A subsea lubricator system is disclosed which includes a lubricator tube adapted to be positioned subsea above a subsea well, a pressure control head adapted to be positioned above the lubricator tube, at least one pressure sensor adapted for sensing at least one of a pressure in the subsea well or an ambient seawater pressure proximate the pressure control head, and at least one pump that is adapted to be positioned subsea to inject a lubricant into the pressure control head at a pressure that is greater than the sensed pressure. A method of operating a subsea lubricator system positioned above a subsea well, the lubricator system including a pressure control head, is also disclosed which includes monitoring at least one of a pressure within the well and an ambient seawater pressure proximate the lubricator system, and injecting a lubricant into the pressure control head at a pressure that is greater than the monitored pressure.
GREASE INJECTION SYSTEM FOR RISERLESS LIGHT WELL INTERVENTION

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a method for controlling grease injection to a subsea intervention system and an apparatus comprising a housing containing a control unit and a pump for grease.

[0003] 2. Description of the Related Art

[0004] When performing intervention in a hydrocarbon well, it is necessary to isolate the well from the environment. Intervention is often carried out using wireline techniques (braided wire, composite cable or slickline). To contain the pressure in the well during operations and avoid hydrocarbons escaping to the environment, intervention operations involve the use of a stuffing box which is part of a pressure control head (PCH). The PCH provides a dynamic seal between the cable and the wellbore enclosures to maintain pressure control and prevent wellbore fluids from leaking into the environment. However, because of its braided (wire rope like) exterior, the cable has a bumpy, crevice-filled surface which is difficult for the PCH to seal around as the cable passes through the PCH as it travels into and out of the well.

[0005] FIG. 1 is a schematic drawing showing a prior art subsea lubricator system 100 attached to a subsea well 105. The subsea well 105 extends into a subterranean formation and has a Christmas tree 106 attached to the wellhead and a flowline/umbilical 107 extending to a process facility. The subsea lubricator stack 100 includes a pressure control unit (BOP) 111, a lubricator (pipe) 112 and the pressure control head (PCH) 113.

[0006] The lubricator system 100 further comprises a control system (IWOCs) 115 with a separate workover umbilical 117 extending to the surface. The control system 115 controls the system 100. In prior art operations, grease is pumped down the line 117 and further through line 123 to the PCH 113 to maintain a seal between the braided wire or cable 109 and the seawater environment.

[0007] Current practice is to inject grease into the PCH body 113 at a higher pressure than that of the well. In addition, grease has to be replenished at some rate to replace grease lost to the surface of the braided cable 109 as it passes through the ends of PCH 113 (going into or out of the well). The grease injection rate is controlled by periodic visual monitoring of the sealing ends of the PCH 113 for leakage and monitoring the grease injection pressure.

[0008] This operation gets complicated when performing this practice subsea on a subsea well. This involves the use of a subsea riserless light well intervention (RLWI) stack. For RLWI, the PCH 113 is now remote and difficult to monitor; making it difficult to determine when and how much grease needs to be injected. Furthermore, as the stack is run in deeper water, the length of the grease supply line feeding the PCH 113 grows longer, making it increasingly difficult to pump viscous grease down to the PCH 113 at a reasonable surface pressure or pump rate. The long grease lines and viscous grease becomes more problematic as deeper colder environments are encountered. To do that requires pumping grease at some empirical rate monitored visually. In subsea situations, the pumping pressure is exacerbated by the length of the grease line going down to the subsea PCH 113 and the rate is often a pure guess, often resulting in sending too much grease down to conservatively compensate for the unknown conditions.

[0009] Current practice for subsea grease injection requires the surface deployment of grease lines as shown in U.S. Pat. No. 4,821,799, which is hereby incorporated by reference in its entirety. That patent discloses the use of an accumulator to enable a better control of injection pressures.

[0010] There is also a more subtle problem associated with grease injection to a subsea PCH 113, namely, water ingress. Normally, the PCH 113 is lowered to the lubricator tube 112 together with the tool. However, in some operations, the PCH 113 is run independently after the wireline tools, cable, etc, are landed in the RLWI stack’s lubricator tube 112. As the PCH assembly is lowered down to the sea floor, the braided cable 109 passes through the PCH 113. If grease is not supplied at a sufficient pressure and rate to offset the increase in ambient seawater pressure, and the loss of grease to the cable 109 passing by, seawater could weep past the seal ends of the PCH 113 into the main cavity of the PCH 113 and/or the tube 112. If this occurs, there is an increased risk that the water will help to form a hydrate plug inside the PCH 113 (later exposed to wellbore pressure and fluids) and prevent the cable 109 from freely moving through the PCH 113.

[0011] The present invention is directed to methods and devices solving, or at least reducing the effects of, some or all of the aforementioned problems.

SUMMARY OF THE INVENTION

[0012] The following presents a simplified summary of the invention in order to provide a basic understanding of some aspects of the invention. This summary is not an exhaustive overview of the invention. It is not intended to identify key or critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is discussed later.

[0013] The present subject matter is generally directed to a method and a device for controlling grease injection to a subsea intervention system, where there is provided an at site pressure compensated system for providing the grease at a pressure higher than the outside pressure, this being either the well pressure, the pressure of the water around the subsea system, outside pressure, or both of these pressures.

[0014] According to one aspect, the present subject matter may be employed in an intervention workover control system (IWOCs) that is all electric or electro-hydraulic that may comprise a processor with the capability to handle information, for example, to record outside ambient seawater pressure, pressure inside the PCH and below the PCH (inside the well). As mentioned above, the purpose of the grease and PCH is to create a dynamic seal that generates a slightly higher (grease) pressure inside the PCH than the pressure of the environment above the PCH or the pressure in the well below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

[0016] FIG. 1 is a schematic depiction of an illustrative prior art subsea lubricator system;
FIG. 2 shows a sketch of an intervention system on a subsea well; FIG. 3 is a diagram showing the grease injection module in IWOCs mode; and FIG. 4 is a diagram showing the grease injection module in autonomous mode.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

Illustrative embodiments of the present subject matter are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers’ specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

The present subject matter will now be described with reference to the attached figures. The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special definition of a term or phrase, i.e., a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be implied by consistent usage of the term or phrase herein. To the extent that a term or phrase is intended to have a special meaning, i.e., a meaning other than that understood by skilled artisans, such a special definition will be expressly set forth in the specification in a definitional manner that directly and unequivocally provides the special definition for the term or phrase.

FIG. 2 is a schematic drawing showing a subsea lubricator system 10 described herein attached to a subsea well 5. The subsea well 5 extends into a subterranean formation and has a Christmas tree 6 attached to the wellhead and a flowline/umbilical 7 extending to a process facility. The subsea lubricator stack 10 includes a pressure control unit (BOP) 11, a lubricator (pipe) 12 and the pressure control head (PCH) 13.

The lubricator system 10 further comprises a control system (IWOCs) 15 that controls the system 10. Electrical power is supplied to the control system by electrical power line 17. In one illustrative embodiment, a grease injection module 21 is attached to the PCH 13. An electric cable 23 connects the grease injection module 21 with the control system 15. With the grease injection module 21 attached to the PCH 13, it can be raised and lowered together with the PCH 13 and operate in an autonomous mode. In another embodiment, the grease injection module 21 is not attached to the PCH 13, but rather is made as a part of the control system 15. In that case, an additional fluid line 25 (shown as a dashed line) is employed to supply grease or lubricant to the PCH 13. In some embodiments, a single line from the control system 15 to the grease injection module 21 may contain both electrical and fluid lines.

The subject matter disclosed herein proposes the elimination of a grease line (like the grease line 117 shown in FIG. 1) to or from the surface to supply lubricant to the PCH 13. In one embodiment, as shown in FIG. 3, lubricant may be supplied to the PCH 13 by means of a depth compensated accumulator 31 filled with a lubricant or grease. The grease injection module 21 comprises an accumulator 31 for grease operatively connected via line 33 to a pump 35. The outlet grease line 37 from the pump 35 is connected to the PCH 13. The pump 35 is controlled by an electric motor 36. A first power supply cable 32 connects the control system 15 with the electric motor 36 for the pump 35. The grease line 37 has a one way valve 43, a shut-off valve 44 and a pressure and temperature sensor 45.

In the embodiment shown in FIG. 3, there is also provided a second pump 38 with associated motor 39, having a separate power supply cable 34. A second grease line 41 connects the pump 38 with the PCH 13. As above, the second grease line 41 includes a one way valve 46, a shut-off valve 47 and a pressure and temperature transmitter 48. The second pump 38 may be added to provide for redundancy in the system, in case of failure of the first pump 35. Providing dual pumps 35, 38 also makes it possible to generate higher grease pumping rates in case of emergency, with both pumps operating together. They may also be used for the rare times when the cable 9 is travelling very quickly through the PCH 13 and may require more grease than one electric motor/pump can supply.

As an alternative, grease may be wiped from the cable 9 as it passes out of the PCH 13 and returned to a container in the grease injector module 21. For example, as shown in FIG. 3, a return grease line 52 that is in fluid communication with a canister 54 may be provided. In this way, very little, if any, grease will be released to the environment.

In addition, an ROV attachment 22 may be added to provide a means to periodically replenish the grease in the accumulator 31 for long duration jobs.

In operation, the control system 15 closely monitors the pressure of the environment outside of the PCH 13, the pressure inside the PCH 13 and/or the pressure in the well 5. Periodically, the control system 15 actuates one or both (depending upon the situation) of the grease pumps 35, 38 to pump grease into the PCH 13. The grease pressure is closely monitored and the pump(s) 35 and/or 38 are regulated to generate a very small pressure differential between the PCH 13 and the well 10, e.g., a differential of approximately 15 psi. Stated another way, the grease is injected at a pressure that is a set or established value above at least one of the monitored pressures.

The close in-situ monitoring of the various pressures by the control system 15 minimizes the amount of grease or lubricant needed because the differential pressure can be kept to a minimum value, e.g., a 15 psi differential pressure. A lower differential pressure or set value may also be employed. This is a significant benefit as compared to prior art systems where operators merely guessed as to the volume of grease needed, and the associated difficulties trying to pump the grease down a grease line. Keeping the differential pressure or set value to a minimum also lessens the amount of
the seal elements (not shown) in the PCH 13 into the well and/or the environment. By employing two pumps 35 and 38, the grease may be injected into the PCH 13 in two locations (again opening one or two lines to compensate for situations of high cable speed, rapid loss of grease, etc.). There also may be a third grease injection line 51 in a location below the PCH 13 for better control of the differential pressure between the PCH 13 and the well, if necessary.

In the embodiment shown in FIG. 4, the grease injection module 21 is equipped with its own separate control unit 60 configured as an autonomous version of the control system 15. The autonomous control unit 60 comprises a processor and data storage (not shown) and is preferably powered by a battery 62. Thus, the electric control can be separated from the main control system 15, while retaining the monitoring and injection control features for grease injection into the PCH 13. This embodiment simplifies the packaging of the PCH 13 assembly by eliminating the need for the subsea electrical connection 23 (FIG. 2) after the PCH 13 is lowered separately and latched to the rest of the intervention (RLWI) stack. However, this autonomous feature adds two new capabilities. First, as the PCH 13 assembly is lowered to the sea floor, it independently monitors the increase in ambient seawater pressure and can adjust by injecting grease into the PCH 13 at just a slightly higher than ambient pressure differential, e.g., 15 psi differential, to keep seawater from entering the cavity in the PCH 13, thereby avoiding the hydrate plugging issues. The control unit 60 is battery powered to maintain its autonomy. Second, in the event that the surface vessel needs to depart and/or the cable is cut somewhere outside of the PCH 13 and the control system 15 is disconnected, the grease injection pressure containment feature of the PCH 13 is maintained even though the rest of the control system 15 is shut down, for as long as battery power is present.

Another issue is the grease itself. Current practice is to use some form of viscous petroleum based grease that has a certain amount of stickiness to adhere to the surface of the seals (not shown) in the PCH 13 and the rough exterior of the cable 9, creating a smooth surface on the braided cable. However, this creates its own "leakage to the environment" as the grease laden cable 9 emerges out the top of the PCH 13 during winchline retrieval. In addition, the ambient seawater environment may be as low as 4°C (39°F), which may lead to an increase in the grease’s viscosity or lead to a hardening condition. To alleviate this condition, it is contemplated to replace petroleum grease with a bio-degradable, non-hydrocarbon lubricant, such as a fish oil based lubricant, e.g., cod liver oil, so as to significantly lower the viscosity of the lubricant and eliminate hydrocarbon discharge to the environment.

The benefit of the present invention is that its architecture is substantially depth insensitive, eliminating the pressure flow rate problems associated with pumping viscous grease longer distances (at higher surface pump pressures) and eliminating waste by using environmentally friendly lubricants that are injected at much lower differential pressures because the injection process is monitored. It also eliminates a line going into the water which is beneficial for better line management; critical for deepwater (>500 m-1500 ft.) operations.

The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. For example, the process steps set forth above may be performed in a different order. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

What is claimed:
1. A method of operating a subsea lubricator system positioned above a subsea well, said lubricator system comprising a pressure control head, the method comprising: monitoring at least one of a pressure within said well and an ambient seawater pressure proximate said lubricator system; and injecting a lubricant into said pressure control head at a pressure that is greater than said monitored pressure.
2. The method of claim 1, wherein the method comprises monitoring both of the pressure in the well and the ambient seawater pressure and monitoring a pressure within the pressure control head.
3. The method of claim 2, wherein the step of injecting a lubricant into the pressure control head is performed at a pressure that is a set value greater than both of the monitored well pressure and the monitored ambient seawater pressure.
4. The method of claim 2, wherein the step of injecting a lubricant into the pressure control head is performed at a pressure that is a set value greater than at least one of the monitored well pressure and the monitored ambient seawater pressure.
5. The method of claim 1, further comprising actuating at least one pump that is positioned subsea to inject said lubricant into said pressure control head at said pressure that is a set value greater than said monitored pressure.
6. The method of claim 1, wherein said lubricant is obtained from an accumulator that is positioned subsea and contains said lubricant.
7. The method of claim 1, wherein said lubricant is a petroleum based lubricant.
8. The method of claim 1, wherein said lubricant is a non-hydrocarbon containing lubricant.
9. The method of claim 1, wherein said lubricant is a bio-degradable lubricant.
10. The method of claim 1, wherein said lubricant comprises fish oil.
11. The method of claim 5, further comprising actuating at least one additional pump that is positioned subsea to inject said lubricant into said pressure control head at said pressure that is a set value greater than said monitored pressure.
12. The method of claim 11, further comprising injecting said lubricant into said pressure control head at said pressure.
13. The method of claim 5, wherein actuating said at least one pump comprises actuating said at least one pump using battery power.
14. The method of claim 5, wherein said at least one pump is operatively coupled to a battery power source and a power cable supplied from a surface vessel or platform, and wherein said at least one pump may be actuated using electrical power supplied from either said battery power source or from said power cable.
15. The method of claim 1, wherein injecting a lubricant into said pressure control head comprises injecting a lubricant into said pressure control head at a pressure that is at least 15 psi greater than the monitored pressure.

16. A method of operating a subsea lubricator system positioned above a subsea well, said lubricator system comprising a pressure control head, the method comprising:
   monitoring at least one of a pressure within said well and an ambient seawater pressure proximate said lubricator system;
   injecting a lubricant into said pressure control head at a pressure that is a set value greater than said monitored pressure; and
   obtaining said lubricant from an accumulator that is positioned subsea and contains said lubricant.

17. The method of claim 16, wherein the method comprises monitoring both of the pressure in the well and the ambient seawater pressure and monitoring a pressure within the pressure control head.

18. The method of claim 17, wherein the step of injecting a lubricant into the pressure control head is performed at a pressure that is a set value greater than both of the monitored well pressure and the monitored ambient seawater pressure.

19. The method of claim 16, further comprising actuating at least one pump that is positioned subsea to inject said lubricant into said pressure control head at said pressure that is a set value greater than said monitored pressure.

20. The method of claim 16, wherein said lubricant is a non-hydrocarbon containing lubricant.

21. The method of claim 16, wherein said lubricant is a bio-degradable lubricant.

22. The method of claim 16, wherein said lubricant comprises fish oil.

23. The method of claim 19, further comprising actuating at least one additional pump that is positioned subsea to inject said lubricant into said pressure control head at said pressure that is a set value greater than said monitored pressure.

24. The method of claim 19, further comprising injecting said lubricant into said pressure control assembly at two spaced apart locations.

25. The method of claim 19, wherein actuating said at least one pump comprises actuating said at least one pump using battery power.

26. The method of claim 19, wherein said at least one pump is operatively coupled to a battery power source and a power cable supplied from a surface vessel or platform, and wherein said at least one pump may be actuated using electrical power supplied from either said battery power source or from said power cable.

27. The method of claim 16, wherein injecting a lubricant into said pressure control head comprises injecting a lubricant into said pressure control head at a pressure that is at least 15 psi greater than the monitored pressure.

28. A subsea lubricator system, comprising:
   a lubricator tube adapted to be positioned subsea above a subsea well;
   a pressure control head adapted to be positioned above said lubricator tube;
   at least one pressure sensor adapted for sensing at least one of a pressure in said subsea well or an ambient seawater pressure proximate said pressure control head; and
   at least one pump that is adapted to be positioned subsea to inject a lubricant into said pressure control head at a lubricant pressure that is greater than said sensed pressure.

29. The system of claim 28, further comprising a lubricant accumulator that is adapted to be positioned subsea and contain said lubricant to be injected into said pressure control head.

30. The system of claim 28, wherein said lubricant pressure is greater than said sensed pressure by a set value.

31. The system of claim 30, wherein said set value is at least 15 psi.

32. The system of claim 29, further comprising a lubricant return line that extends between said pressure control head and a used lubricant container.

33. The system of claim 28, further comprising a control system that is adapted to be positioned subsea, said control system adapted to receive said sensed pressure and actuate said at least one pump in response to said sensed pressure.

34. The system of claim 33, wherein said control system controls said at least one pump such that said lubricant pressure is greater than said sensed pressure by a set value.

35. The system of claim 33, wherein said control system is adapted to regulate a pressure of the lubricant injected into the pressure control head.

36. The system of claim 28, wherein said system comprises at least two pumps that are adapted to be positioned subsea, each of which are adapted to inject liquid into said pressure control head.

37. The system of claim 36, wherein said first and second pumps are adapted to inject said lubricant into said pressure control head at spaced apart locations.

38. The system of claim 28, wherein said system further comprises a battery that is adapted to be positioned subsea, said battery adapted to supply electrical power to said at least one pump.

39. The system of claim 38, wherein said system further comprises an umbilical from a surface vessel or platform that is adapted to supply electrical power to said at least one pump.

40. The system of claim 28, wherein said system comprises at least one pressure sensor for sensing a pressure within said subsea well, at least one pressure sensor for sensing a pressure of said ambient seawater, and at least one pressure sensor for sensing a pressure within the pressure control head.