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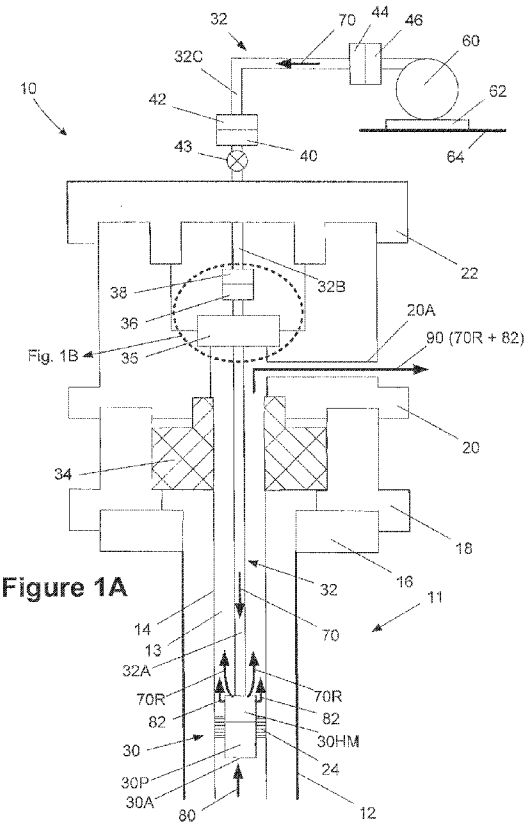


Figure 1A

(57) Abstract: A system located in a subsea environment is disclosed comprising a submersible pump positioned in a well, a hydraulic motor that is operatively coupled to the submersible pump and a pressurized fluid supply pump that is positioned on or near a floor of the subsea environment and in fluid communication with the hydraulic motor.

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SYSTEM FOR OPERATING A HYDRAULICALLY-POWERED SUBMERSIBLE PUMP

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

Generally, the present disclosure relates to a system that may be employed in recovering hydrocarbons from oil and gas wells. More specifically, the present disclosure is directed to various embodiments of a system for operating a hydraulically-powered submersible pump that uses a pump positioned subsea to supply the pressurized fluid to drive the submersible pump.

2. DESCRIPTION OF THE RELATED ART

As the technology for offshore deep-water exploitation becomes available at a reasonable cost, the number of sub-sea completions in deep and ultra-deep waters is expected to increase significantly. Today, high productivity wells have been producing steadily and successfully at water depths greater than 5000 feet in several regions around the world. Such subsea wells are very expensive to drill and to complete. Thus, there is always a constant drive to keep such subsea wells producing for as long as possible to extract as much of the hydrocarbons from the formation as is economically feasible.

Over time, the production rates of subsea wells may be reduced to uneconomic levels. Another problem that is frequently encountered is that the natural pressure of the reservoir, or drive energy of the well, is insufficient to cause the flow of hydrocarbons out of the well at economically feasible quantities. Various artificial-lift methods have been developed to extend the useful life of such wells. The use of submersible pumps positioned in the well is one common technique that is employed to increase the flow rate of hydrocarbons to

economically acceptable levels. Such pumps may take a variety of forms, *e.g.*, an electrical submersible pump (ESP), a hydraulic submersible pump (HSP), a progressing cavity pump, a jet pump, etc. An ESP or an HSP typically includes a multistage centrifugal pump. An ESP is operatively coupled to and driven by an electric motor. An HSP is operatively coupled to a hydraulic motor. The ESP or HSP may be installed inside the well in a tubing string, and it is typically situated at a certain depth within the well. An ESP is powered via an electrical umbilical that includes an electric cable that is connected to a source of electrical power, *e.g.*, a generator, positioned on a topside facility, *e.g.*, a platform, a ship, etc. An HSP is powered via a hydraulic umbilical, a tubing or pressurized fluid in an annular space that includes a conduit for the supply of pressurized fluid to the HSP, wherein the conduit is connected to a source of pressurized hydraulic fluid, *e.g.*, a pump that is positioned on a topside facility, *e.g.*, a platform, a ship, etc. In other cases, the HSP may be powered via pressurized fluid supplied via a tubing or via pressurized fluid supplied via an annular space.

An ESP is typically positioned within a well or a Christmas tree by suspending it on the production tubing and strapping an electrical cable on the outside of the production tubing from the ESP to the wellhead or Christmas tree. The electrical cable is operatively coupled to the electrical motor portion of the ESP. Electrical connectors or penetrators are coupled to the opposite end of the electrical cable within the wellhead of Christmas tree production tubing hanger. Multiple electrical connections will be made to thereby establish electrical conductivity with the electrical umbilical so as to provide electrical power to the electrical motor portion of the ESP. A similar arrangement is made for HSPs except that a conduit, such as the annular space between the outside diameter of the production tubing and the inside diameter of the casing, extends between the HSP hanger and the HSP positioned down-hole. The conduit is operatively coupled to the hydraulic motor portion of the HSP,

and high-pressure fluid is supplied to the hydraulic motor via the conduit so as to drive the pump portion of the HSP. Eventually a hydraulic connector that is in fluid communication with the conduit will be coupled to another hydraulic connector to thereby establish fluid communication with the hydraulic umbilical so as to provide a pressurized fluid to the hydraulic motor portion of the HSP. The working fluid for an HSP motor can be either a component of the fluid the HSP is pumping, or a separate working fluid dedicated to driving the HSP may be used.

A typical problem encountered with the use of ESPs relates to reliability or longevity of electrical connectors and other electric components, *e.g.*, electric motors. It is frequently the case that the electrical components that are responsible for powering the pump in an ESP fail for one reason or another leading to well downtime and/or expensive repairs. A hydraulic powered submersible pump utilizes a more robust power delivery system which has a significantly longer mean time to failure than electrically powered submersible pump systems. However, as wells are being drilled in deeper and deeper water, the use of a hydraulic umbilical to supply pressurized fluid from a pump positioned on a topside facility to drive an HSP becomes more problematic. For example, in a closed-loop system, as the water depth increases, the liquid head that must be overcome when the drive fluid is returned to the surface is becoming a very significant factor as it relates to system design and quality.

In an effort to decrease the cost of replacing an electrical submersible pump that has failed, the traditional installation technique of attaching the ESP to the production tubing and strapping the electrical power cable to the outside diameter of the production tubing is being abandoned in favor of a method that does not require retrieval of the production tubing. Installing the ESP inside of the production tubing and conveying the ESP into the production

tubing by a power cable, or a conduit containing power cabling such as coiled tubing or the like, is seen as a means to reduce the overall replacement costs, eliminating the time and effort required to pull the completion, however, this does not improve the mean time to failure of the ESP, it simply reduces the total cost of replacement.

The present disclosure is directed to various embodiments of a system for operating a hydraulically-powered submersible pump that may solve or reduce one or more of the problems identified above.

SUMMARY OF THE INVENTION

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.

Generally, the present disclosure is directed to various embodiments of a system for operating a hydraulically-powered submersible pump that uses a pump positioned subsea to supply the pressurized fluid to drive the submersible pump. One illustrative system disclosed herein includes a submersible pump positioned in a well, a hydraulic motor that is operatively coupled to the submersible pump and a pressurized fluid supply pump that is positioned on or near a floor of the subsea environment and in fluid communication with the hydraulic motor.

Another illustrative system disclosed herein includes a production tree positioned above a well, a submersible pump positioned in the well, a hydraulic motor that is operatively

coupled to the submersible pump, a booster pump that is adapted to receive a hydrocarbon fluid from a production outlet of the tree and a pressurized fluid supply pump that is positioned on or near a floor of the subsea environment, wherein the pressurized fluid supply pump is in fluid communication with the hydraulic motor. In further embodiments, the system may also include a separator that is adapted to receive a pressurized fluid from an outlet of the booster pump, and the pressurized fluid supply pump is in fluid communication with the hydraulic motor.

Yet another illustrative system disclosed herein includes a production tree positioned above a well, a submersible pump positioned in the well, a hydraulic motor that is operatively coupled to the submersible pump, a booster pump positioned on or near a floor of the subsea environment, wherein the booster pump is adapted to receive a hydrocarbon fluid from a production outlet of the tree, and a separator that is adapted to receive a pressurized fluid from an outlet of the booster pump, wherein the separator comprises a fluid outlet that is in fluid communication with the hydraulic motor.

Yet another illustrative system disclosed herein includes a production tree positioned above a well, a submersible pump positioned in the well, a hydraulic motor that is operatively coupled to the submersible pump, a booster pump positioned on or near a floor of the subsea environment, wherein the booster pump is adapted to receive a hydrocarbon fluid from a production outlet of the tree, and a valve that is in fluid communication with an outlet of the booster pump and adapted to receive a pressurized hydrocarbon fluid from the outlet of the booster pump and direct a portion of the pressurized hydrocarbon fluid to the hydraulic motor.

Yet another illustrative system disclosed herein includes a production tree positioned above a well, a submersible pump positioned in the well, a hydraulic motor that is operatively coupled to the submersible pump, a booster pump that is adapted to receive a hydrocarbon fluid from a production outlet of the tree, a pressurized fluid supply pump that is positioned on or near a floor of the subsea environment, wherein the pressurized fluid supply pump is in fluid communication with the hydraulic motor, and a turbine comprising a shaft that is operatively coupled to the pressurized fluid pump, the turbine being in fluid communication with an outlet of the booster pump and adapted to receive a pressurized hydrocarbon fluid from the outlet of the booster pump, wherein the shaft is adapted to be rotated by the pressurized hydrocarbon fluid, and wherein the shaft is further adapted to drive the pressurized fluid pump via rotation of the shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure 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:

Figures 1A-1G are various views of various illustrative embodiments of a system for operating a hydraulically-powered submersible pump that uses a pump positioned subsea to supply the pressurized fluid to drive the submersible pump.

While the subject matter disclosed herein 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

Various illustrative embodiments of the invention 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. Various structures, systems and devices are schematically depicted in the drawings for purposes of explanation only and so as to not obscure the present disclosure with details that are well known to those skilled in the art. Nevertheless, the attached drawings are included to describe and explain illustrative examples of the present disclosure. 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.

The present disclosure is directed to various embodiments of a system for operating a hydraulically-powered submersible pump that uses a pump positioned subsea to supply the pressurized fluid to drive the submersible pump. Figures 1A-1B are simplistic and schematic depictions of one illustrative embodiment of a system 10 that includes a hydraulically-powered submersible pump 30 (HSP) that is positioned down-hole in a well 11. The HSP 30 is generally comprised of a pump 30P and a hydraulic motor 30HM that is operatively coupled to the pump 30P. The pump 30P is intended to be representative of any type of pump that may be used to pump hydrocarbon fluids, *e.g.*, a centrifugal pump, a progressing cavity pump, a jet pump, etc. Thus, the present invention should not be considered to be limited to any particular type or form of the pump 30P that may be used as part of the HSP 30. In general, in the systems disclosed herein, a pressurized fluid 70 that is used to actuate the HSP 30 to pump hydrocarbons out of the well 11 is supplied by an illustrative pressurized fluid supply pump 60 (PFS pump 60) that is positioned subsea, *i.e.*, in the water.

With continuing reference to Figure 1A, in the depicted example, the system 10 is comprised of production casing 12, production tubing 14 positioned within the production casing 12, a well head 16 that is coupled to the production casing 12, a tubing head 18, a production or Christmas tree 20 and a tree cap 22. The system 10 is further comprised of a sealing member 24, several sections of tubing that are generally designated with the reference numbers 32A, 32B and 32C, a production tubing hanger 34, a HSP hanger 35, and a plurality of hydraulic connectors 36, 38, 40, 42, 44 and 46. Importantly, the illustrative PFS pump 60

is positioned on a schematically depicted skid 62 that is positioned on or near the sea floor 64. Figure 1B is an enlarged view of the area of the system adjacent the HSP hanger 35. As shown in Figure 1B, a schematically depicted isolation valve 48 (not shown in Figure 1A), *e.g.*, a ball valve or a gate valve, is incorporated in the production tree 20. The isolation valve 48 is large enough to allow the HSP hanger 35 and the hydraulic connectors 36, 38 to pass therethrough during the installation of the HSP system in the well 11 and production tree 20, as will be described more fully below. In Figure 1B, the hydraulic connectors 36, 38 are depicted in a spaced-apart, un-mated condition. Additional details of the various aspects of the various systems disclosed herein will be discussed further below. In general, the various components of the system 10 disclosed herein may be of traditional construction that may be made using traditional materials. The system 10 includes numerous clamps, bolts and seals for assembling the various components depicted in the attached figures to one another, but such details are not included in the attached drawings so as not to obscure the presently disclosed invention and because such details of construction are well known to those skilled in the art.

In terms of general operation, in one embodiment, the subsea PFS pump 60 is adapted to supply a pressurized fluid 70 to the hydraulic motor 30HM via the tubing 32, *e.g.*, coiled tubing. The HSP 30 is positioned below the level of hydrocarbons (liquid and/or gas) in the well 11. The pump 30P of the HSP 30 has an intake 30A where hydrocarbons enter the pump 30P. As is known to those skilled in the art, the pressurized fluid 70 causes the hydraulic motor 30HM to rotate, which in turn, in the case where the submersible pump 30P is a centrifugal pump, causes the submersible pump 30P to rotate and thereby increases the pressure of the hydrocarbon fluids as they pass through the pump 30P. More specifically, hydrocarbons enter the pump 30P, as schematically depicted by the arrow 80, and leave the

pump 30P as a pressurized hydrocarbon fluid 82 via various outlets (not shown) in the pump 30P. The pressurized hydrocarbon fluid 82 is discharged into the annular space 13 between the production tubing 14 and the tubing 32. The discharged fluid 70R from the hydraulic motor 30HM, which is now at a relatively lower pressure, leaves the hydraulic motor 30HM via various outlets (not shown), and, in this embodiment of the system 10, is also discharged into the annular space 13 between the production tubing 14 and the tubing 32 where it co-mingles with the pressurized hydrocarbon fluid 82 that passed through the pump 30P. The production tree 20 includes a production outlet 20A where a production fluid 90 (a combination of the pressurized hydrocarbon fluid 82 and the discharged fluid 70R) exits the tree 20 and flows to other processing equipment, described more fully below, for further processing.

As will be recognized by those skilled in the art after a complete reading of the present application, the various systems 10 disclosed herein may be implemented using either open-loop or closed-loop type pumping systems. Moreover, it should be understood that the PFS pump 60 depicted herein is intended to be representative in nature in that it represents any type of pump that may be used to increase the pressure of a fluid (gas or liquid, or a combination thereof) as it passes through the PFS pump 60. The PFS pump 60 may have any type of configuration, *e.g.*, a centrifugal type pump, a positive displacement type pump, etc., it may be of any size or horsepower, and it may be adapted to pump a single phase fluid or a multi-phase fluid. In one illustrative embodiment, the PFS pump 60 may be an electrical pump that is powered and controlled via an electrical umbilical (not shown) that is connected to an electrical power supply source positioned on a topside facility, *e.g.*, a platform. Thus, the PFS pump 60 should not be considered as limited to any particular type or form of pump. In one particular embodiment, the PFS pump 60 is of a size such that it alone is adapted to

increase a pressure of a hydrocarbon fluid so that hydrocarbon fluid may flow from a floor of the subsea environment to a surface of the subsea environment without the need to further increase the pressure on the hydrocarbon fluids. The tubing 32 is also intended to be representative of any type of conduit, *e.g.*, coiled tubing, that may be employed in a well to conduct and contain a pressurized fluid from one location to another location.

Figures 1C-1G are process flow diagrams that schematically depict various illustrative examples of specific implementations of the system 10 as it relates to producing hydrocarbons from the well 11. Figure 1C depicts one illustrative system 10A that includes a plurality of subsea pumps 102, 104 and a schematically depicted liquid/gas separator 106. In this example, the production fluid 90 (a combination of the pressurized hydrocarbon fluid 82 and the discharged fluid 70R) may be a multi-phase fluid containing liquid and gaseous hydrocarbon components. The production fluid 90 exits the tree 20 via production outlet 20A (see Figure 1A) and flows to the pump 102 where its pressure is increased and where it thereafter leaves the pump 102 as a pressurized production or pressurized hydrocarbon fluid 90P. The pressurized production fluid 90P flows to the separator 106 where its liquid and gas components are separated. The separated production liquid 90PL may be transmitted to a topside facility or a pipeline for collection and/or transmission. The separated gas 90G may be transmitted to the surface for collection and/or transmission via a separate pipeline and riser. In this example, a portion of the separated production liquid 90PL is supplied to the pump 104 where its pressure is increased to the desired pressure level for driving the HSP 30 in the well 11. *i.e.*, the output from the pump 104 is the pressurized fluid 70 that is used to drive the HSP 30. This pressurized fluid 90PL generally will have been treated with various types of flow assurance chemicals to prevent the formation of hydrates, scale, asphaltenes, etc. that might negatively impact the system performance. Thus, in the system 10A, the

pump 104 is the PFS pump 60. Although not depicted in the drawings, if desired, a choke may be positioned between the separator 106 and the pump 104 to regulate the flow of the production liquid 90PL to the pump 104. Various valves and flanged connections that would normally be provided to allow assembly of the components of the system 10A are not depicted so as not to obscure the presently disclosed inventions. In one illustrative embodiment, the pump 102 may be booster pump that is adapted to pump a multi-phase fluid. Such booster pumps are typically employed to increase the pressure of the production fluid 90 so that it may be transmitted via a pipeline over relatively long distances. In this example, the pump 104 may be a pump that is adapted to pump a single phase fluid, *e.g.*, the production liquid 90PL from the separator 106. Within the industry, the pumps 102, 104 are sometimes generically referred to as "mud-line" pumps as they are often positioned in one or more skids that are positioned on or near the sea floor. However, the pumps 102, 104 need not be positioned on the same skid. The sizing of the pumps 102, 104 may vary depending upon the particular application. When it is stated herein and in the claims that a pump is positioned in a subsea environment and "on or near" the floor of the subsea environment, it should be understood to mean that the pump itself need not contact the sea floor (although it may) but rather that the subject pump is structurally supported directly or indirectly by some structure (for example a skid) that is positioned on or contacts the sea floor.

Figure 1D depicts another system 10B that employs the novel concepts disclosed herein. System 10B is substantially identical to system 10A described above except that, in system 10B, the pump 104 has been removed. In this example, a portion of the separated production liquid 90PL is at a sufficient pressure within the separator 106 such that it may be used to drive the HSP 30 in the well 11 without further increasing its pressure. *i.e.*, the production liquid 90PL from the separator 106 is the pressurized fluid 70 that is used to drive

the HSP 30. Although not depicted in the drawings, if desired, a choke may be positioned between the separator 106 and the HSP 30 to regulate the flow or pressure of the production liquid 90PL as it is supplied to the HSP 30. Thus, in the system 10B, the pump 102 is the PFS pump 60.

Figure 1E depicts another illustrative system 10C that employs the novel concepts disclosed herein. System 10C is substantially identical to system 10B described above except that, in system 10C, the separator 106 has been removed. In this example, the pressurized production fluid 90P (after it leaves the pump 102) is at a sufficient pressure such that a portion of the pressurized production fluid 90P may be used to drive the HSP 30 in the well 11, *i.e.*, the pressurized production fluid 90P is the pressurized fluid 70 that is used to drive the HSP 30. A schematically depicted valve 112 may be positioned between the outlet of the pump 102 and the HSP 30 to direct a portion 90PA of the pressurized hydrocarbon fluid 90P to the HSP 30. Although not depicted in the drawings, if desired, a choke may be positioned between the valve 112 and the HSP 30 to regulate the flow or pressure of the liquid 90PA as it is supplied to the HSP 30. The portion of the pressurized production fluid 90P that is not used to drive the HSP 30 may be transmitted to a topside facility or a pipeline for collection and/or transmission. Thus, in the system 10C, the pump 102 is the PFS pump 60.

Figure 1F depicts yet another illustrative system 10D that employs the novel concepts disclosed herein. The system 10D includes the pump 102, a schematically depicted turbine 116 with an output shaft 116S that is operatively coupled to a pump 118. The turbine 116 is adapted to drive the pump 118. A separate fluid 120 is supplied to the intake of pump 118 from other sources, *i.e.*, dead oil or other fluid from topsides that does not pose any flow assurance risks. In this example, the output from the pump 118 is the pressurized fluid 70

that is used to drive the HSP 30. Thus, in the system 10D, the pump 118 is the PFS pump 60. The pressurized hydrocarbon fluid 90P that passes through the turbine 116 may be transmitted to a topside facility or a pipeline for collection and/or transmission.

Figure 1G depicts yet another illustrative system 10E that employs the novel concepts disclosed herein. The system 10E includes a closed loop system 130 that includes the HSP 30, a fluid reservoir 134 and a pump 138. As with the system 10D described above, the system 10E includes a schematically depicted turbine 116 with an output shaft 116S that is adapted to drive the pump 138. In this example, since the system 130 is a closed system, only pressurized hydrocarbon fluid 82 exits the production outlet 20A of the tree 20 (see Figure 1A), *i.e.*, the hydrocarbon fluid 82 is not co-mingled with discharged fluid from the HSP 30. The pressure of the hydrocarbon fluid 82 is increased as it passes through the pump 102 where it exits as hydrocarbon fluid 82P. In this example, the output from the pump 138 is the pressurized fluid 70 that is used to drive the HSP 30. The system 130 includes a feed or supply line 131 and a return line 132 whereby, after the pressurized fluid 70 passes through the HSP 30, it is returned to the reservoir 134. The liquid within the reservoir 134 is supplied to the intake of the pump 138 via line 136. Thus, in the system 10E, the pump 138 is the PFS pump 60. The hydrocarbon fluid 82P that passes through the turbine 116 may be transmitted to a topside facility or a pipeline for collection and/or transmission.

With reference to Figures 1A-1B, the system 10 may be assembled as follows. Initially, after the production tubing 14 is secured in the tubing hanger 34, the HSP hanger 35 is positioned and secured in the tree 20 via known locking or clamping mechanisms. The HSP 30 is secured to the HSP hanger 35 using a coiled tubing or similar conductor and run into the well 11 during the installation of the HSP hanger 35. The isolation valve 48 is closed

after the process of running the HSP 30 into the well is complete and provides a pressure-barrier while the blow-out preventer (not shown) is removed from the tree 20. The seal member 24 provides a barrier seal between the production tubing 14 and the intake to the pump 30A of the HSP 30. Once the blow-out preventer is removed from the tree 20, the tree cap 22 is lowered into position and secured to the tree 20. At this point in time, the hydraulic connector 36 is not operatively coupled to the hydraulic connector 38. After the cap 22 is secured to the tree 20, the isolation valve 48 is opened and the hydraulic connectors 36, 38 are operatively coupled to one another, using any of a variety of known techniques. For example, a screw type assembly (not shown) may be provided in the tree cap 22 that, when actuated, causes the connector 38 to move downward through the open isolation valve 48 and into engagement with the connector 36. Another alternative would be to provide a piston-type assembly that, when actuated, also causes the connector 38 to move downward through the open isolation valve 48 and into engagement with the connector 36. After the connection between the hydraulic connectors 36, 38 is established, a tubing jumper 32C is installed and the hydraulic connections 40-42 and 44-46 are made to establish fluid communication between the HSP 30 and the PFS pump 60. Once all the hydraulic fluid connections are mated and tested to ensure integrity, an isolation valve 43 on the tree cap 22 can be opened to allow fluid communication between the pump 60 and the HSP 30.

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 modi-

fied 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.

CLAIMS

WHAT IS CLAIMED:

1. A system located in a subsea environment, comprising:

a submersible pump positioned in a well,

a hydraulic motor that is operatively coupled to said submersible pump; and

a pressurized fluid supply pump that is positioned within said subsea environment, said pressurized fluid supply pump being in fluid communication with said hydraulic motor.

2. The system of claim 1, wherein said pressurized fluid supply pump is positioned in an open-loop pumping system.

3. The system of claim 1, wherein said pressurized fluid supply pump is one of a centrifugal pump or a positive displacement pump.

4. The system of claim 1, wherein said pressurized fluid supply pump is one of a multi-phase pump or a single phase pump.

5. The system of claim 1, wherein said hydraulic motor is adapted to be driven by said pressurized fluid and wherein said hydraulic motor is further adapted to drive said submersible pump.

6. The system of claim 1, wherein said pressurized fluid supply pump is positioned on a skid that is positioned on said sea floor.

7. The system of claim 1, wherein said pressurized fluid supply pump is positioned on or near a floor of said subsea environment.

8. The system of claim 1, wherein said pressurized fluid supply pump is of a size that it alone is adapted to increase a pressure of a hydrocarbon fluid such that the hydrocarbon fluid may flow from a floor of said subsea environment to a surface of said subsea environment.

9. A system located in a subsea environment, comprising:

a production tree positioned above a well, said production tree having a production outlet;

a submersible pump positioned in said well,

a hydraulic motor that is operatively coupled to said submersible pump;

a booster pump that is adapted to receive a hydrocarbon fluid from said production outlet; and

a pressurized fluid supply pump that is positioned on or near a floor of said subsea environment, said pressurized fluid supply pump being in fluid communication with said hydraulic motor.

10. The system of claim 9, wherein said hydraulic motor is adapted to be driven by said pressurized fluid and wherein said hydraulic motor is further adapted to drive said submersible pump.

11. The system of claim 9, wherein said booster pump is a multi-phase pump and said pressurized fluid supply pump is a single phase pump.

12. The system of claim 9, further comprising a separator that is adapted to receive a pressurized fluid from an outlet of said booster pump, and wherein a fluid outlet of said separator is in fluid communication with said pressurized fluid supply pump.

13. The system of claim 9, wherein said booster pump is of a size that it alone is adapted to increase a pressure of a hydrocarbon fluid such that the hydrocarbon fluid may flow from a floor of said subsea environment to a surface of said subsea environment.

14. A system located in a subsea environment, comprising:

a production tree positioned above a well, said production tree having a production outlet;

a submersible pump positioned in said well,

a hydraulic motor that is operatively coupled to said submersible pump;

a booster pump that is positioned on or near a floor of said subsea environment and adapted to receive a hydrocarbon fluid from said production outlet; and

a separator that is adapted to receive a pressurized hydrocarbon fluid from an outlet of said booster pump and wherein said separator comprises a fluid outlet that is in fluid communication with said hydraulic motor.

15. The system of claim 14, wherein said hydraulic motor is adapted to be driven by said pressurized fluid and wherein said hydraulic motor is further adapted to drive said submersible pump.

16. The system of claim 14, wherein said booster pump is a multi-phase pump.

17. The system of claim 14, wherein said booster pump is of a size that it alone is adapted to increase a pressure of a hydrocarbon fluid such that the hydrocarbon fluid may flow from a floor of said subsea environment to a surface of said subsea environment.

18. A system located in a subsea environment, comprising:

a production tree positioned above a well, said production tree having a production outlet;

a submersible pump positioned in said well,

a hydraulic motor that is operatively coupled to said submersible pump;

a booster pump that is positioned on or near a floor of said subsea environment and adapted to receive a hydrocarbon fluid from said production outlet; and

a valve that is in fluid communication with an outlet of said booster pump and adapted to receive a pressurized hydrocarbon fluid from said outlet of said booster pump and direct a portion of said pressurized hydrocarbon fluid to said hydraulic motor.

19. The system of claim 18, wherein said hydraulic motor is adapted to be driven by said pressurized fluid and wherein said hydraulic motor is further adapted to drive said submersible pump.

20. The system of claim 18, wherein said booster pump is a multi-phase pump.

21. The system of claim 18, wherein said booster pump is of a size that it alone is adapted to increase a pressure of a hydrocarbon fluid such that the hydrocarbon fluid may flow from a floor of said subsea environment to a surface of said subsea environment.

22. A system located in a subsea environment, comprising:

a production tree positioned above a well, said production tree having a production outlet;

a submersible pump positioned in said well,

a hydraulic motor that is operatively coupled to said submersible pump;

a booster pump that is adapted to receive a hydrocarbon fluid from said production outlet;

a pressurized fluid supply pump that is positioned on or near a floor of said subsea environment, said pressurized fluid supply pump being in fluid communication with said hydraulic motor; and

a turbine comprising a shaft that is operatively coupled to said pressurized fluid pump, said turbine being in fluid communication with an outlet of said booster pump and adapted to receive a pressurized hydrocarbon fluid from said outlet of said booster pump, wherein said shaft is adapted to be rotated by said pressurized hydrocarbon fluid, and wherein said shaft is further adapted to drive said pressurized fluid pump via rotation of said shaft.

23. The system of claim 22, wherein a fluid output from said pressurized fluid pump is adapted to drive said hydraulic motor, said hydraulic motor being adapted to drive said submersible pump.

24. The system of claim 22, wherein said booster pump is a multi-phase pump.

25. The system of claim 22, wherein said booster pump is of a size that it alone is adapted to increase a pressure of a hydrocarbon fluid such that the hydrocarbon fluid may flow from a floor of said subsea environment to a surface of said subsea environment.

26. A system located in a subsea environment, comprising:

a production tree positioned above a well, said production tree having a production outlet;

a submersible pump positioned in said well,

a hydraulic motor that is operatively coupled to said submersible pump;

a booster pump that is adapted to receive a hydrocarbon fluid from said production outlet;

a closed-loop system, comprising:

a pressurized fluid supply pump that is positioned on or near a floor of said subsea environment, said pressurized fluid supply pump being in fluid communication with an inlet of said hydraulic motor; and

a fluid reservoir that is in fluid communication with an outlet of said hydraulic motor and an intake of said pressurized fluid supply pump; and

a turbine comprising a shaft that is operatively coupled to said pressurized fluid pump, said turbine being in fluid communication with an outlet of said booster pump and adapted to receive a pressurized hydrocarbon fluid from said outlet of said booster pump, wherein said shaft is adapted to be rotated by said pressurized hydrocarbon fluid, and wherein said shaft is further adapted to drive said pressurized fluid pump via rotation of said shaft.

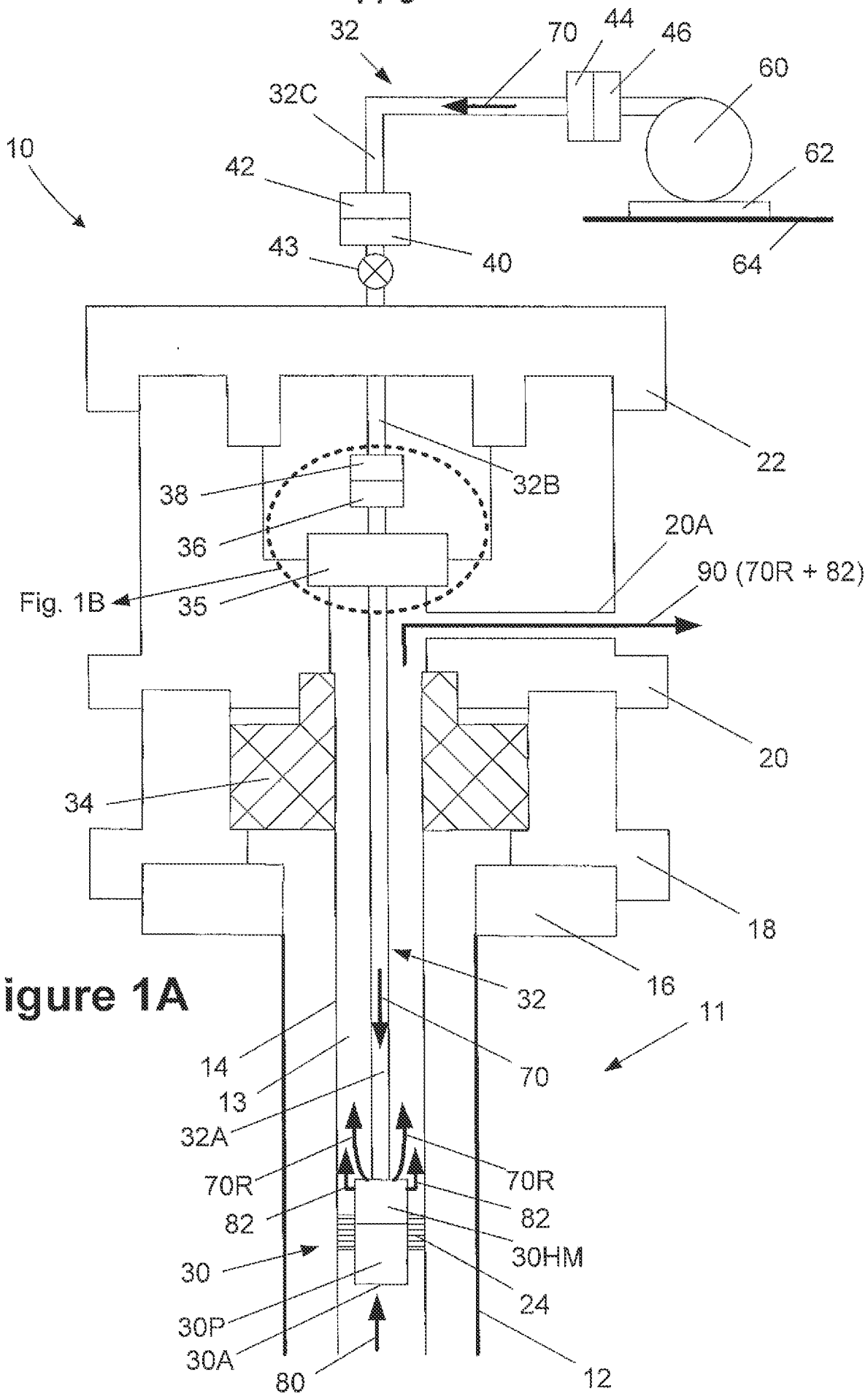

32
70
44
46
60
32C
10
42
62
43
40
64
22
32B
38
36
20A
90 (70R + 82)
Fig. 1B
35
20
34
18
16
32
11
14
70
13
32A
70R
70R
82
82
30HM
30
24
30P
30A
12
80

Figure 1A

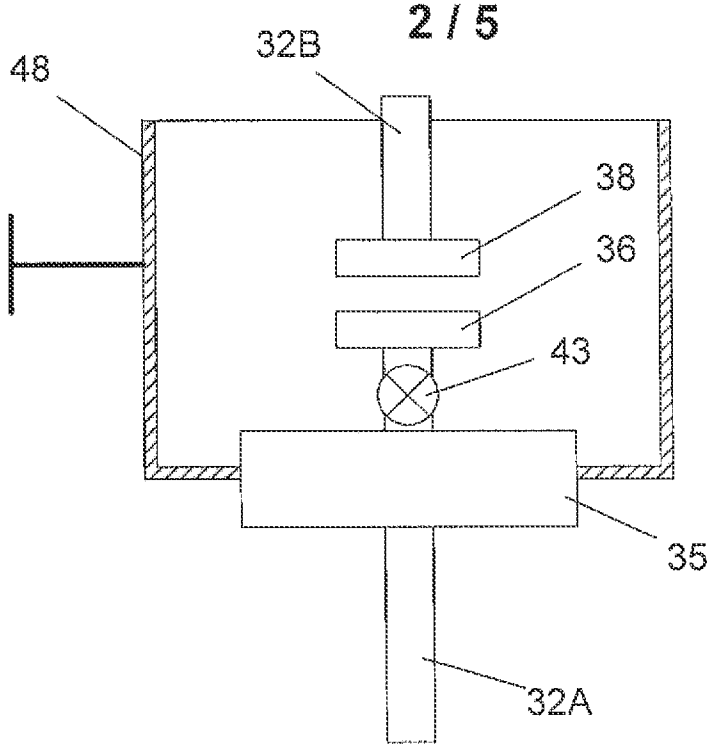


Figure 1B

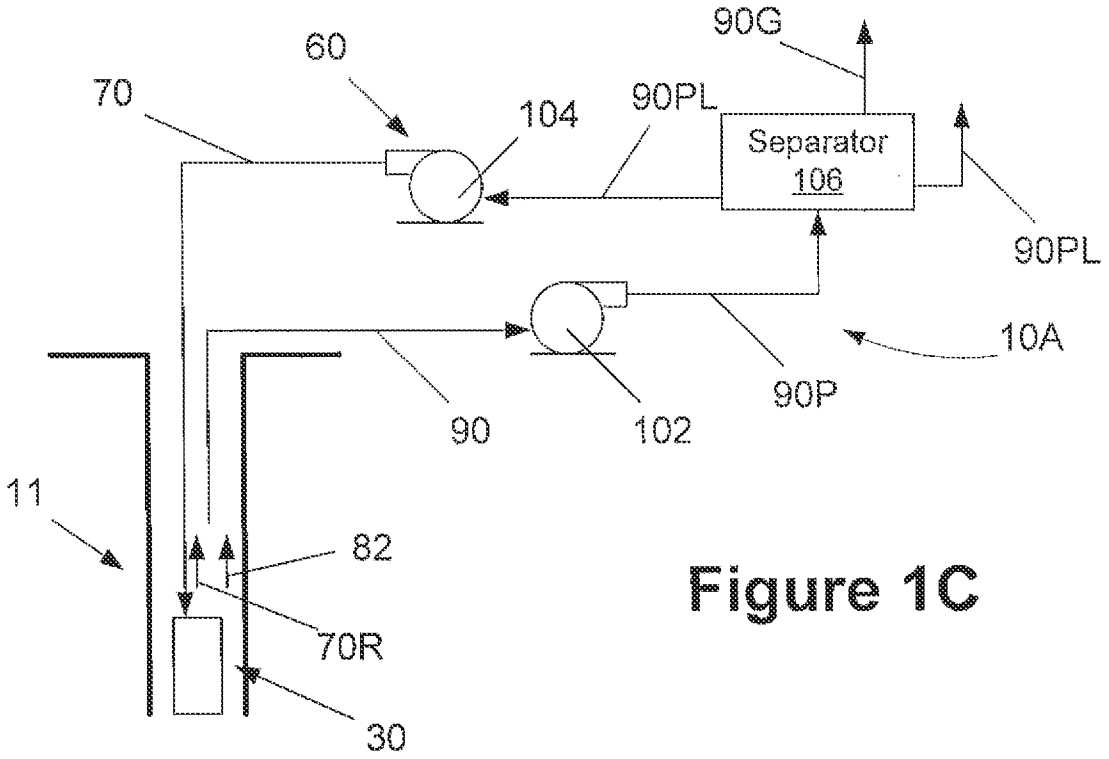


Figure 1C

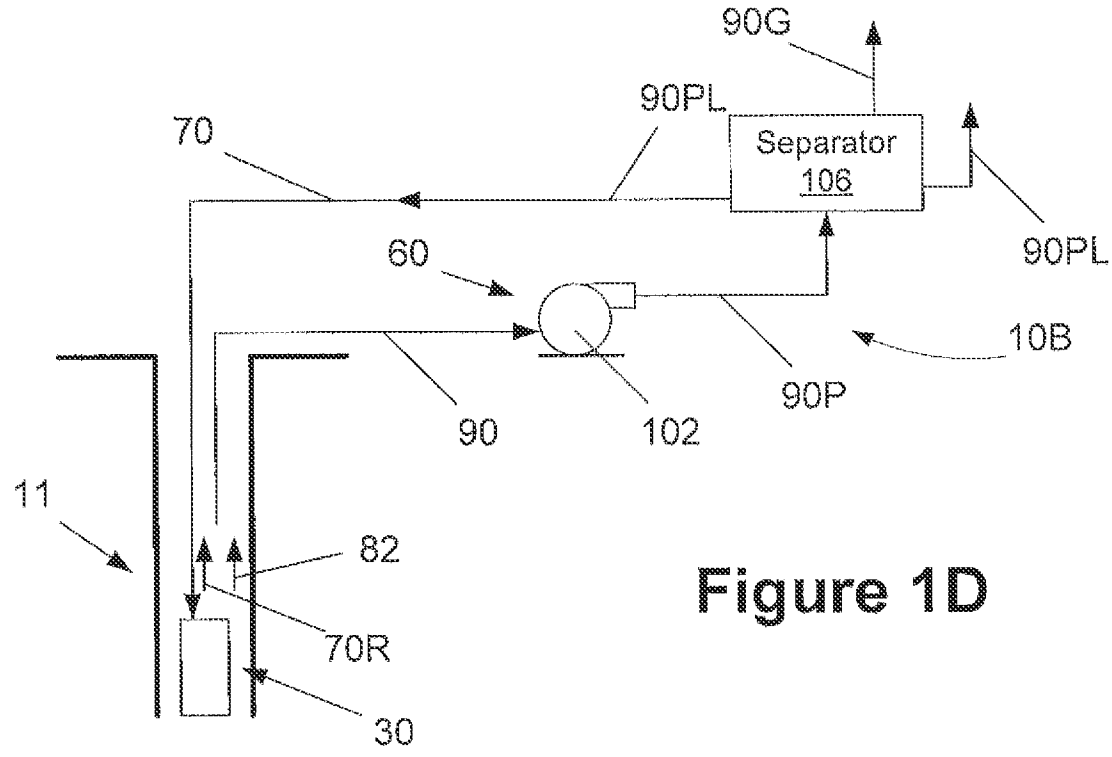


Figure 1D

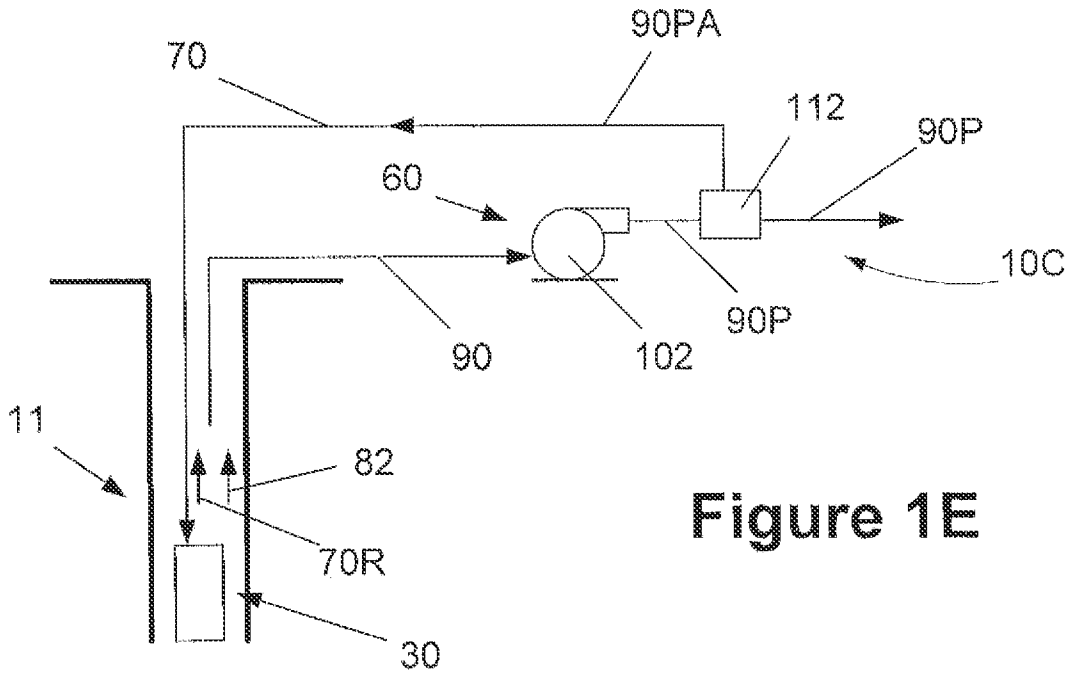


Figure 1E

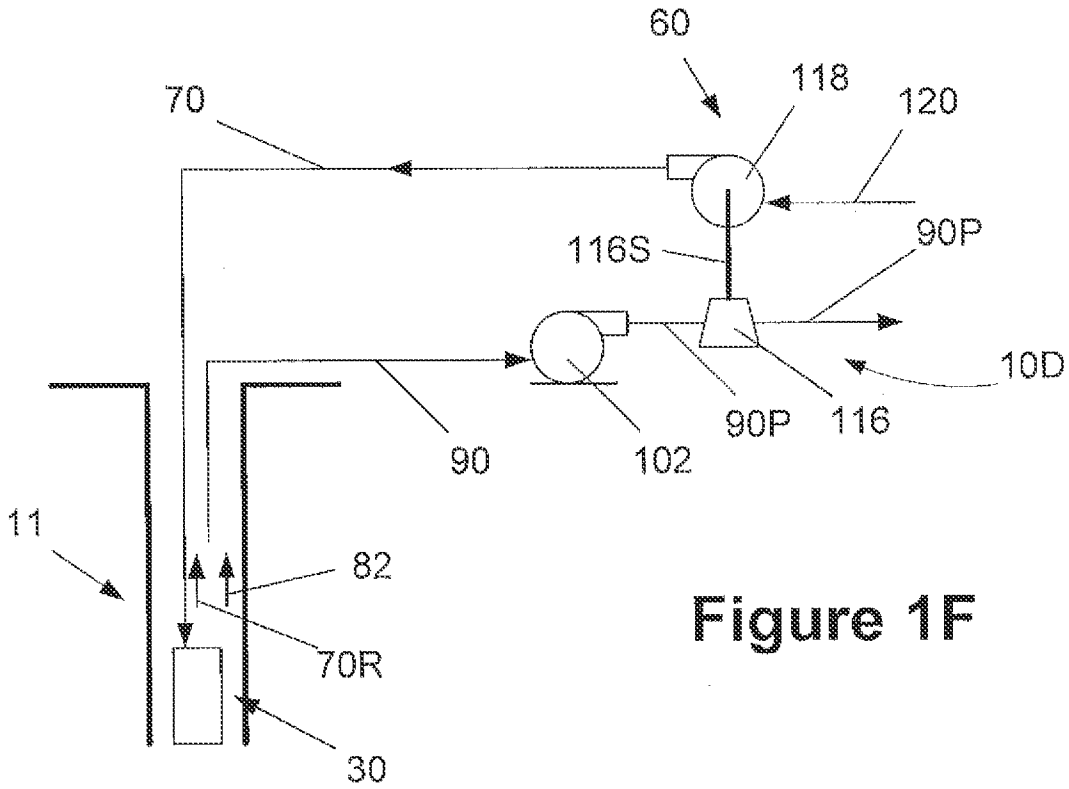


Figure 1F

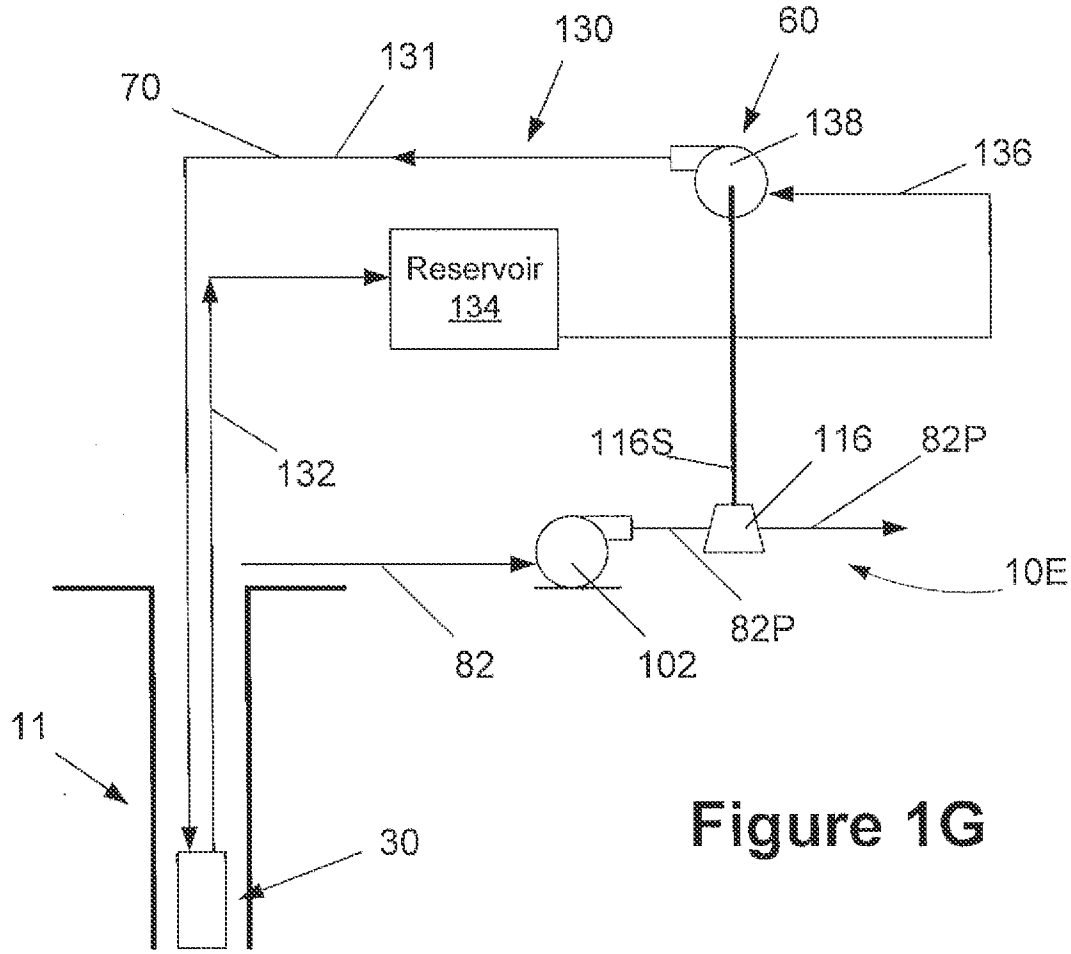

70
131
130
60
138
136
Reservoir
134
132
116S
116
82P
10E
82P
82
102
11
30

Figure 1G

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/059652

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/12 F03C1/26 F04B47/08 F04B47/10 F04D13/04
F04D13/10
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B F03C F04B F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/167116 A1 (LIMA GONCALVES MARCELO DE ALBU [BR] ET AL DE ALBUQUERQUE LIMA GONCALVE) 4 August 2005 (2005-08-04)	1-8
Y	paragraph [0040] - paragraph [0044] figure 1	9-11,13

Y	US 2011/232912 A1 (CLOSE FRANK [US]) 29 September 2011 (2011-09-29) abstract	9-11,13

X	US 2007/187110 A1 (LIMA GONCALVES MARCELO D A [BR] ET AL GONCALVES MARCELO DE ALBUQUERQUS) 16 August 2007 (2007-08-16) paragraph [0059] - paragraph [0064] figures 3,9 paragraph [0116] - paragraph [0118]	1-8

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 March 2013	13/03/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Schouten, Adri

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/059652

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2012/034113 A1 (POREL LOUIS-CLAUDE [FR]) 9 February 2012 (2012-02-09) paragraph [0048] - paragraph [0050] figure 1	1-8
A	GB 2 195 606 A (NORSKE STATS OLJESELSKAP NORSKE STATS OLJESELSKAP [NO]) 13 April 1988 (1988-04-13) abstract	9-26

4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/059652

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8

A system located in a subsea environment comprising a pressurized fluid supply pump positioned on a skid.

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2. claims: 9-26

A system located in a subsea environment comprising a booster pump.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/059652

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005167116 A1	04-08-2005	BR 0303094 A	05-04-2005
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US 2011232912 A1	29-09-2011	NONE	
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		US 2007187110 A1	16-08-2007
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		NO 863130 A	05-02-1988
		US 4848471 A	18-07-1989