

CONTROL SYSTEM

Field of the Invention

5 The present invention regards a method and device for relieving a pressure within a first cavity to a second cavity in a subsea facility.

Background of the Invention

10 There are several wireline and well control functions that require occasional pressure testing and/or pressure build-up monitoring to assure that barriers and seals are functioning properly during installation and workover operations. Typically this involves a test line conduit that can either supply pressurized fluids to the testing location or allow the venting and removal of fluids for leak detection. However, operations associated with light well intervention (RLWI) often adopt a philosophy
15 of "no hydrocarbons to surface". In other words, the conduit between the test location and the pressure/ monitor source is no longer there because of the possibility of wellbore fluids (hydrocarbons) travelling through the conduit to the pressure/monitor source on the vessel in proximity to personnel. If the conduit is present, more safety measures and higher vessel certification are required in order
20 to properly handle and dispose of hydrocarbons should they become present. All of this in turn increases the day rate (charges per day) which would otherwise make RLWI less economical.

25 The proposed invention provides a means to create a differential pressure and redirect hydrocarbons back into the well; providing for both the pressure test mission and preventing hydrocarbons from escaping.

Summary of the invention

30 The present invention relates to a method for moving a fluid from a first cavity with a lower pressure, for instance an annulus, to a second cavity with a higher pressure, for instance a flow line, in a subsea facility. According to the invention a fluid within the first cavity is allowed to flow through a first line to a transfer accumulator which fluid then is pressurized by a piston arrangement within the
35 transfer accumulator and then transferred from the transfer accumulator into the second cavity. This process may either be used for building pressure within a cavity with a fluid from a cavity with a lower pressure than the pressure one desire in the cavity or to release a fluid from a cavity with a fluid at a lower pressure to a fluid with a higher pressure.

According to the first aspect of the present invention, there is provided a method for pressure testing by reducing a pressure within a first cavity associated with a subsea wellhead structure by moving fluid from said first cavity having a first pressure, to a second cavity having a second pressure, where the second pressure is higher than the first pressure, wherein it comprises the steps of actuating a piston in a transfer accumulator to draw fluid from the first cavity through a first line, then pressurizing the fluid within the transfer accumulator using said piston, and discharging the fluid from said transfer accumulator into the second cavity.

According to the second aspect of the present invention, there is provided an apparatus for testing a seal in a subsea wellhead structure, the seal being located adjacent a cavity associated with the subsea wellhead structure, whereby the testing is carried out by reducing the pressure in said cavity, wherein the apparatus comprises a transfer accumulator connected via a first fluid line, comprising a one-way valve with said cavity, and connected via a second fluid line comprising a second one-way valve with a flowline, where the transfer accumulator comprises an actuated piston arrangement for pressurizing the fluid within the transfer accumulator independent of the pressures in the cavity and the flowline.

The benefit of the invention is that it complements and improves pressure testing safety associated with the "no hydrocarbons to surface" philosophy used elsewhere (such as the lubricator circulation patent WO0125593).

- 5 The invention makes it possible to flush all kinds of fluids, such as hydrocarbons, hydrate inhibitors (MEG) and seawater.

10 It also makes it possible to bleed off parts of the system having pressure lower than the well pressure or flowline pressure, such as the annulus. By using the invention, annulus pressure can be bled to the flowline.

The items that can be tested may include, but not restricted to, a downhole safety valve, crown plug, rams in the LRP, isolation valves and production valves, the pressure control head (PCH) and grease injection unit.

- 15 With the present invention it will be possible to reduce the pressure at a location in the subsea system. The ability to reduce the pressure achieves two purposes. On the one hand it will enable a testing of the integrity of seals so that it can be ascertained they are working properly. On the other hand it will enable hydrates accumulated
20 into a cavity to be "boiled" off. The formation of hydrates is very dependent upon the pressure and temperature. A lowering of the temperature, as for instance when hydrocarbons come into contact with the cooler surrounding sea water will lead to hydrate formation at a set pressure. Lowering the pressure and/or increasing the temperature allow the hydrates to melt and convert back to hydrocarbon gas. The
25 formation of hydrates may block off a cavity or a pipe and, at a remote seabed location, there can be considerably difficulties in removing this hydrate plug.

Brief description of the Drawings

- 30 The invention will now be described with reference to the accompanying drawing where
Fig. 1 is a sketch of an intervention system on a subsea well,
Fig. 2 is a diagram showing a first embodiment of the invention,
Fig. 3 is a sketch showing a detail of a second embodiment of the invention,
35 Fig. 4 is a diagram of a chemical injection unit according to the invention, and
Figs. 5 – 8 are diagrams showing the different modes of operation.

Description of the preferred Embodiments

- 40 Fig. 1 is an exemplary schematic drawing showing a RLWI system where the invention might find use. This is only an example and it should be obvious that the invention might find use with any subsea system where such functions are desirable.

- Fig. 1 shows a subsea lubricator stack for an intervention system attached to a subsea well 5 equipped with a Christmas tree 4 and a flowline/umbilical 6 extending to a process facility (not shown). A subsea lubricator stack includes a pressure control device such as a Lower Riser Package (LRP) 11, a lubricator (pipe) 12 and the pressure control head (PCH) 13. The system has a control unit 15 for the control of the various processes during the operation. A special intervention umbilical 17 may be attached to the control unit 15 and extending to a remote control station (not shown). However, the invention also contemplates a completely autonomous system, with the necessary signal and power requirements being met by using the production umbilical. Finally, a line 23 extends from the control unit 15 to a PCH control unit 21. The line 23 may carry electrical and/or optical signals and hydraulic lines for fluid communication between the control unit and devices in the PCH 13.
- The lubricator is used to insert tools into the well as is well known in the art. The present invention will preferably be made as part of the control unit 15 for the intervention system but may also be provided as a separate module located in the vicinity of the well.
- Fig. 2 shows a diagram of the principle for reducing the pressure of a cavity. The cavity may be in the Christmas tree, for example crown plug cavity, in the LRP or even in the PCH. A transfer accumulator 30 comprises a piston 32 that divides the accumulator into two chambers 31 and 33. In a first embodiment of the invention the piston is via a rod 25 connected to an electric motor 24 such that the motor can move the piston in the accumulator 30. The chamber 31 may be open to the surrounding sea water while chamber 33 has a first fluid connection with the flowline 6 by line 38. A one-way valve 42 and an actuated valve 43 are incorporated into line 38. There is also a sensor 41 comprising a pressure and temperature transmitter.
- The chamber 33 has a second fluid connection with a cavity 40 by line 39. A one-way valve 45 and an actuated valve 46 are incorporated in line 39.
- In fig. 3 there is shown an alternate embodiment of the actuation of the piston in the transfer accumulator. A first cylinder 110 comprises a movable piston 112 that divides the cylinder into two chambers 114 and 115. A second cylinder 120 likewise comprises a movable piston 122 that divides the cylinder into two chambers 124 and 125. A rod 118 connects the two pistons with each other so that they will move in tandem. The chamber 124 of the second cylinder is via line 126 connected to a control valve 130. The other chamber 125 is likewise via line 127 connected to the control valve 130. On the other side of the control valve a line 128 connects to the outlet of a pump 132. The pump inlet is via line 136 connected to an accumulator

134. Another line 129 is connected between the control valve 130 and directly to the accumulator 134. The function of line 129 is a return line while line 128 is the supply line.

- 5 With the control valve 130 in the position shown in Fig. 3, starting the pump will pump hydraulic fluid into chamber 124, forcing piston 122 to move downwards. Fluid in chamber 125 empties via lines 127 and 129 back to the accumulator 134. To move piston 122 upwards the control valve is switched to its second position.
- 10 Cylinder 120 can be regarded as a master cylinder and cylinder 110 a slave cylinder. The area of pistons 122 and 112 may be different. For example, it may be advantageous to make the area of piston 112 smaller to minimize the "dead" volume in chamber 115.
- 15 It should be noted that chambers 33 and 115 are connected with pipes or voids that may contain gas. Since gas is a compressible medium it is difficult to use a pump to operate directly in a gas environment for pressurizing or evacuation. The arrangement will, as stated above, also make it possible to have different areas of the pistons. This feature enables the unit to be easily adapted to different
- 20 circumstances, e.g. different gas fractions.

Referring again to Fig. 2 the function of the device will now be described. When piston 32 is moved upwards this will reduce the pressure in cavity 40. One-way valve 42 will prevent fluid to be drawn up from the flowline 6. When the movement

25 of the piston 32 is reversed it will increase the pressure in line 38, thereby moving the fluid in chamber 33 into the flowline 6. The one-way valve 45 will stop fluid moving into line 39. The piston is cycled as many times as necessary, to reach the desired pressure in cavity 40. The pressure sensor 41 records the pressure reached in each cycle.

30 This arrangement enables pressure to be reduced to a lower level than the ambient pressure. The only limitation for how far down pressure can be reduced is the "dead volume" in the accumulator.

35 If the cavity 40 is behind a seal to be tested for integrity the pressure is reduced to a level where the pressure difference across the seal will be large enough to verify that the seal functions normally.

40 If the cavity 40 for some reason has been clogged up with a hydrate plug, reducing pressure will enable the hydrate to "boil" off, thereby removing the plug. The pressure is continuously recorded. When the pressure has reached a level where the hydrate plug starts to disintegrate the pressure will stay at the same level while

there still are hydrates in the system. That is because as hydrate "ice" turns into gas it will expand and fill the volume in the cavity 40. When the pressure sensor again records a falling pressure, this is a sign that the hydrate plug has been completely dissolved.

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As shown in Fig. 1 the control unit 15 with the unit may be connected to all parts of the intervention system, such as the Christmas tree 4, the LRP 11 or, via line 23 the PCH 13. This enables all parts of the system to be tested or, alternatively, hydrate plugs removed. The items that can be tested may include, but not restricted to, a
10 downhole safety valve, crown plug, rams in the LRP, isolation valves and production valves, the pressure control head (PCH) and grease injection unit.

In an alternative embodiment the pressure reducer is combined with a chemical injection system into a compact unit. In fig. 4 there is shown a diagram of a
15 Chemical Injection and Barrier Test Unit (CIBTU) according to the invention.

As previously described the unit is operatively connected to all parts of the subsea intervention system. In addition to the connection to the flowline 6 and a cavity 40, the unit has a separate connection line 57 to the well control package (WCP) and to
20 one or more external lines or equipment, represented by lines 71 and 72, as indicated in fig 4. These are connected with the module using an interface 70 that is attached to the unit by way of a multiple quick connector (MQC). This enables fluids from an external source, for example from the umbilical 17, to be introduced into the system. The connection also includes lines for signal and electrical power
25 (not shown). The operative parts of the system (actuators, motors) have connections to a source of power that is not shown but is well known in the art. This may be hydraulic or electrical power, the connections omitted from the diagram for clarity.

The unit comprises a first fluid line 14 extending between the MQC interface 70 and
30 the inlet of a liquid pump 20 driven by an electric motor 22. The pump is preferably a high capacity, 690 bar electric driven circulation pump. The pump should have a capacity of $3.6\text{m}^3/\text{h}$ at 500bar – to be verified during detail design. The pump 20 is preferably connected directly (not shown) to a topside variable speed drive (VSD) for speed control via 3.3 kV umbilical conductors (typical 100kW available electric
35 power) supplied through umbilical 10.

A line 28 extends between the pump 20 outlet and the first chamber 31 of transfer accumulator 30. A one-way valve 34 and an operated valve 36 is included in line
40 28. The transfer piston accumulator is capable of 690 bar delta pressure in both directions for bleed down of downstream pressure. As explained with reference to Fig. 2 the chamber 33 of the transfer accumulator is connected to the well fluid system

5 A line 52 extends from the interface 70 to connect with the cavity line 39. Line 52 includes an operated valve 53. A first cross line 54 connects line 52 with the output side of pump 68. Line 54 includes one-way valve 65 and operated valve 66. The inlet side of pump 68 is via line 23 connected to line 14. A second cross line 56 connects line 52 with line 28 at a point between the one-way valve 34 and valve 36. Line 56 includes an operated valve 67. Finally a third cross line 58 connects line 23 with line 56. A pressure reducer 62 and an operated valve 63 is provided in line 58.

10 The unit can be connected with the well control package (WCP) for injection of chemicals into the well or well intervention system via line 57 that is connected to line 52. It includes a one-way valve 59. A line 64 is also connected with line 52. Line 64 terminates in an ROV hot stab for connecting a jumper to the unit, using an ROV. This enables chemical injection into other parts of the well system that is not
15 reached by the standard connections.

A first bladder tank 2, with a volume of for instance 4m^3 is via interface 70 connected to line 14. In the preferred embodiment the tank is a separate retrievable unit so that, when empty, it can be exchanged for a new full tank. The tank normally
20 contains a hydrate inhibitor such as methanol or MEG.

A second bladder tank 3, normally smaller than the first bladder tank 2, for instance with a volume of 1m^3 , is via interface 70 connected to fluid line 23 before the inlet of pump 68. This bladder tank contains other chemical fluids that may be
25 needed during the operation. This enables chemical injection during the period when the wireline tool string is retrieved to surface. There may of course be more tanks with different chemical fluids as deemed necessary. There may for example be provided a "bank" of containers that can be switched at will. Another alternative is to have at least the smaller tank located within the unit, as shown on Figs 5-8.

30 The bladder tank on the LRP will always be filled up from the tank on lubricator tube due to higher specific gravity of chemical and the tank adjacent to a lubricator tube located above the LRP.

35 An ROV hot-stab 19 is provided for topping up the bladder tank 3. The supply may be via separate hose from the surface (through umbilical 10) or from an additional retrievable bladder tank located subsea and operated by the ROV. ($\frac{1}{2}$ " - $\frac{3}{4}$ ") 10k chemical hose with ROV hot-stab for direct injection or for topping up the bladder tank, provided on separate reel for deployment when needed. Capacity shall be
40 sufficient to circulate the lubricator volume.

Pressure and temperature sensors are provided throughout the unit as necessary. One, designated 18, is provided in the line 14.

5 The second low capacity chemical electric driven injection pump 68 is in the shown example a 690 bar rated pump for continuous injection of up to 300 l/h. Pump control shall allow for regulated injection rates down to 5% of full capacity.

10 Flow meters may be positioned at various points in the system to verify correct chemical injection rates.

The main components added to the chemical Injection Unit to enable the barrier test functionality are: Topside chemical tanks and topside chemical injection pumps for topping up subsea bladder tanks via chemical hose. Improved instrumentation and carefully selected injection points may reduce chemical consumption significantly.

15 According to a first aspect of the invention shown in Fig. 3 the unit may be used for chemical circulation of the lubricator 12. It will from time to time be necessary to circulate out of water and/or well fluids from the lubricator to avoid hydrate formation or release of hydrocarbons to the environment. In such cases a relatively large amount of chemical is needed and will therefore be drawn from bladder tank 2. Valves 36, 53, 63 and 66 are closed and valve 67 is opened. The chemical fluid from the bladder tank 2 is pumped (using high capacity pump 20) through line 14, 56 and 57 into the lubricator.

25 According to another aspect of the invention shown in Fig. 4 there is provided for continuous chemical injection into the lubricator system or into the well system. The fluid may be a treatment fluid, scale inhibitor or grease to the PCH. The chemical is preferably drawn from bladder tank 3 but in case of larger amounts, a tank 2 with another chemical fluid may be substituted as desired. In this case valves 30 36, 63 and 67 are closed while valve 66 is opened. When pump 20 is started fluid will flow from bladder tank 3 (or 2, as the case may be) into the well system. By manipulating the various lines the chemical fluid may be supplied to the PCH (through line 64), the WCP (through line 57) or the cavity 40 /through line 39 and opening valve 53).

35 The principles for chemical circulation (low flow rates) and chemical injection (high flow rates) are illustrated in Figs. 3 and 4 respectively.

40 According to a third aspect of the invention the unit will be used for pressure testing.

The unit will be used for main barrier and seal tests. The tests will be performed in the flow direction and would be able to test all parts of the system. The parts that

cannot be reached directly may be reached by providing a jumper from the part to the connect up with line 64.

5 The principles for reducing the pressure for barrier seal tests and barrier tests are illustrated in Figs. 7 and 8. As described with reference to Fig. 2 the object is to reduce the pressure in cavity 40 to enable a pressure differential to be created. The arrangement allows differential pressure test of barrier valves and plugs without bleeding off well fluids at the downstream pressure side to surface.

10 The pump 20 is started to push the piston 32 to its lower position. Valves 53, 66 and 67 are closed. Then the pump 20 is stopped and valve 53 opened. Because bladder tank 2 is at ambient pressure and cavity 40 is at a (higher) well pressure the higher pressure in cavity 40 will push the piston 32 upwards and emptying the fluid in chamber 31 to the tank 2. This cycle is repeated until the pressure in cavity 40 has
15 reached ambient pressure. There is now a pressure differential between well pressure and the ambient pressure in the cavity. This enables the testing of the seal.

20 The circulation pump 20 may therefore indirectly be used to pump fluid from the downstream cavity and inject the fluid to a pressurized flowline, as described with relation to Fig. 2. Reciprocating action is controlled by sequentially running pump and open/close chemical bleed back valve. Each stroke will have a significant swept volume and the "dead volume" will be minimal. The circuit will therefore function even with gas. The two strokes in the pumping action are illustrated in Figs 7 and 8.

25 The system may also be used to inject hydrate inhibiting fluid into the flowline 6 if necessary. In this case valve 36 is closed and valves 67, 53 and 46 are opened. Chemical fluid from tank 2 may now be pumped through lines 14, 56, 52, 39 and 38 into the flowline.

30 Seal test

Seal test functions shall be provided for verification of correctly mated subsea process connections. This function shall be operated by the mini subsea control modules by trapping high pressure hydraulic fluid or chemical and to monitor pressure decay via subsea pressure transmitter. As above valve 36 is closed but in
35 this case valve 46 is also closed. Fluid can now be pumped through lines 14, 56 and 52 into cavity 40. After the desired pressure has been reached the pump 20 is stopped and the pressure decay monitored.

40 The present invention has now been explained with non-limiting embodiments and a skilled person will understand that there may be made alterations and modifications to these embodiments within the scope of the invention as defined in the claims.

CLAIMS

1. Method for pressure testing by reducing a pressure within a first cavity associated with a subsea wellhead structure by moving fluid from said first cavity having a first pressure, to a second cavity having a second pressure, where the second pressure is higher than the first pressure, wherein it comprises the steps of actuating a piston in a transfer accumulator to draw fluid from the first cavity through a first line, then pressurizing the fluid within the transfer accumulator using said piston, and discharging the fluid from said transfer accumulator into the second cavity.
2. Method according to claim 1, wherein the movement of the piston arrangement in the transfer accumulator is achieved by an electric motor.
3. Method according to one of the preceding claims, wherein the movement of the piston arrangement in the transfer accumulator is achieved by a second piston arrangement connected to a control valve, a pump and a accumulator, where the pump and the control valve is set to move the second piston arrangement and thereby forcing the movement of the piston arrangement within the transfer accumulator.
4. Apparatus for testing a seal in a subsea wellhead structure, the seal being located adjacent a cavity associated with the subsea wellhead structure, whereby the testing is carried out by reducing the pressure in said cavity, wherein the apparatus comprises a transfer accumulator connected via a first fluid line, comprising a one-way valve with said cavity, and connected via a second fluid line comprising a second one-way valve with a flowline, where the transfer accumulator comprises an actuated piston arrangement for pressurizing the fluid within the transfer accumulator independent of the pressures in the cavity and the flowline.
5. Apparatus according to claim 4 wherein the first fluid line comprises a control valve and the second fluid line comprises a control valve.
6. Apparatus according to claim 4 or 5, wherein the one-way valve in the first fluid line allows fluid from the first cavity through the first line to the transfer accumulator, and the one-way valve in the second fluid line allows fluid from the transfer accumulator through the second line to the flow line.

7. Apparatus according to claim 4, wherein the piston arrangement in the transfer accumulator is connected to an electric motor for movement of the piston arrangement.
8. Apparatus according to claim 4, wherein the piston arrangement in the transfer accumulator is connected to a second cylinder connected to a pump, and accumulator and a control valve for forced movement of the piston arrangement.
9. Apparatus according to claim 5, wherein a fluid line comprising valve devices, connects a bladder tank with the first fluid line between the control valve and the first cavity.
10. Apparatus according to claim 5, wherein a fluid line comprising valve devices connects a ROV hot-stab with the first fluid line between the control valve and the first cavity.