US010385641B2

(12) **United States Patent**
Carlsen et al.

(10) **Patent No.: US 10,385,641 B2**
(45) **Date of Patent: Aug. 20, 2019**

(54) **FLUSHING A TOOL FOR CLOSED WELL OPERATION AND AN ASSOCIATED METHOD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/565,165**

(22) PCT Filed: **Apr. 8, 2016**

(86) PCT No.: **PCT/EP2016/057728**

§ 371 (c)(1),
(2) Date: **Oct. 8, 2017**

(87) PCT Pub. No.: **WO2016/162471**

PCT Pub. Date: **Oct. 13, 2016**

(65) **Prior Publication Data**

US 2018/0094497 A1 Apr. 5, 2018

(30) **Foreign Application Priority Data**

Apr. 9, 2015 (NO) 20150419

(51) **Int. Cl.**

E21B 21/00	(2006.01)
E21B 33/035	(2006.01)
E21B 33/076	(2006.01)
E21B 21/10	(2006.01)

(52) **U.S. Cl.**
CPC ***E21B 33/035*** (2013.01); ***E21B 21/001*** (2013.01); ***E21B 21/10*** (2013.01); ***E21B 33/076*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 33/035; E21B 21/001; E21B 21/10
See application file for complete search history.

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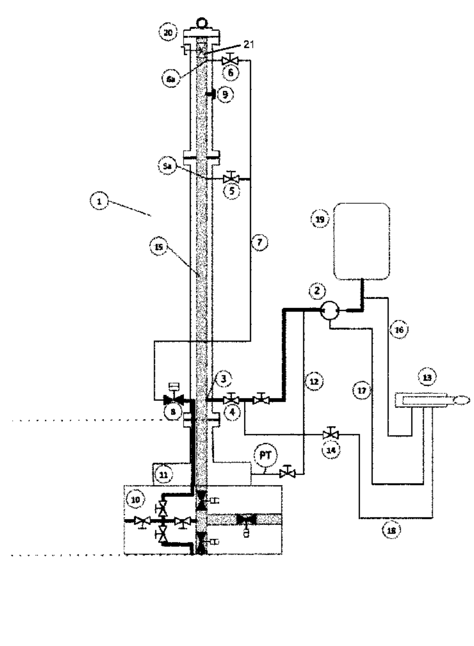
(57) **ABSTRACT**

A closed operation subsea well tool assembly with a flushing system flushing a first fluid in the main bore (**15**) of the tool assembly (**1**). The flushing system of the tool assembly comprises a container (**19**) with a second fluid, a pump (**2**), a swab valve (**20**) in the top of the main bore (**15**), an inlet (**3**) in the bottom of the main bore of the tool assembly, which is connected to the pump. Outlet(s) (**5*a*, 6*a***) are below the swab valve, configured to guide out the first fluid from the main bore. A fluid channel (**7**) extends from the outlet (**5*a*, 6*a***) and down to channels of the wellhead module (**10**) or the wellhead (**31**). Methods using the tool assembly are also disclosed.

11 Claims, 7 Drawing Sheets



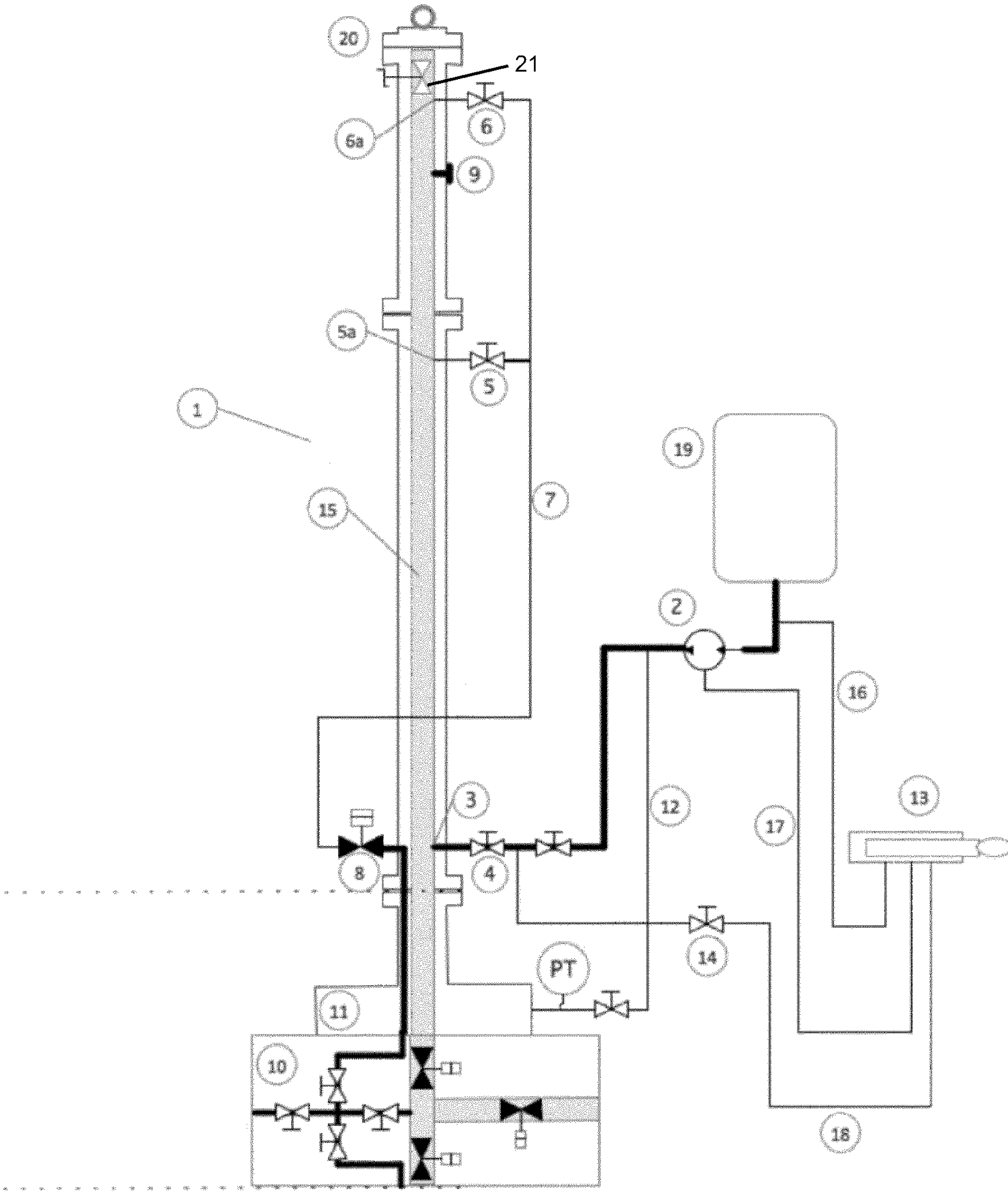


Fig. 1

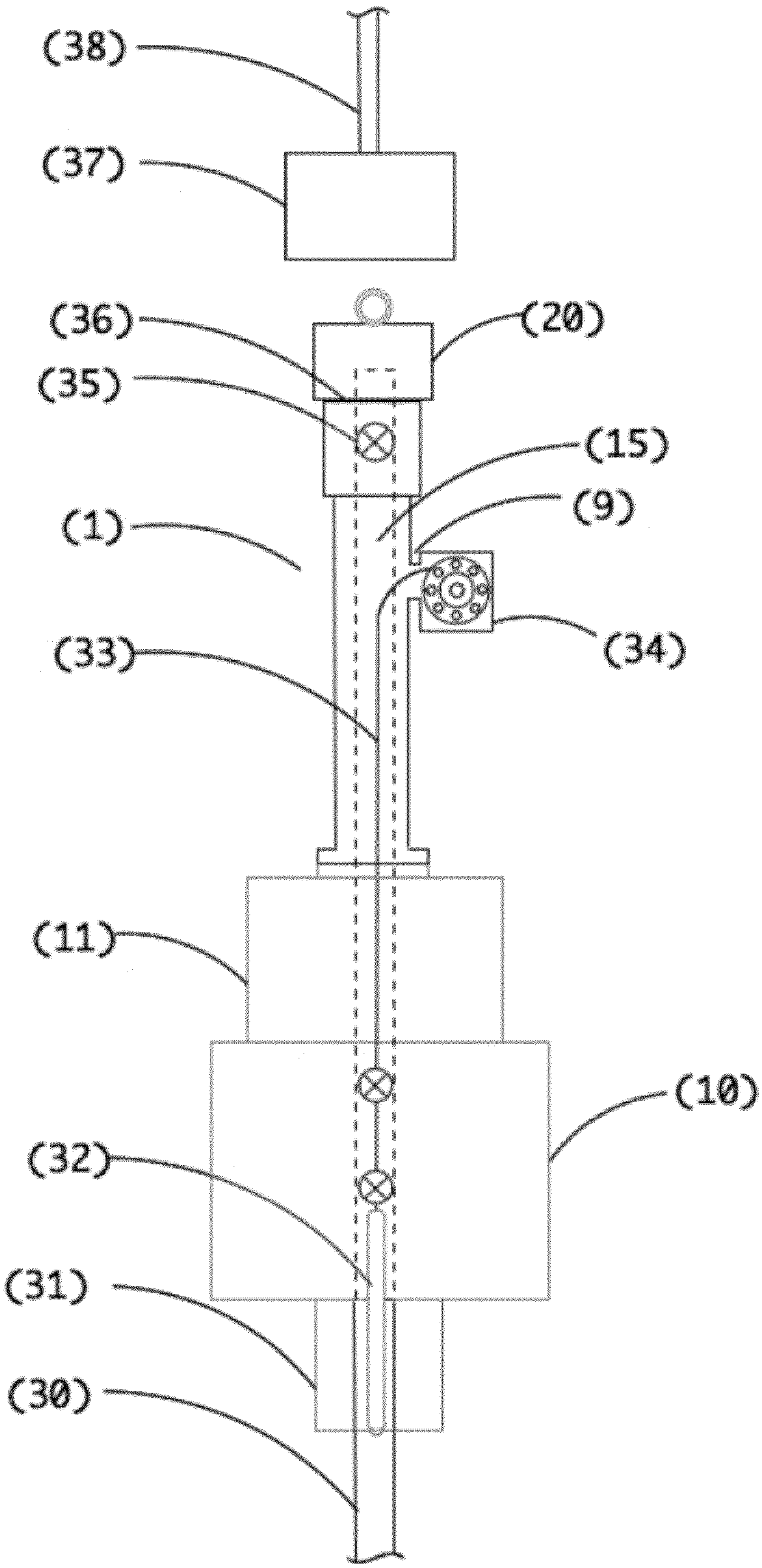


Fig. 2

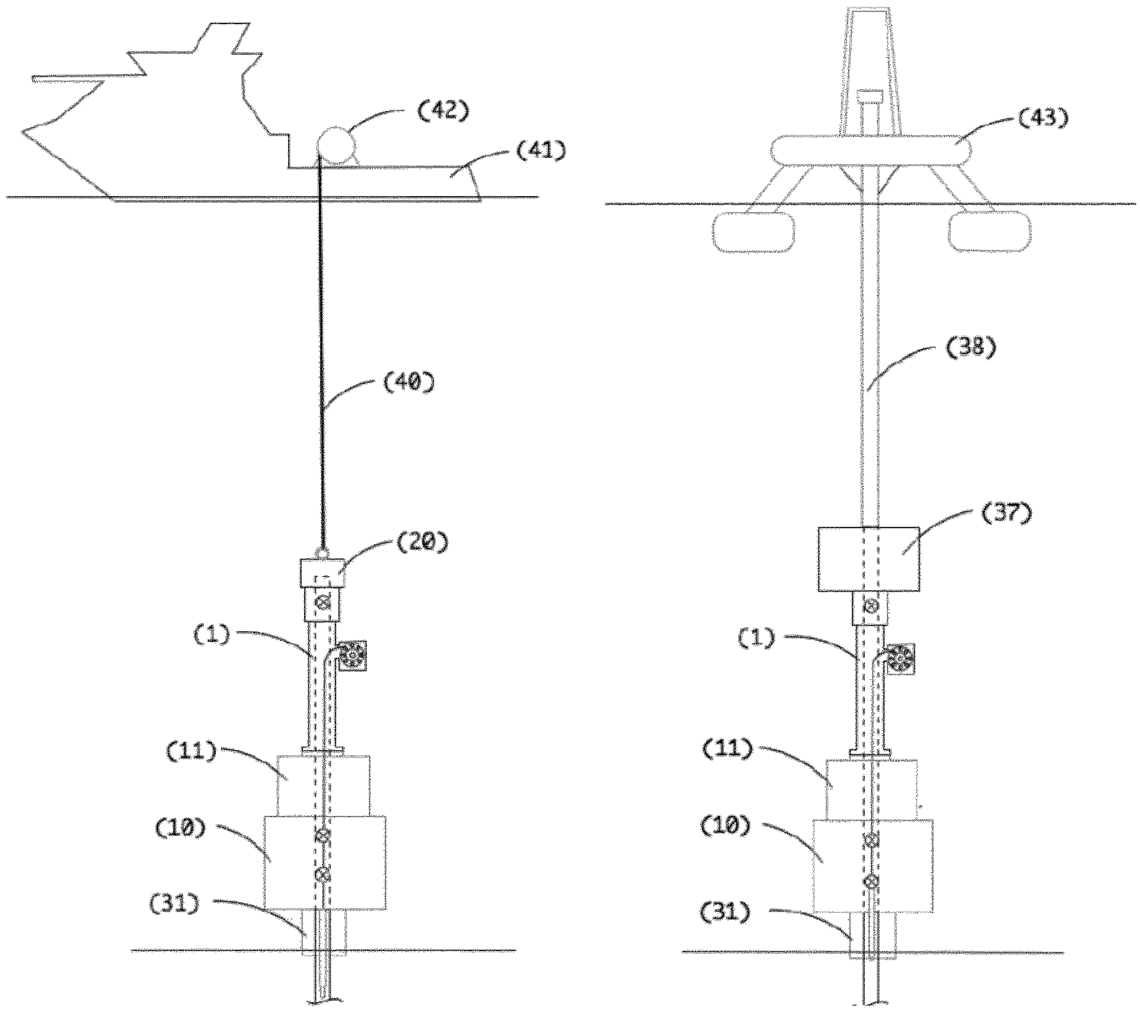


Fig. 3

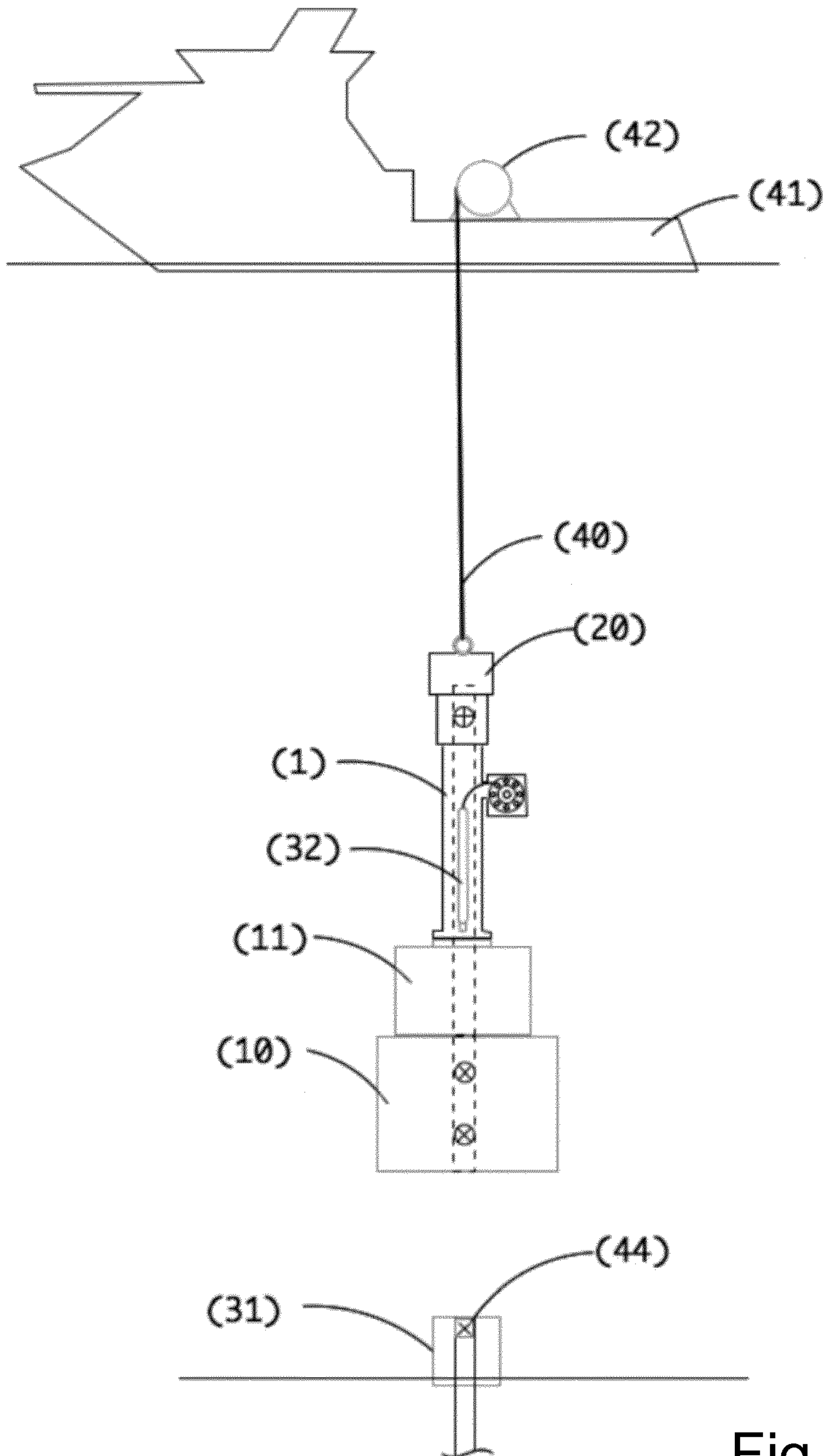


Fig. 4

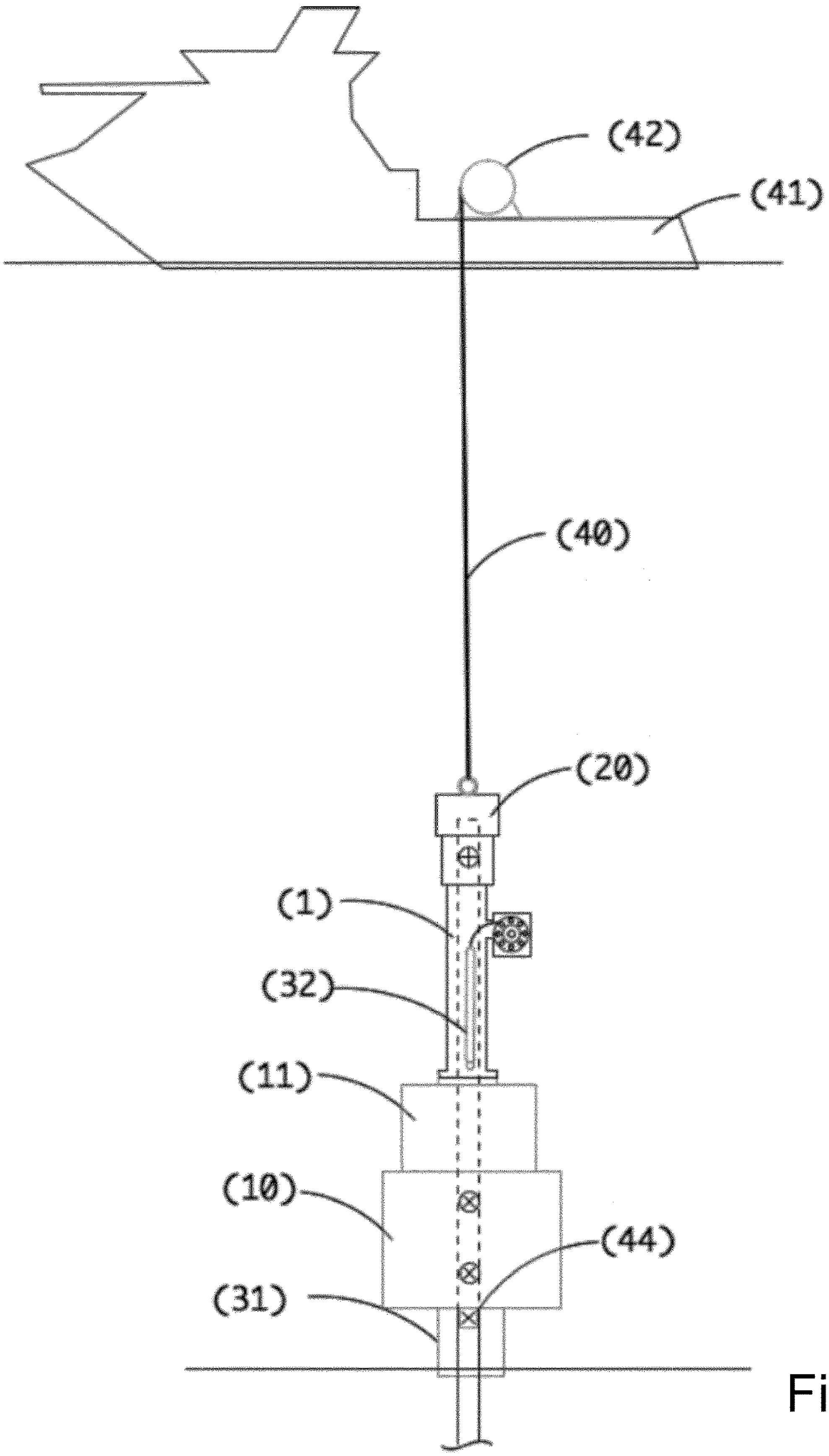


Fig. 5

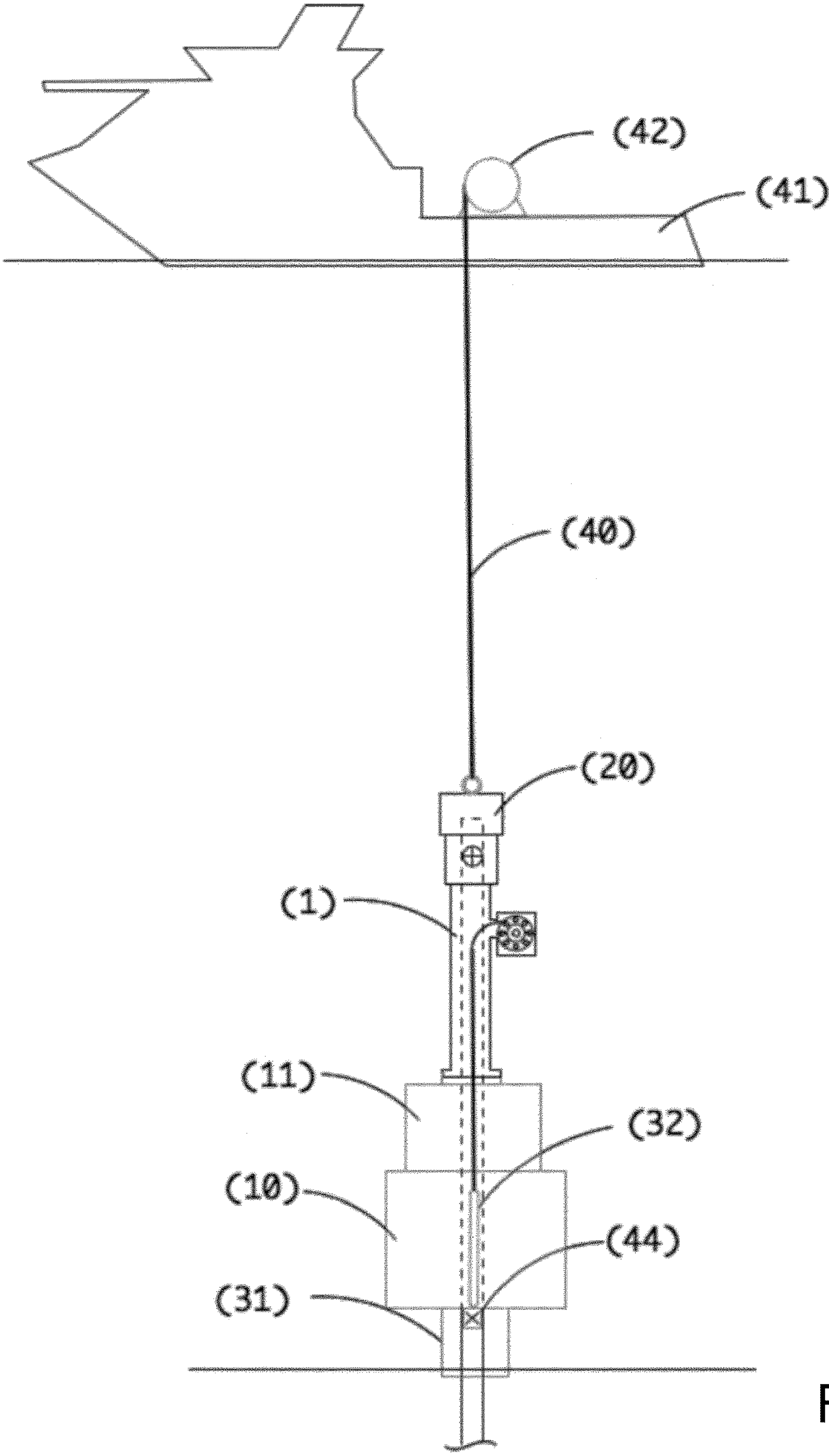


Fig. 6

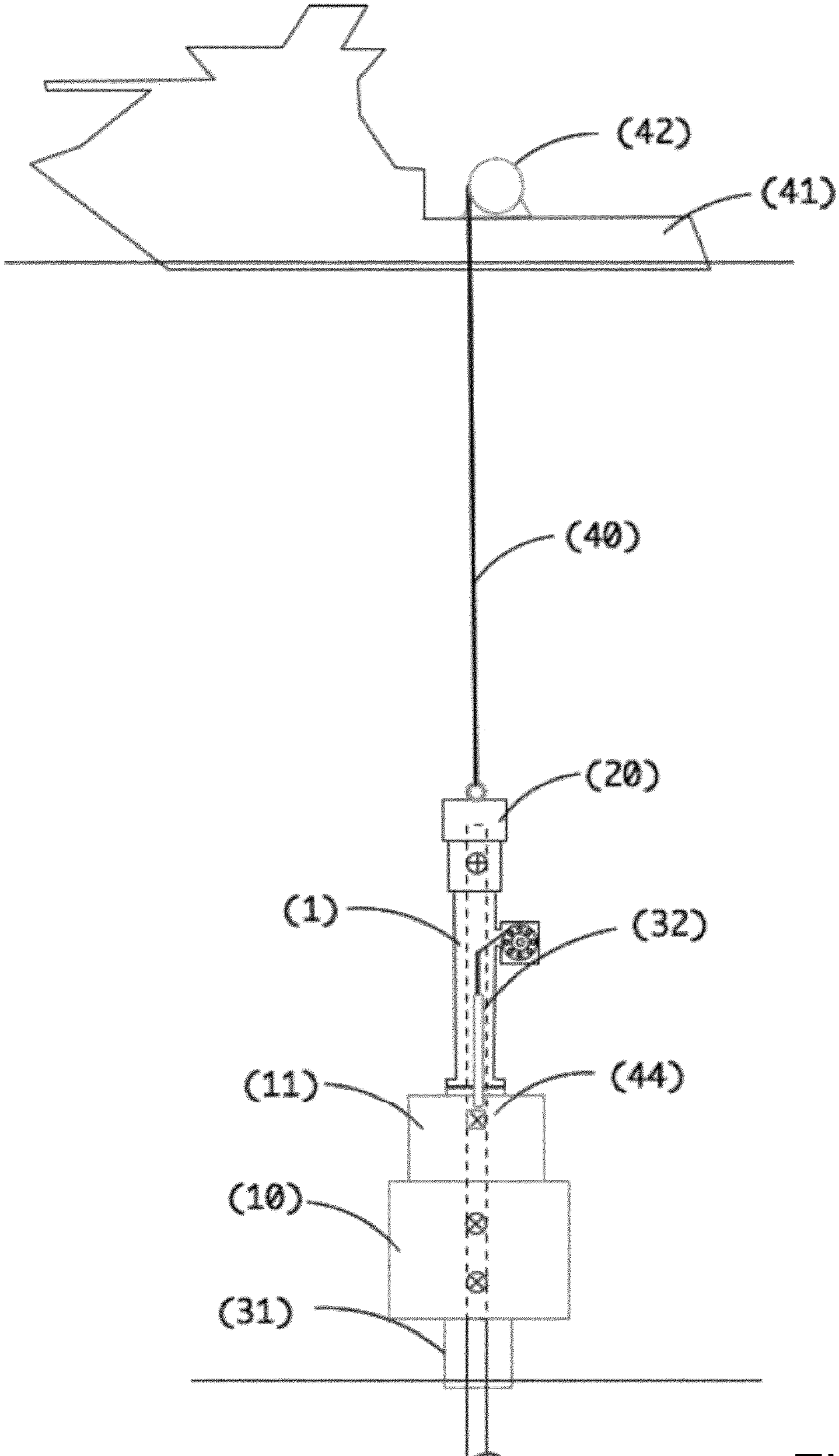


Fig. 7

FLUSHING A TOOL FOR CLOSED WELL OPERATION AND AN ASSOCIATED METHOD

The invention relates to a fluid circulation system for use in a tool that makes mechanical and/or pump operations possible in subsea wells or wellheads, without the use of wire or coiled tubing up to the rig, ship or platform. In particular, the present invention relates to flushing of an enclosed cavity which may contain a well tool arranged in a well liquid environment, without the well barriers for well control being penetrated or containing fluid inflow to the operation vessel, so that flushing is performed without exposure or return of hydrocarbons to the vessel. It is also vital that the invention avoids high pressure well liquid, such as hydrocarbons, back to the operation vessel, so that a more plain ship can be used for the desired well operation.

BACKGROUND OF THE INVENTION

The background of the invention is the need in the petroleum industry for cost reducing subsea operation with an equal or higher level of safety, compared to the present practice. It is commonly known that developing and operating a subsea field that typically has multiple wells with associated Xmas trees requires a large investment both in equipment and operational costs. A large portion of the cost for such a development stems from the drilling, completion, startup and service of the wells. Traditionally the industry has used large drilling rigs with appurtenant drilling system for drilling towards a reservoir, and then installing a subsea wellhead and well casings. When these have been installed, an Xmas tree (well head module) is landed on the wellhead in order to control the production after starting up. It has been common to also install the Xmas tree from the drilling rig. Starting up the well is typically performed with so-called workover systems (service systems) which are connected to the Xmas tree and which provide a mechanical access from the drilling rig to the subsea well and reservoir. It will be possible to run an internal work tool on a steel wire (wireline operation) or a small work pipe (coiled tubing—typically a 2" pipe) down into the well, by means of a workover system, in order to pull plugs and to open to reservoirs for production. Such a workover system can also be used for service in the well and for control or optimization of the production throughout the lifetime of the well. Common for such operations and systems is that they involve large costs to manufacture, operate and maintain.

Accordingly there exists a demand for solutions that are useful for installation and testing of subsea Xmas trees, as well as well service, without the use of a drilling rig. This technology or equipment shall therefore make it possible to move such operations to lighter vessels or ships which are not necessarily required to handle hydrocarbons up to the vessel deck. It will also be advantageous to let the drilling rig perform the operation for which it is optimized, namely to drill the well and to install casings and tubing. This will result in a more efficient use of the drilling rig, since it then does not need to shift between the types of risers which are in use. The logistic aboard the rig will also become easier if the Xmas tree is not taken aboard, since this requires both space and handling of large weights (typically 30-50 tons). The heavy weight and the size of a workover system is also significant, as such a system includes many containers on deck, as well as large reels with umbilicals.

It will be desirable to introduce new technology which reduces the operational costs, has less weight and size, and

does not expose personnel to equipment exposed to well pressure. This will provide reduced requirements to the lifting and handling equipment on the vessel, as well as improved HSE. A main reason for the large weight of drilling and workover systems is the requirement of cutting the drilling or work string that penetrates the barrier envelopes if needed. An example of this will be at loss of well control, where the main safety valves must be activated to shut in or isolate the well from the environment. Such safety valves are typically known as elements in a blowout preventer (BOP) or a lower riser package (LRP). The weight of a BOP can typically be from 200 tons to 500 tons, while an LRP typically has a weight of 30 tons to 50 tons. An object of the present invention is to flush a main bore in an installation and intervention tool where the barrier envelopes are not penetrated, so that the requirement of cutting functionality can be avoided. This will again result in significantly lighter equipment for maintaining well control. Another desirable object is to avoid well exposure directly up to the vessel. This also includes avoiding potential direct or indirect leakage paths through attached hoses and pipes (umbilicals). It is essential that the tool does not contain pressurized hydrocarbons when it is placed on the vessel, before or after the well operation, so that less requirements are raised for such handling aboard.

Alternative systems for flushing have been suggested, and the nearest known art is described in the patent publications NO330819, NO309439, WO2011/039514, and US2011/0192610. Common for these solutions is that they will potentially expose the operation vessel to hydrocarbons—either directly by carrying along filled tanks or indirectly via leakages through attached umbilicals or pipes. Their use also requires that the suggested systems operate together with a well control package (lower riser package/well control package), as the known art discusses use in association with a subsea lubricator where a tool string (wire) penetrates through a pressure control head (pack box and grease injector head). This implies the inclusion of a closing and cutting valve on the lower side of the pressure control head as a result of the penetration.

The object of the invention is to make a closed well operation possible. With closed well operation is meant activities down in a subsea well without the use of cable or coiled tubing that penetrates well barriers, or use of riser from well to vessel.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, a tool assembly is provided which is a closed operation subsea well tool assembly. The tool assembly has a flushing system configured for flushing of a first fluid in the main bore of the tool assembly. The flushing system of the tool assembly comprises a container that contains a second fluid and a pump that is connected to the container. The tool assembly also comprises an upper swab valve in the top of the tool assembly with full mechanical access to the main bore in the open position, or an end cap. Further, the tool assembly comprises an inlet in the bottom of the main bore of the tool assembly, which is connected to the pump, one or more outlets below the swab valve in the top of the main bore of the tool assembly, which are configured to release the first fluid from the main bore of the tool assembly, and a fluid channel that extends from the outlet and down to channels of the wellhead module or the wellhead.

The closed operation subsea well tool assembly according to the invention is for closed operation of subsea wells or associated well modules.

With the use of term closed operation is meant that the tool assembly is employed without penetration of well barriers and associated cutting functions. That is, the operation is performed without crossing any well barriers.

The tool assembly can advantageously be operated on a wire from a surface vessel.

In an embodiment of the tool assembly, the second fluid contained in the container is a hydrate inhibiting agent, and/or the container is pressure-compensated with respect to the environment.

The pump can in some embodiments be supplied with power and operated from an ROV or a separate electric umbilical from the operation vessel.

Advantageously, the inlet in the bottom of the main bore of the tool assembly is supplied with one or more isolation valves, check valves or a combination of such.

Also, the outlet or the outlets in the top of the main bore of the tool assembly can be provided with one or more isolation valves, check valves or a combination of such.

The fluid channel from the outlet and down to the channels of the wellhead module can in some embodiments be significantly smaller than the main bore of the tool assembly, so that the velocity of the flowing liquid is higher than the rising rate of gas bubbles.

The fluid channel from the outlet can advantageously be provided with one or more isolation valves, check valves or a combination of such.

The pump, with fluid supply from the container with the second fluid, can in some embodiments be configured for pressure testing of well barrier elements within the tool assembly, wellhead module or the wellhead.

According to a second aspect of the present invention, a method is provided for using the tool assembly when installing a wellhead module, such as a Xmas tree. The method comprises the following steps:

- with the tool assembly, lowering a wellhead module on wire from a drilling rig or a ship;
- landing the wellhead module on the wellhead, and testing function and barrier;
- by means of the tool assembly, pulling or opening a pre-installed barrier element in the top of the wellhead so that possible well fluid can rise up into the main bore of the wellhead module and the tool assembly;
- closing and testing valves of the wellhead module from the tool assembly;
- flushing out the well liquid in the main bore of the tool assembly by means of the flushing system;
- disconnecting the tool assembly from the wellhead module and pulling it back to the drilling rig or ship.

According to a third aspect of the present invention, a method is provided for using the tool assembly when pulling a wellhead module, such as a Xmas tree. The method is characterized by the following steps:

- installing the tool assembly containing a flushing system for flushing out a first fluid in the main bore of the tool assembly on wire from a drilling rig or a ship;
- landing the tool assembly on the wellhead module, and testing function and barrier;
- setting a barrier element in the top of the wellhead and pressure testing it by means of the pump of the tool assembly and a container;
- closing the valves of the main bore of the wellhead module;

- flushing out the well liquid in the main bore of the tool assembly by means of the flushing system;
- disconnecting the wellhead module from the wellhead and pulling it back on wire to the drilling rig or ship.

A well control package which comprises cutting and sealing elements in its main bores will thus be excessive, since the pressurized hydrocarbons of the well already are enclosed and isolated from the environment with the tool, wellhead module, and possible deeper deployed plugs/valves in the well. The starting point after an ended drilling operation will always be a well which is isolated with two barrier envelopes that means that the reservoir must overcome at least two sealing elements in all directions towards the environment. This is normally referred to as the primary and secondary barrier, where the primary barrier is all the closest sealing elements towards well pressure, while the secondary barrier is an envelope of all the next external sealing elements. It is further divided between vertical and horizontal completion of the well, for start of production. Vertical completion will involve a vertical Xmas tree (VXT) where the production tubing is hung off in the wellhead before installation of the VXT. Horizontal completion will on the other hand involve a horizontal Xmas tree (HXT), where the production tubing is hung off in the HXT itself. This results in that the HXT must be installed on the wellhead before the tubing is run. Both types of completion will involve operation and systematic movement of controlled barrier elements in such a way that the well and the reservoir can start production without releasing hydrocarbons to the environment. This applies to the entire life of a well, from drilling operations, completion and production start, to production, service (intervention) and finally permanent shutdown (so-called plug and abandonment—P & A).

As described above, a vertical completion with a VXT will result in that the well is isolated with two barriers before the VXT itself is installed. This can for instance be performed with mechanical plugs or valves within the tubing. The said tool can for instance be used for installation of a VXT with a following operation or pulling of a plug which is arranged high up in the tubing. It will not be unexpected that there may exist pressurized well fluid (hydrocarbons) below the plug, so that this may come up through the VXT and further up in the main bore of the tool. A disconnection of the tool from the wellhead module can hence result in that this fluid (gas or liquid) will be released to the environment, unless this is removed before disconnection.

BRIEF DESCRIPTION OF THE DRAWINGS

While various features of the present invention have been discussed above in general terms, a more detailed and non-limiting example of an embodiment will be provided in the following description, with reference to the drawings, in which:

FIG. **1** is a schematic view of an embodiment of the invention;

FIG. **2** is a schematic view of a tool being used subsea;

FIG. **3** depicts the tool in use (left drawing) and an alternative operation (right drawing);

FIG. **4** is a schematic view of a well module being run from a surface vessel;

FIG. **5** is a schematic view corresponding to FIG. **4**, illustrating the well module having landed onto a subsea wellhead;

FIG. **6** illustrates a well tool in a well, employed for pulling a plug; and

FIG. **7** illustrates the tool in FIG. **6**, having pulled a plug.

DETAILED DESCRIPTION

FIG. **1** is a principle sketch of the invention, where the purpose is to flush out potential hydrocarbons in the main bore (**15**) of the tool (**1**). The figure shows a VXT (**10**), which typically comprises valves in the production bore and the annulus/service bore for control of the first annulus (A-annulus) of the well. A mechanical adapter (**11**) is shown which normally is used for adaptation of the tool to various connection geometries for different XTs but is mainly an extension of the vertical main bore and annulus to the XT. The flushing is based on the tool having with it a reservoir (**19**) which contains typically a hydrate inhibiting agent, such as mono-ethylene glycol (MEG), methanol or appropriate mixtures with water. The reservoir is moreover pressure compensated with respect to the environment pressure, which is the hydrostatic liquid column of the seawater depth. A known membrane can advantageously be used in this context. The liquid in the reservoir is then pumped into the main bore (**15**) with a local pump unit (**2**) through an inlet (**3**). The inlet will be equipped with valves (**4**) that can be isolation valves or check valves that prevent backflow from the main bore towards the pump and the reservoir. It is also not uncommon that the pump may be equipped with such check valves. The pump can be run with electric or hydraulic supply (**17**) from an ROV which is connected via a so-called "hotstab" (**13**). The hotstab normally has a plurality of separate hydraulic lines where one can supply the reservoir via a separate channel (**16**) as needed. The hotstab can also provide direct hydrate-inhibiting liquid to the main bore of the tool with a dedicated line (**18**) if the pump (**2**) or reservoir (**19**) should lose their function. In normal operation the liquid will come from the pump and the reservoir and displace the volume in the main bore (**15**) so that the pressure in the main bore will rise unless one or more outlets (**5***a* and **6***a*) are provided. Hence, the tool has an outlet line (**7**) which guides the pumped liquid from the main bore down into the channels of the wellhead module or the wellhead. The outlets can also be provided with isolation valves (**5**, **6** and **8**) or check valves, so that the flushed fluid can be controlled, i.e. to avoid the return of hydrocarbons from the well or wellhead module. After the pump operation has ended, the main bore of the tool will be filled with environmentally friendly fluid which can be released to the environment when disconnection of the tool and wellhead module takes place. There will not be a requirement for the vessel to handle hydrocarbons since these are pumped back to the well.

The tool as shown in FIG. **1** is used in a closed well operation which occurs through a side outlet (**9**), where for instance a pressurized winch can operate an internal well tool for pulling a plug (not shown in FIG. **1**). If this primary method should fail unexpectedly, a traditional intervention system can be connected on the top of the tool, once a pressure cap of the tool is lifted off, and the method can commence once an internal valve (**21**) is opened for access to the main bore (**15**).

The said pump (**2**) can, in addition to its primary function of flushing the main bore, be used for pressure testing of desired barrier elements such as valves and seals in the tool, the wellhead module, the wellhead, well or any connected units. The figure shows a line (**12**) for pressure testing of the seal element between adapter (**11**) and wellhead module (**10**), but the pressure can also come via the inlet (**3**) to the main bore.

The invention, as placed into a larger system as shown in FIG. **2**, will make flushing of a closed well operation through a Xmas tree (XT) possible. A typical subsea well will be constructed with a wellhead (**31**) and a production tubing (**30**). On top of the wellhead (**31**) there may be arranged a well module or a Xmas tree (**10**). Furthermore, an adapter (**11**) for connection to the well module (**10**) can be used. The adapter (**11**) can comprise one or more valves for guiding in well tools, but the main valves for guiding in will normally be arranged in the well module (**10**). The adapter (**11**) can also comprise functions for control of the well module (**10**). These functions may be subsea pumps, a reservoir for control liquid, and control valves for control of valves on the well module (**10**). It will now be possible to lower a well tool (**32**), with for instance a winch (**34**), down into the well through an inlet (**9**) for well operation. FIG. **2** shows that a workover system (**37**) with a riser (**38**) can be connected to a connection point (**20**) on the tool (**1**) for independent, alternative operations. This will make possible the performance of an auxiliary operation if the primary, ongoing operation should fail. Valve (**35**) can be opened for access to the main bore (**15**) in the tool (**1**), the well module (**10**), and the well.

FIG. **3** depicts the invention put into operation. The invention can be performed from a boat (**41**), and the tool (**1**) can be lowered with a crane (**42**) down onto the well module using a wire (**40**).

For alternative operations, a rig (**43**) can be used with a riser (**38**) and a traditional workover system (**37**).

Operational Method:

A method for closed well operation with the tool (**1**) of the present invention is shown in FIGS. **4**, **5**, **6**, and **7**. The tool (**1**) with the well module adapter (**11**) and the well module/Xmas tree (**10**) is lowered down from a vessel (**41**), with the well tool (**32**) arranged in the main bore (**15**) of the tool, as shown in FIG. **4**. Orientation during installation can advantageously be performed with ROV assistance. FIG. **5** it is shown that shows the tool (**1**), the adapter (**11**) and the well module (**10**) landed on well head (**31**). When the tool is connected to the well module, the seals and valves in the well module (**10**) are tested against the wellhead (**31**). Thereafter the well tool (**32**) is lubricated in towards the valves in the well module by balancing the pressure over the valves in the well module. FIG. **6** depicts the valves in the well module (**10**) being open and the well tool (**32**) pulling possible plugs (**44**) arranged in the wellhead (**31**) or deeper in the production tubing (**30**). These are pulled back as shown in FIG. **7**, where succeeding closure of the valves in the wellhead module main bore takes place. It is in this situation that hydrocarbons can be present in the main bore (**15**) of the tool. If so, the hydrocarbons can be flushed out of the main bore (**15**) as described above.

The invention claimed is:

1. A closed operation subsea well tool assembly for use in performing closed operations on a subsea well or on a wellhead module or a wellhead which is installed on the subsea well, the tool assembly being connectable to the wellhead module or the wellhead and comprising:

- a main bore which extends axially through the tool assembly;
- a flushing system which is configured to flush a first fluid from the main bore, the flushing system comprising:
  - a container which contains a second fluid;
  - a pump which is connected to the container;

at least one of an end cap and a first valve which is located at a top of the main bore, the first valve being configured to provide full mechanical access to the main bore in an open position;

an inlet which is connected to a bottom of the main bore, the pump being connected to the inlet;

at least one outlet which is connected to the top of the main bore below the at least one of the end cap and the first valve; and

a fluid channel having a first end which is connected to the at least one outlet and a second end which is connectable to a channel which is located in the wellhead module or in the wellhead;

wherein in operation of the flushing system, the pump is activated to pump the second fluid through the inlet and into the main bore to thereby displace the first fluid through the outlet and the fluid channel and into the channel located in the wellhead module or in the wellhead.

2. The tool assembly according to claim **1**, wherein the tool assembly is configured to be operated on a wire from a surface vessel.

3. The tool assembly according to claim **1**, wherein the second fluid is a hydrate inhibiting agent.

4. The tool assembly according to claim **1**, wherein the pump is supplied with power and operated from an ROV or an electric umbilical from a surface vessel.

5. The tool assembly according to claim **1**, wherein the inlet is provided with one or more valves.

6. The tool assembly according to claim **1**, wherein the outlet is provided with one or more valves.

7. The tool assembly according to claim **1**, wherein the fluid channel comprises a diameter which is significantly smaller than a diameter of the main bore.

8. The tool assembly according to claim **1**, wherein the pump is configured for pressure testing of well barrier elements within the tool assembly or the wellhead module or the wellhead to which the tool assembly is connected.

9. A method of using the tool assembly of claim **1** for installing a wellhead module on a wellhead, comprising:

with the tool assembly, lowering a wellhead module on a wire from a drilling rig or a ship;

landing the wellhead module on the wellhead;

using the tool assembly, pulling or opening a pre-installed barrier element in the top of the wellhead to thereby enable well fluid to rise up into the main bore;

using the tool assembly, closing and testing valves of the wellhead module;

using the tool assembly, flushing the well fluid from the main bore;

disconnecting the tool assembly from the wellhead module and retrieving the tool assembly to the drilling rig or ship.

10. A method of using the tool assembly of claim **1** for pulling a wellhead module which is connected to a wellhead, the method comprising:

installing the tool on a wire from a drilling rig or a ship;

landing the tool assembly on the wellhead module;

setting a barrier element in the wellhead and pressure testing the barrier element using the pump and a fluid from the container;

closing the valves of the main bore of the wellhead module;

flushing well fluid from the main bore;

disconnecting the wellhead module from the wellhead and retrieving the wellhead module to the drilling rig or ship on the wire.

11. The tool assembly according to claim **1**, wherein the container is pressure compensated.

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