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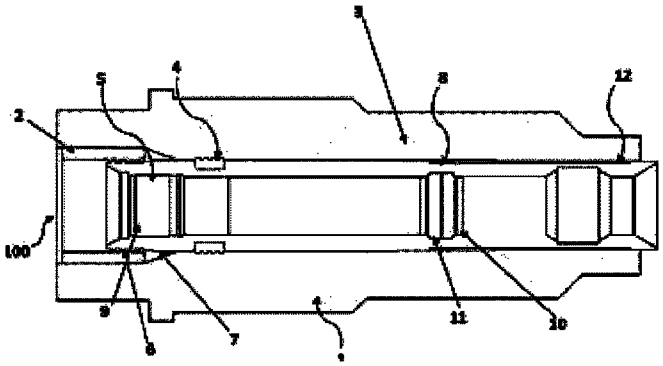
(54) Title **Tubing Hanger Plug**

(57) Abstract

A cartridge plug (100) for use in a production bore element (12) in a wellbore, said cartridge plug (100) comprising a connection means (9) configured to connect the cartridge plug (100) to an installation tool, a locking means (5) configured to lock the cartridge plug (100) into the said production bore element (12), said locking means (5) being movable between a lock position for holding the cartridge plug (100) in said production bore element (12), and an un-lock position for releasing the cartridge plug (100) from said production bore element (12), a fluid barrier (11) arranged inside the cartridge plug (100). The cartridge plug (100) further comprises a sealing means (8) arranged outside the cartridge plug (100) and configured to seal the cartridge plug (100) against the production bore element (12), wherein said fluid barrier (11) being configured to be dissolvable.



Field of the invention

The invention relates to a cartridge plug, a method for installing a cartridge plug in production bore/tubing hanger adapted for receiving said cartridge plug, and a method for opening a cartridge plug.

Background of the invention

Use of tubing hanger plugs for testing oil wells is well known. Typically, test operations include installing two or more plugs in different locations of a wellbore increasing fluid pressure from the surface in order to record possible leaks between the plugs. Typically, a pressure drop in and/or a loss fluid between the plugs will be a sign of well integrity. If the casing, tubing etc. leaks, remedial work has to be conducted. In the case of casing, perforating and remedial cementing may resolve the problem. In the case of tubing, the tubing has to be pulled out.

When testing tubing, one plug is installed near the lower end, i.e. furthest away from the wellhead, and another plug is installed near upper end, typically in the tubing hanger or one of the first pipe sections below the tubing hanger. There may be further plugs installed between these two plugs for added safety/redundancy.

Conventionally, the plugs are of a massive/solid type that either must be retrieved or opened. Both kinds of operations are time consuming and typically require complicated and heavy operations on and above the wellhead, i.e. replacing a Christmas Three (XT) with a Blow Out Preventer (BOP), conducting various operations through the BOP, replacing the BOP with the XT before conduction further tests. Each such replacing operation is time consuming and involves high costs. With conventional methods and apparatus, even if the tests are successful, the tubing hanger plug must be removed by an operation involving replacing the XT and BOP back and forth. There are conventional plugs that may be opened instead of removed, but these still require complicated operations that are time consuming. Furthermore, a significant number of such conventional plugs tend to not open as planned, requiring further operations involving replacing the XT and BOP back and forth.

Workover riser operations are typically used to deploy and remove wireline set plugs. Workover riser operations are costly and time consuming operations.

Recently, so-called disappearing plugs have been introduced into and adopted by the market. Some well-known disappearing plugs comprising crushable or dissolvable ceramic discs, glass disks or hard pressed salt or sand elements that encapsulated in a rubber material or the like, the latter being dissolvable by exposing the encapsulation for a degrading chemical, whereby the salt or sand elements dissolve when exposed to well fluids.

However, none of these disappearing plugs have been used as tubing hanger plugs, primarily because they are not easily replaceable in the event that tests should fail.

US 6,026,903 describes a plug comprising a dissolvable fluid barrier which is used in tests of a well comprising one or more circulation channels around channel that lies between the pipe wall and the plug. The plug is pushed so that it closes the circulation channel, and the fluid connection between the well space above and below the plug will then be permanently closed. US 2008/0073075 also describe a plug of a removable material and here there is an outer pipe lying on the outside of the inner pipe and an annular channel is set up which forms a fluid connection between the well space above and below the plug. A closing body can close the fluid connection in the channel. All though these plugs have significant merit for their intended use, they are not easily replaceable.

WO 2011/122957 A1 describes tubing hanger plug made of crushable material such as glass or a ceramic material. The plug is installed as part of the tubing hanger pipe in the well and allows a fluid communication through a channel past the plug body.
This plug has a large technical advance compared to the conventional test plugs, one has the possibility to use this plug as a tubing hanger test plug since there are fluid communication channels past the plug body, which can communicate across the plug body without having communication to the annulus side of the tubing. This has shown a considerable cost savings for the operators as they do not have to drive a workover riser.
All though this plugs has significant merit, it is not easily replaceable. The plug

disclosed in WO 2011/122957 A1 is pre-installed in the tubing hanger pipe and has to be deployed together with the tubing hanger pipe into the well.

The present invention according to the enclosed independent claim 1 provides a tubing hanger plug which alleviates at least one of the aforementioned drawbacks. Further advantageous or alternative features are indicated in the dependent claims.

Summary of the invention

The invention is set forth and characterized in the main claims, while the dependent claims describe other characteristics of the invention.

It is provided a cartridge plug for use in a production bore element in a wellbore, said cartridge plug comprising a connection means configured to connect the cartridge plug to an installation tool, a locking means configured to lock the cartridge plug into the said production bore element, said locking means being movable between a lock position for holding the cartridge plug in said production bore element, and an un-lock position for releasing the cartridge plug from said production bore element. A fluid barrier arranged inside the cartridge plug, wherein said fluid barrier being configured to be dissolvable. The cartridge plug further comprises a sealing means arranged outside the cartridge plug and configured to seal the cartridge plug against the production bore element.

In one embodiment the production bore element is a tubing hanger.

In another embodiment the production bore is an extension part of a tubing hanger adapted for receiving the cartridge plug.

In another aspect of the invention the production bore element is another part of the production bore adapted for receiving the cartridge plug.

In one embodiment the locking means comprises at least one dog.

In one embodiment the dissolvable fluid barrier comprises at least one glass disc.

In another embodiment the dissolvable fluid barrier is chemically desolvable.

In one embodiment the barrier crushing mechanism is activated by a pressure signal.

In another embodiment the fluid barrier removal system comprises a crushing mechanism mechanically remove the fluid barrier.

In another embodiment the fluid barrier removal system comprises a releasable chemical package adapted chemically remove the fluid barrier.

In one embodiment of the present invention the barrier crushing mechanism is activated by an electric signal or a telemetric signal.

In one embodiment the cartridge plug comprises a cartridge plug landing shoulder arranged on the outer surface of the cartridge, for interaction with a bore landing shoulder in the installation position. The plug landing shoulder is provided with means to move relative the rest of the cartridge housing at certain loads, by either deformation of the plug landing shoulder or the plug landing shoulder is connected to the cartridge housing by shear pins or ring, such that the bore landing shoulder at the position for installation, is not damaged.

In one embodiment the locking means are configured such that when the locking means are moved to a locked position the cartridge plug is lifted off the bore landing shoulder at the position for installation.

It is also provided a method of installing the cartridge plug comprising the steps of: connecting an installation tool to the connection means of the cartridge plug; running the installation tool with the cartridge plug to the production bore element; activating the locking means into a lock position in the production bore element; after locking said locking means into said production bore element, disconnection the installation tool from the connection means; conducting necessary testing operations.

It is also provided a method of opening the cartridge plug comprising by activating a barrier crushing mechanism, wherein the barrier crushing mechanism weakens the tension of the dissolvable fluid barrier, thereby opening a dissolvable fluid barrier arranged inside the cartridge plug.

It is also provided a production bore element for receiving a plug cartridge, comprising an inner bore wherein there in the inner bore is provided with a bore landing shoulder and dedicated locking profile for the plug cartridge and at least one sealing surface. In

one embodiment the at least one sealing surface is positioned relatively below the locking profile. In another embodiment the at least one sealing surface is positioned relatively below the bore landing shoulder.

In one embodiment the at least one locking profile is being formed such that is takes loads in both directions of the inner bore. In one embodiment the at least one locking profile, by interaction with the locking means of the cartridge plug, is configured such that it lifts the cartridge plug off the bore landing shoulder when the locking means are moved to a locked position.

Brief description of the drawings

The following description provides a detailed description of possible embodiments of the invention with reference to the enclosed drawings, wherein:

Figure 1 show the cartridge plug according to the invention installed in production bore/tubing hanger.

Figure 2 shows the cartridge plug in unlocked position.

Figure 3 shows the cartridge plug in locked position.

Figure 4a-4c show the cartridge plug installed in the well.

Detailed description of a preferential embodiment

The following description may use terms such as “horizontal”, “vertical”, “lateral”, “back and forth”, “up and down”, ”upper”, “lower”, “inner”, “outer”, “forward”, “rear”, etc. These terms generally refer to the views and orientations shown in the drawings and are associated with a normal use of the terms. The term “BOP” is used as abbreviation for a Blow Out Preventer, “XT” for a Christmas tree and “TH” for a tubing hanger. The terms are solely used in an attempt to explain the invention should not be construed in a limiting manner.

Figure 1 shows a tubing hanger cartridge plug, hereafter referred as a cartridge plug 100 in a tubing hanger 1. The term “cartridge” is used to capture its removable and

replaceable ability. The cartridge plug 100 comprises a landing shoulder 3, a connection means 9 for connecting the cartridge plug 100 to an installation tool (for example a running tool). The connection means 9 will typically comprise an interface which mates with conventional running tools. The cartridge plug 100 further comprises a locking means 5 configured to lock the cartridge plug 100 into the tubing hanger 1. Typically, the locking means 5 may comprise so-called dogs 4, but other locking means 5 are also possible. The cartridge plug 100 further comprises a dissolvable fluid barrier 11, barrier crushing mechanism 10 configured to be activated by a pressure signal, a sealing means 8 outside of the cartridge plug 100 in order to avoid any unwanted fluid communication or flow passage passing the space outside said cartridge plug 100.

By a dissolvable fluid barrier 11 is meant: crumbling, disintegrating, crushable, collapsible, or otherwise vanishable. The shown present embodiment comprises at least one crushable glass disc.

When installing the cartridge plug 100 into the tubing hanger 1, the installation tool is mounted to the connection means 9 which is attached to the locking means 5. The locking means 5 comprises dogs 4 which are located in a housing of the locking member 5, leaf springs which are arranged beneath the dogs 4 and a locking ring which may be configured to slide back and forth towards the dogs 4. When the installation tool 2 places the cartridge plug 100 at the desired location in the tubing hanger 1, the locking means 5 is forced downward towards the dogs 4and in this way forcing the dogs 4 out into a gripping position in the tubing hanger 1. After the cartridge plug 100 is installed in the tubing hanger 1, the installation tool is disconnected and the tubing hanger 1 acts as a seal for the wellbore. The passage between the cartridge plug 100 and the tubing hanger is sealed by the sealing means 8. A seal 14 is mounted on the outer side for of the locking means 5 to prevent debris and impurities from above (the wellhead) falling into passage 7 and the moving parts of the plug cartridge 100.

Although the above and below described and shown embodiments describe a cartridge plug arranged in a tubing hanger, it should be understood that the cartridge plug according to the present invention can be arranged in an extension part of a tubing hanger or another part of the production bore adapted for receiving a cartridge plug.

Figure 2 and figure 3 show the cartridge plug 100 in unlocked and locked position. Circumferential sealing means 8 are arranged somewhere around the cartridge plug 100 and acts as a fluid flow barrier in the annular space between the tubing hanger 1 and the cartridge plug 100.

Figure 4a shows a floating installation structure 20 with an installation pipe 21 extending from the floating structure 20 to a BOP 22 which is located on the top end (wellhead) of a wellbore 23 drilled beneath the seafloor 24. The tubing hanger 1 and the cartridge plug 100 are installed in the top end of the well through the BOP 22. The cartridge plug 100 may be pre-installed in the tubing hanger before deployment or installed in a later operation. In this example the cartridge plug 100 is pre-installed. Further down the well a lower plug 101 is inserted through a production tubing 25, the lower plug 101 isolates the tubing section between the lower plug 101 and the wellhead from reservoir fluids and the lower completion of the wellbore 23. The lower plug 101 may be of any suitable kind, e.g. conventional formation isolation valve (FIV) or a dissolvable disappearing plug. Other kinds of lower plugs are also conceivable.

Conventionally when the tubing testing has been successfully carried out, the XT 26 can be installed, this however requires the BOP 22 to be pulled out to surface. After pulling the BOP 22, the XT 26 can be run and landed on the wellhead. During this operation, the tubing hanger plug and a lower barrier of either FIV type or disappearing plug type will form the required two barriers in the well. In order to start the well for production the TH plugs of traditional types has to be removed this conventionally requires rerunning the BOP, landing and locking the BOP on top of the XT. After landing and locking the BOP 22 to XT 26 top, a workover riser system is in most cases run internally in the marine riser system and locked internally in to the XT top to facilitate safe pulling of the traditional TH plug. This is time consuming and expensive operations. The, operations of rerunning the BOP, running WOR, pulling of TH plug, setting of crown plug in XT and finally pulling the BOP is from 6-9 rig days.

The cartridge plug 100 according to the present invention obviates the need for these last time consuming heavy operations if the tubing integrity tests have been successful because the cartridge plug 100 does not require the presence of the BOP to be opened. The cartridge plug 100 according to the present invention is remotely and readily

opened by an increase of pressure above the fluid barrier. This increased pressure may activate a crushing or dissolving device arranged to crush or otherwise remove the dissolvable fluid barrier 11 according to the present invention. The activation device may be mechanical, hydraulic, electrical or by means of explosives. According to one embodiment, cyclic pressure increases and decreases may activate a counter system that actuates the crushing or dissolving device. Alternatively, a telemetric system or an electric signal system may activate the crushing or dissolving device. Other options are also possible.

On the other hand, if the tubing testing is not successful and remedial operations has to be carried out, the fluid barrier must still be opened by any one of the methods and devices described above, but the remedial operations can be carried out through the opened plug without having to remove it first because the inner diameter of the cartridge plug 100 is the same as the tubing inner diameter. After the remedial operations have been completed, the open cartridge plug 100 can be replaced by a new cartridge plug 100 without having to pull out the tubing hanger. Alternatively, the tubing has to be pulled out because no downhole operations are possible to remedy the cause of the unsuccessful tubing testing, which will be no different from conventional operations.

Therefore, the significant advantages of the present invention is that normal production easily can initiated after successful tubing testing without having to remove a tubing hanger plug as per the use of conventional tubing hanger plugs, or if remedial operations can be carried out while the tubing is in the well. In either of these cases, it is sufficient to crush or otherwise remove the dissolvable fluid barrier 11 as described herein. The great saving that the present invention provides is the avoidance of one or several time-consuming and heavy operations to open and/or remove the tubing hanger plugs.

When hydrocarbon is to be produced from the well 23, the BOP 22 is removed and a XT 26 is installed (production tree) on the wellhead. A method of replacing BOP with a XT is now described. Before this operation is carried out, there must be at least two mechanical barriers sealing the wellbore vertically as shown in figure 4a (100 and 101).

The second barrier may be installed first as shown in figure 4b while the BOP 22 is still on the top end of the well 23. In one aspect of the invention the second barrier 101 may be a formation isolation valves (FIV) which serves as a bidirectional barrier within the lower completion. The first barrier is now installed, the first barrier being the tubing hanger cartridge plug 100. When both the first and the second barriers are in place, a test may be conducted to investigate the integrity of the tubing and/or the plugs 100 and 101. After the tubing integrity tests are completed and are in accordance with required standards, the BOP 22 is removed and replace with XT 26 shown in figure 4c. The method of replacing BOP with XT is well known in the art and will not be explained herein. Furthermore, all the elements of the BOP 22 and XT 26 are also well known in the art and will be not discussed herein.

As mentioned above, the use of the disappearing cartridge plug 100 dimensioned to be installed in the tubing hanger 1 is cost saving compared to the conventional tubing hanger plugs where workover risers are essential for pulling out these plugs. If a conventional tubing hanger plug is used as the first seal barrier during installation of the XT, then after installation of the XT, the tubing hanger plug must be retrieved from the tubing hanger. The process of retrieving conventional tubing hanger plugs needs a rerun off the BOP and a workover riser operation and may take days retrieve, something which leads considerable cost for operators. The use of the disappearing tubing hanger cartridge plug 100 has a large technical advantage over the conventional tubing hanger plug because the cartridge plug 100 is opened remotely and does not need a BOP and workover riser operation after the XT is installed.

Another advantage of the cartridge plug 100 is that if well intervention is carried out, for example replacing the XT during the life cycle of the well, there is no need to pull out the tubing hanger 1 to remove the shell of the cartridge plug 100. If a new XT is to be installed, first step is to reactivate the second barrier which may be the formation isolation valve or another disappearing plug valve configured to fit the tubing or any other isolation barrier suitable for the purpose within the lower part of the production tubing. After the well is sealed by the second barrier, a new tubing hanger cartridge plug can be installed by first pulling the empty cartridge from the TH and then installing a new cartridge plug in its place. The cartridge plug 100 can be retrieved with a running

tool, wireline, slickline or any other tools known in the art. The cartridge plug are set shallow in the TH, this facilitates usage of a riser less well intervention vessel for setting and pulling of cartridge type plugs, RLWI vessels also have the advantage of costing fractions of a rig cost per day. Two new barriers are now installed and the X-mas tree can now be replaced and the plugs can be opened again with pressure cycles applied through the XT. This way it is possible to restore the production and hydrocarbon can be produced from the well without rerunning the BOP.

The cartridge plug 100 system according to the present invention can reduce in the order of 6-9 rig days for operators, as the pulling of the new cartridge disappearing TH plug is not needed for production to start. Both the new cartridge plug 100 and the lower plug 101 can be opened with hydraulic pressure or a chemical package supplied through the XT 26. Therefore, no wellbore intervention is needed post installation of XT 26.

As the XT 26 is landed and locked to the wellhead a full well control unit may be installed, the new cartridge plug 100 has due to its construction and installation directly in to the tubing hanger sufficient ID in the cartridge to produce the well without posing a restriction for flow.

Therefore, it is possible to applying pressure through the XT down to the top of the cartridge plug 100 whereas the cartridge plug on correct pressure key will open the centrepiece and give axes down to the lower barrier plug 101 which can be open.

This means that re-running of BOP on top of the XT to pull the TB plug is not needed, as we can remove both barriers in the well by applying pressure through the XT.

While the invention has been described with reference to the illustrated embodiment, it should be understood that modifications and/or additions can be made to the tubing hanger plug, but these shall remain within the field and scope of the invention.

Claims

1. A cartridge plug (100) for use in a production bore element (12) in a wellbore, said cartridge plug (100) comprising:

a connection means (9) configured to connect the cartridge plug (100) to an installation tool;

a locking means (5) configured to lock the cartridge plug (100) into the said production bore element (12), said locking means (5) being movable between a lock position for holding the cartridge plug (100) in said production bore element (12), and an un-lock position for releasing the cartridge plug (100) from said production bore element (12);

a fluid barrier (11) arranged inside the cartridge plug (100);

characterized in that, said cartridge plug (100) further comprises a sealing means (8) arranged outside the cartridge plug (100) and configured to seal the cartridge plug (100) against the production bore element (12); wherein said fluid barrier (11) being configured to be dissolvable.

2. The cartridge plug (100) according to claim 1, wherein the production bore element (12) is a tubing hanger (1).

3. The cartridge plug (100) according to claim 1, wherein the production bore element (12) is an extension part of a tubing hanger (1) adapted for receiving the cartridge plug.

4. The cartridge plug (100) according to claim 1, wherein the production bore element (12) is another part of the production bore adapted for receiving the cartridge plug.

5. The cartridge plug (100) according to claim 1, wherein the locking means (5) comprises at least one dog (4).

6. The cartridge plug (100) according to claim 1, wherein the fluid barrier (11) comprises at least one glass disc.

7. The cartridge plug (100) according to one of the preceding claims, wherein the cartridge plug comprises a fluid barrier removal system.

8. The cartridge plug (100) according to 7, wherein the fluid barrier removal system comprises a crushing mechanism (10) mechanically remove the fluid barrier.

9. The cartridge plug (100) according to 7, wherein the fluid barrier removal system comprises a releasable chemical package adapted chemically remove the fluid barrier.

10. The cartridge plug (100) according to one of the claims 7-9, wherein barrier crushing mechanism (10) is activated by a pressure signal.

11. The cartridge plug (100) according to one of the claims 7-9, wherein barrier crushing mechanism (10) is activated by an electric signal.

12. The cartridge plug (100) according to one of the claims 7-9, wherein barrier crushing mechanism (10) is activated by a telemetric signal.

13. The cartridge plug (100) according to claim 2-4, wherein it comprises a cartridge plug (100) landing shoulder (3) arranged on the outer surface of the cartridge, for interaction with a bore landing shoulder in the installation position.

14. The cartridge plug (100) according to claim 13, wherein the plug landing shoulder (3) is provided with means to move relative the rest of the cartridge housing at certain loads, by either deformation of the plug landing shoulder or the plug landing shoulder is connected to the cartridge housing by shear pins or ring, such that the bore landing shoulder at the position for installation, is not damaged.

15. The cartridge plug (100) according to claim 13, wherein the locking means (5) are configured such that when the locking means (5) are moved to a locked position the cartridge plug is lifted off the bore landing shoulder at the position for installation.

16. A method of installing the cartridge plug (100) according to any one of claims 1-15, **characterized by** the steps of:

connecting an installation tool to the connection means (9) of the cartridge plug (100);

running the installation tool with the cartridge plug (100) to the production bore element (12);

activating the locking means (5) into a lock position in the production bore element (12);

after locking said locking means into said production bore element (12), disconnection the installation tool from the connection means (9);

17. Method according to claim 16, wherein the cartridge plug (100) is landed in the production bore element (12)at a landing shoulder before the locking means are activated, and the activation of the locking means interacting with the locking profile in the tubing hanger lifts the cartridge plug off the landing shoulder in the production bore element (12).

18. A method of opening the cartridge plug (100) according to any one of claims 1-15, **characterized by**,

activating a barrier crushing mechanism (10), wherein said barrier crushing mechanism (10) weakens the tension of the dissolvable fluid barrier (11), thereby opening a dissolvable fluid barrier (11) arranged inside the cartridge plug (100).

19. Production bore element for receiving a plug cartridge according to claim 1, comprising an inner bore wherein there in the inner bore is provided with a bore landing shoulder and dedicated locking profile for the plug cartridge and at least one sealing surface.

20. Production bore element according to claim 19, wherein the at least one sealing surface is positioned relatively below the locking profile.

21. Production bore element according to claim 20, wherein the at least one sealing surface is positioned relatively below the bore landing shoulder.

22. Production bore element according to claim 19, wherein the at least one locking profile is being formed such that is takes loads in both directions of the inner bore.

23. Production bore element according to claim 19, wherein the at least one locking profile, by interaction with the locking means of the cartridge plug, is configured such

that it lifts the cartridge plug off the bore landing shoulder when the locking means are moved to a locked position.

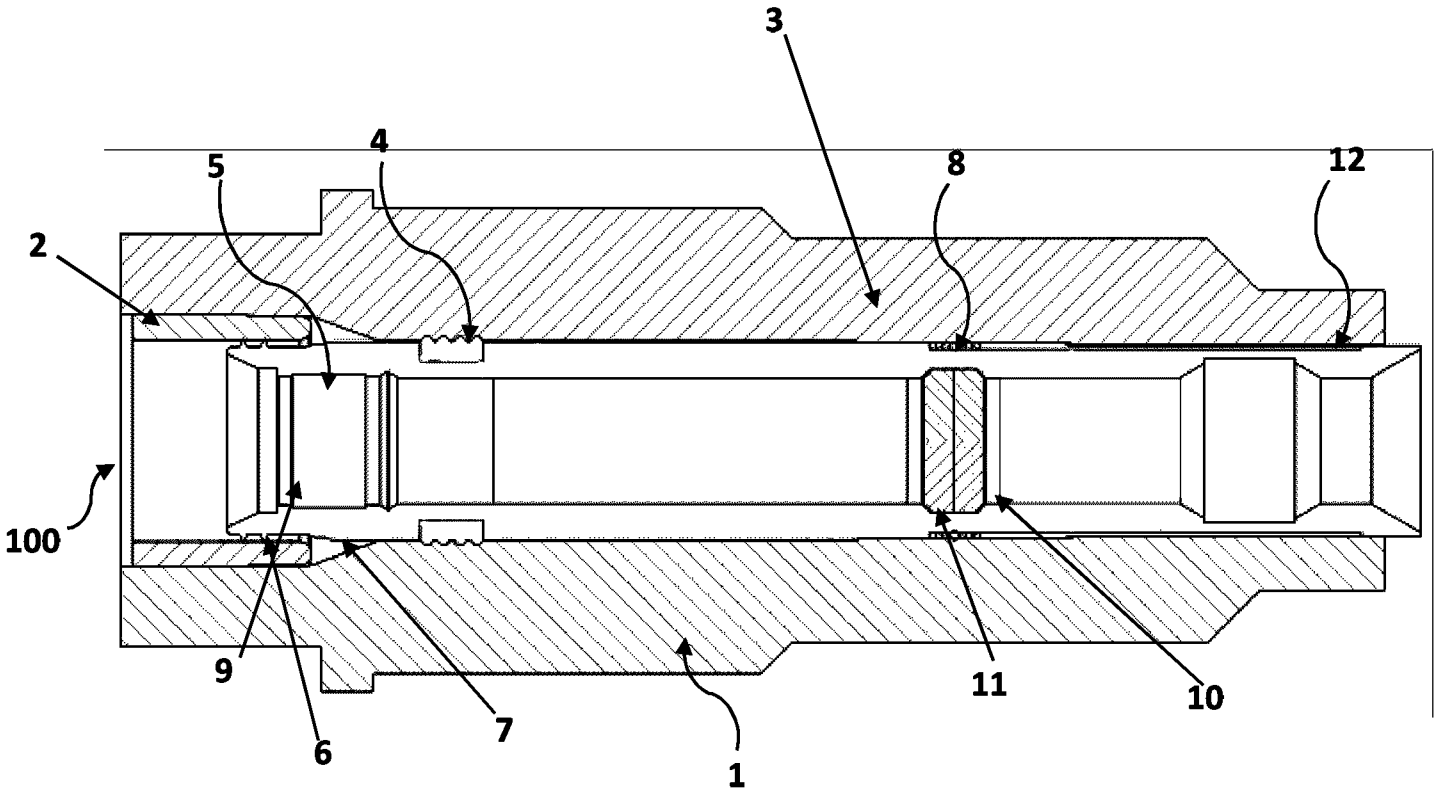


Figure 1.

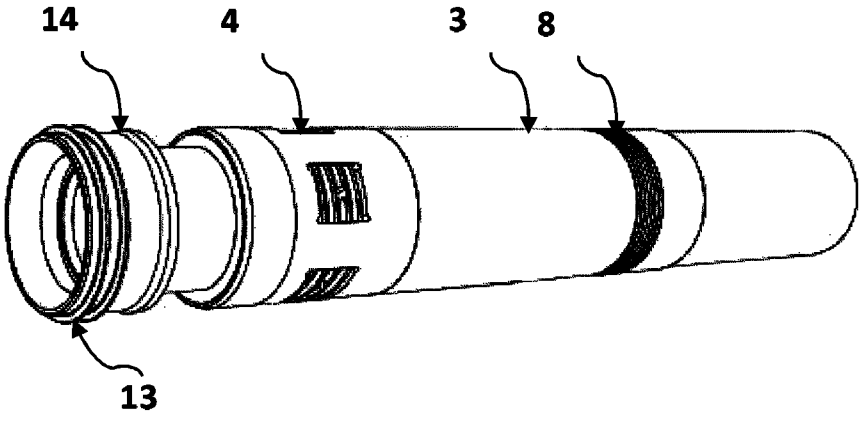


Figure 2.

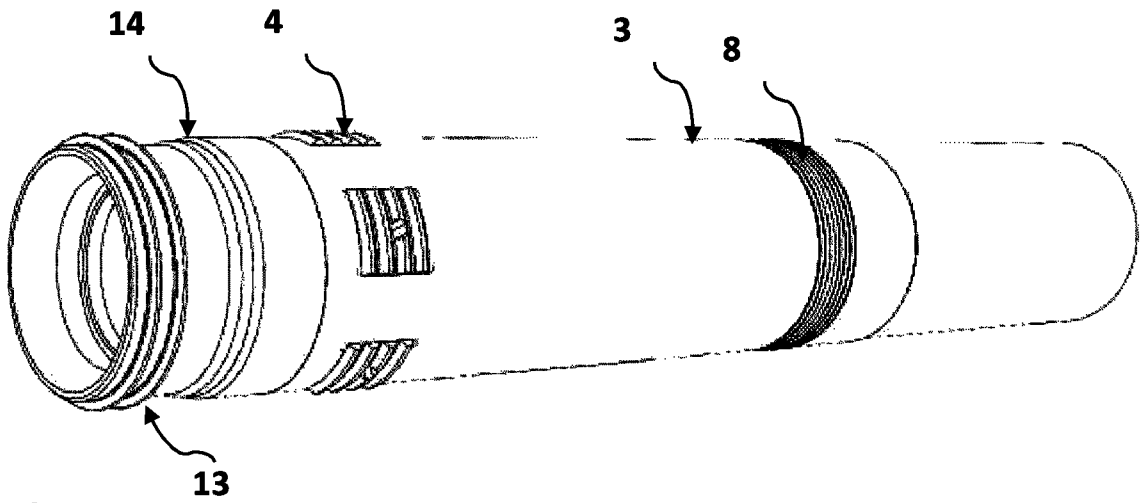


Figure 3.

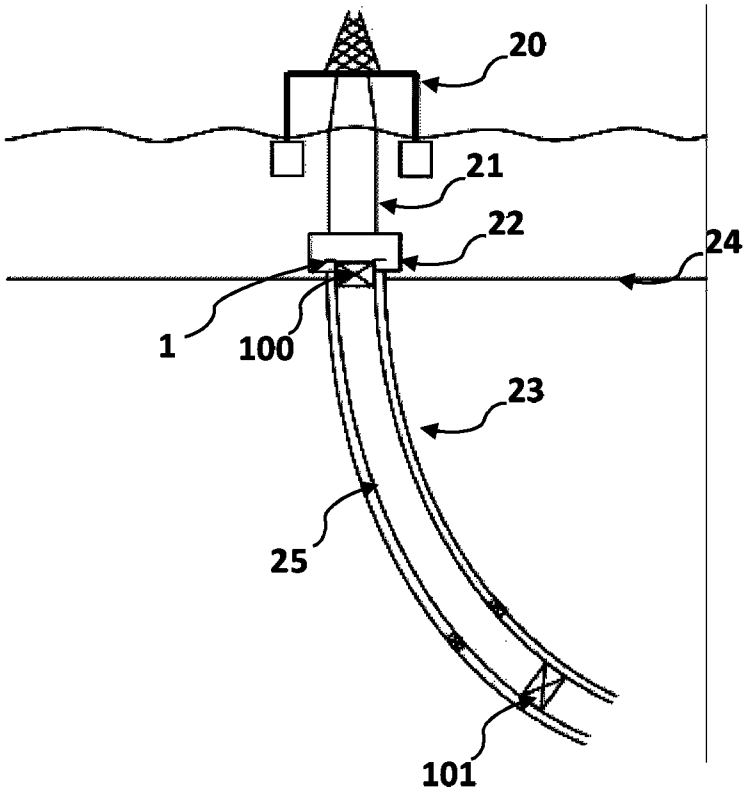


Figure 4a.

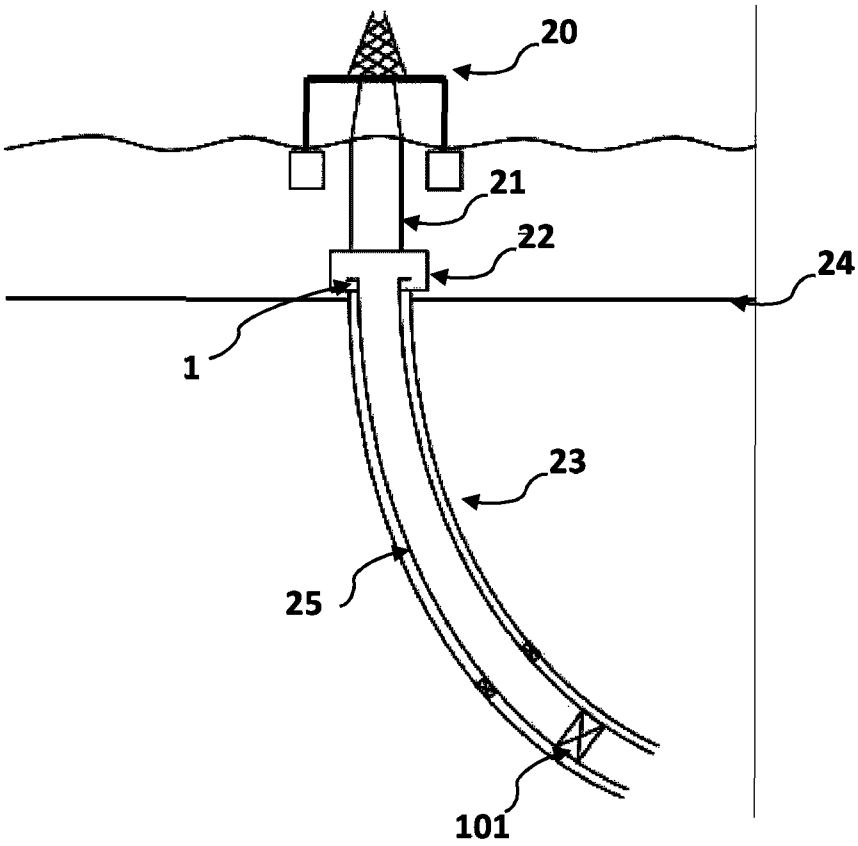


Figure 4b

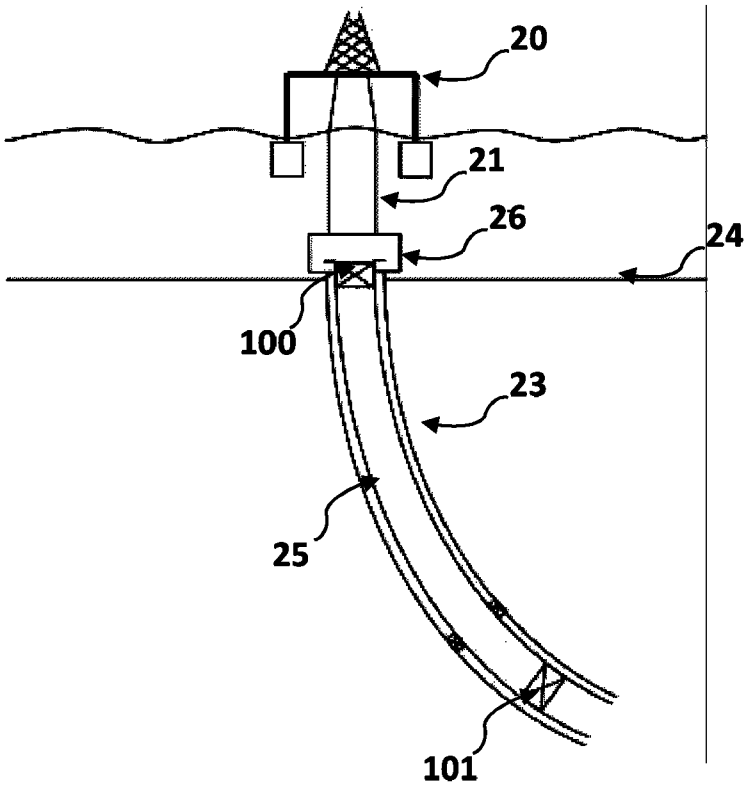


Figure 4c.