only configurable from the closed state to the open state.
19. The apparatus according to any preceding claim, wherein the valve arrangement comprises a burst disk arrangement.
20. The apparatus according to any preceding claim, wherein the valve arrangement is mounted relative to a lower region of the chamber.

21. The apparatus according to any preceding claim, comprising a sensing arrangement configured to sense at least one of pressure and temperature and to generate an activation signal addressed to the valve arrangement.

5

22. A method of providing pressure relief within a wellbore annulus, such as a closed or isolated wellbore annulus, defined at least in part by a tubular member, comprising:

10 providing a chamber associated with the tubular member, and a valve arrangement associated with the chamber;

maintaining the valve arrangement in a closed state to isolate the wellbore annulus from the chamber;

15 reconfiguring the valve arrangement to an open state in response to a pressure event to permit fluid to flow into the chamber from the wellbore annulus to relieve pressure within said annulus.

23. A method of installing a pressure relief apparatus within a wellbore, comprising:

20 securing a pipe concentrically on a tubing string to define a chamber;

forming a valve arrangement associated with the chamber; and

further running the tubing string carrying the chamber into the wellbore to a desired depth.

24. The method of claim 23, comprising running a tubing string into the wellbore and then ceasing running of the tubing string to secure the pipe on the tubing string.

25. A downhole pressure relief apparatus, comprising:

a chamber configured to be located within a fluid filled wellbore region subject to varying fluid pressure;

30 a valve arrangement configurable from a closed state to an open state in response to a pressure event within the wellbore region, wherein in the closed state the chamber is isolated from the wellbore region, and in the open state fluid is permitted to flow into the chamber from the wellbore region to relieve pressure within the wellbore region.

35

26. A method of providing pressure relief within a wellbore region, such as a closed or isolated wellbore region, comprising:

providing an initially sealed void within the wellbore region; and
opening the void to provide fluid communication with the wellbore region in response to a pressure event to permit fluid to flow into the void from the wellbore region to relieve pressure within said region.

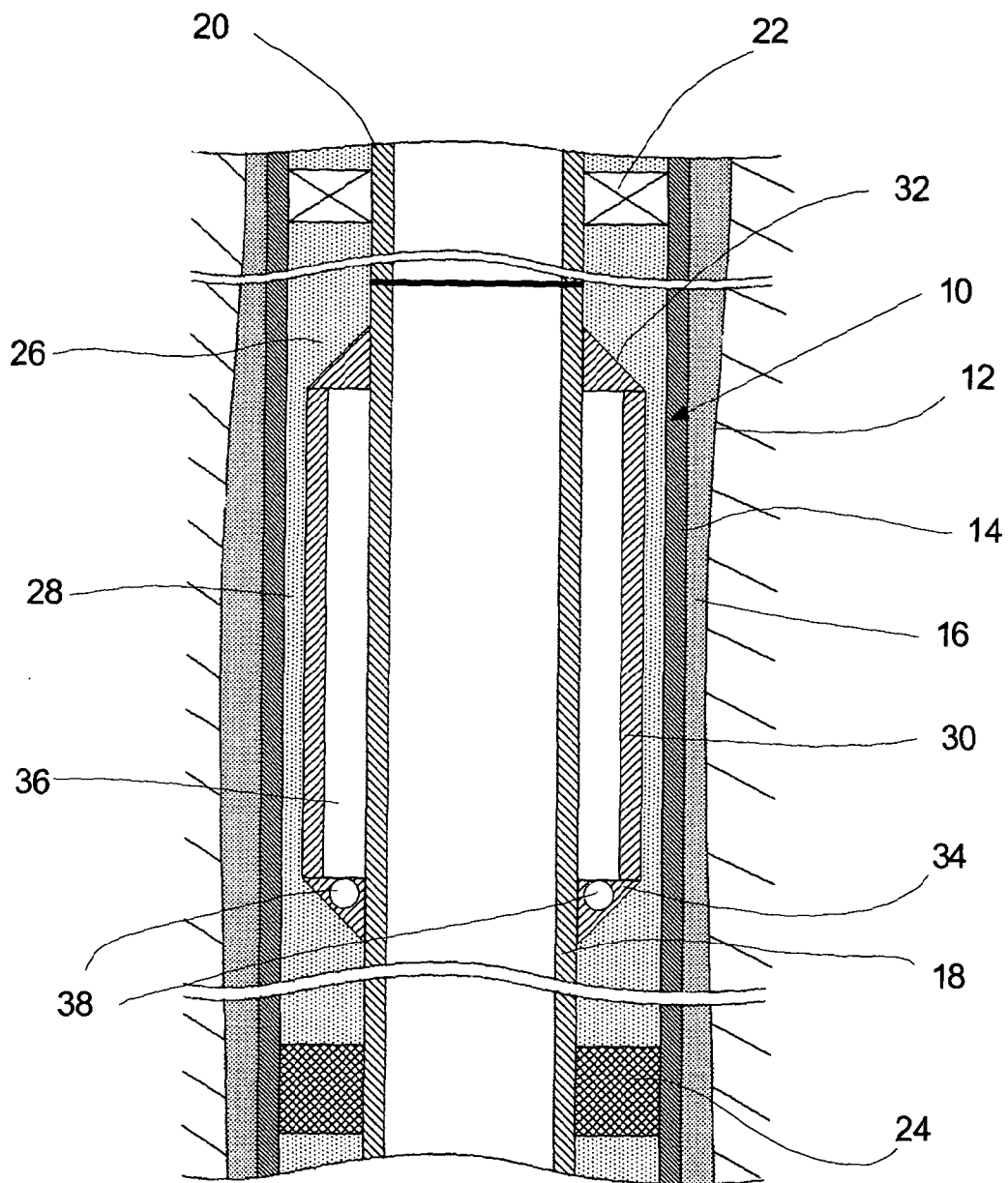


FIGURE 1

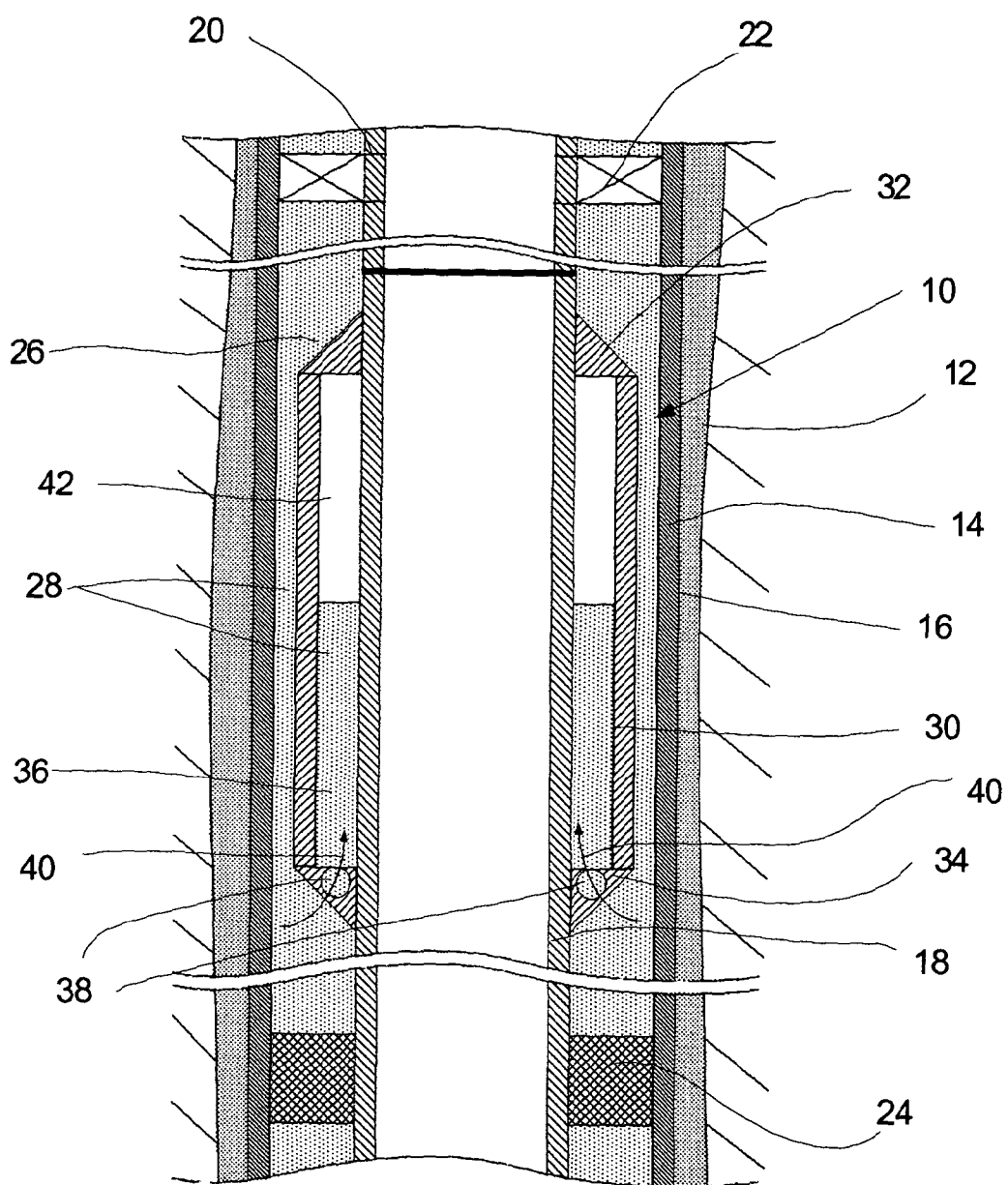


FIGURE 2

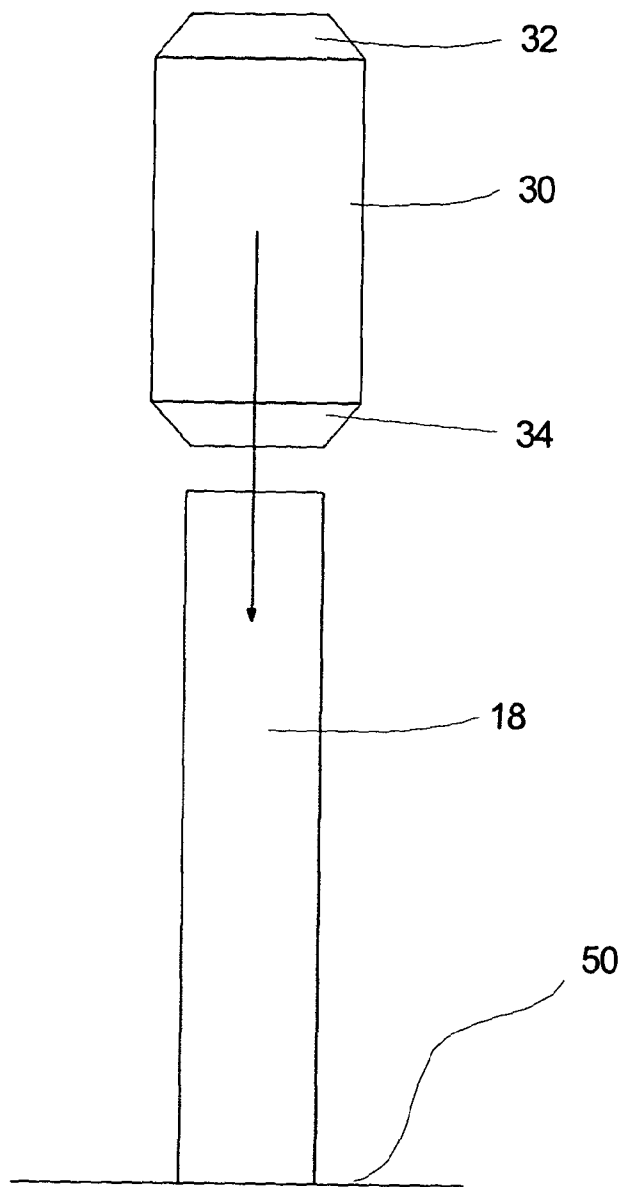


FIGURE 3

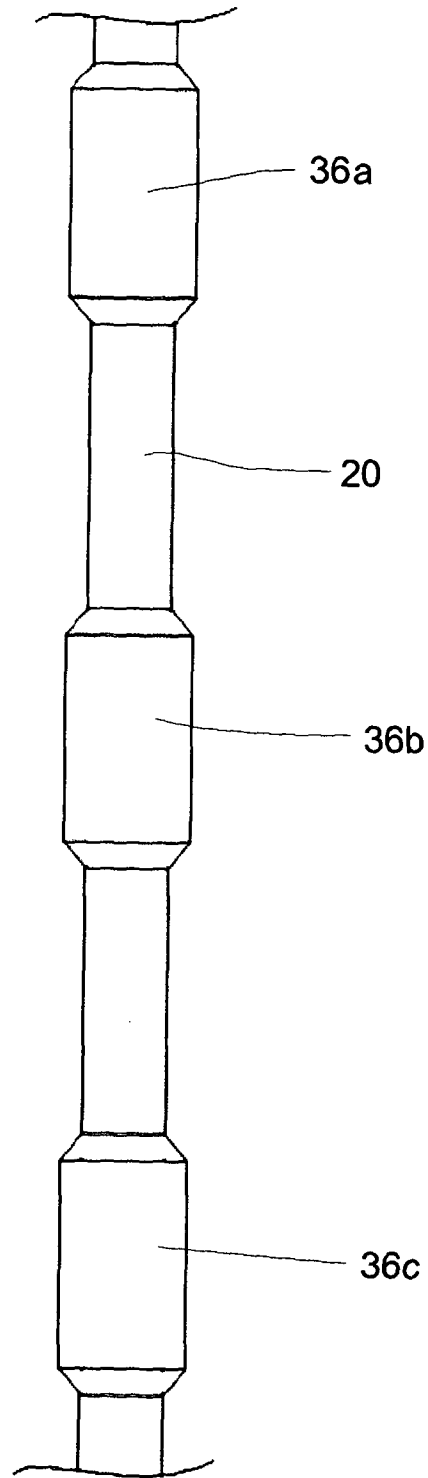


FIGURE 4

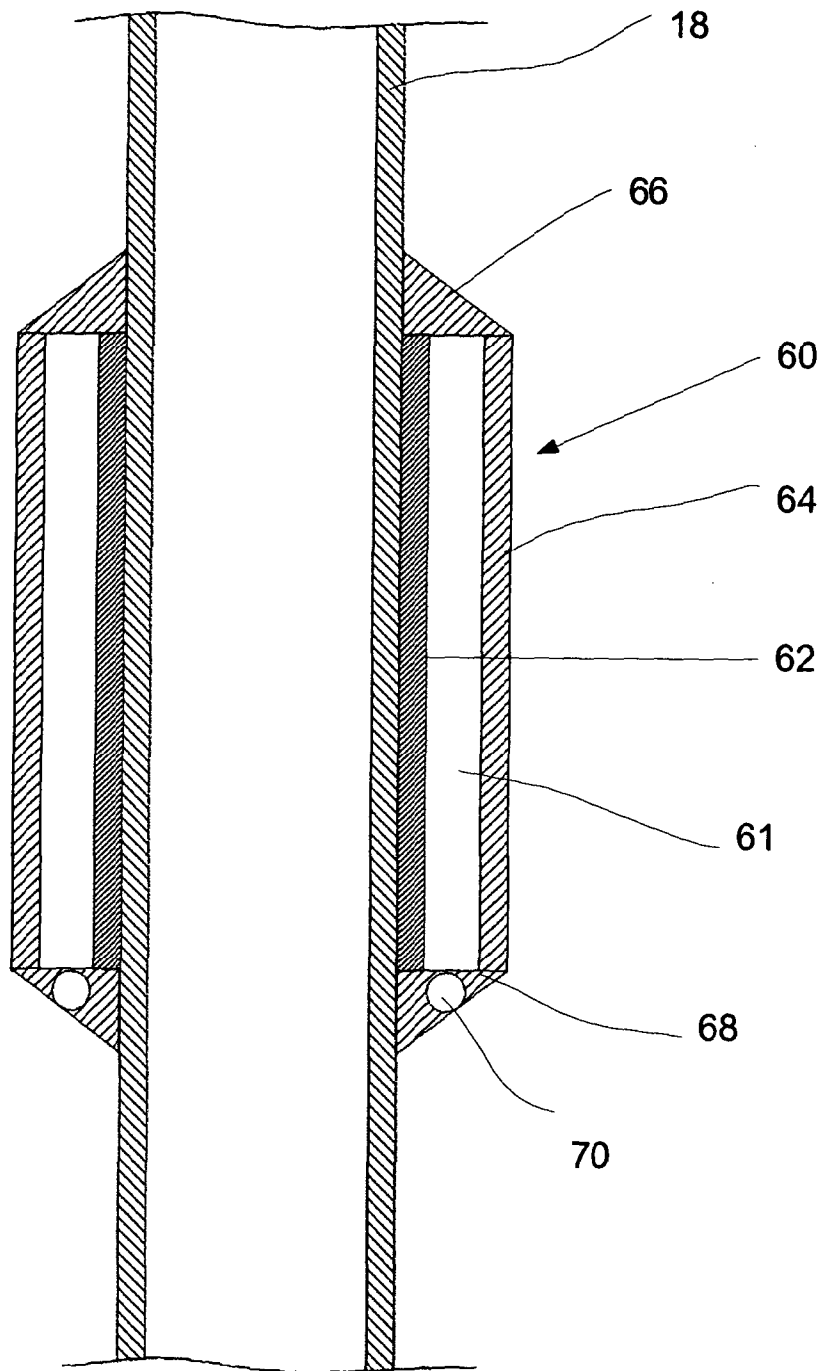


FIGURE 5