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**US 7314084 B2** **US 20100119380 A1**

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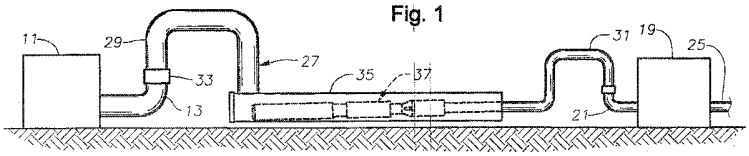
(54) Title of the Invention: **Subsea flowline jumper containing esp**
Abstract Title: **Subsea flowline jumper containing ESP**

(57) A subsea production system on a sea floor has a pump flowline jumper with a straight intermediate portion (35) and two end portions (29,31). Each end portion (29,31) has a connector for ROV assisted connection between production units. A submersible pump assembly (37) is mounted in the straight portion of the flowline jumper (35) and is lowered along with the flowline jumper into engagement with the production receptacles (13,21). The pump assembly (37) boosts pressure of fluid flowing from one of the receptacles to the other. A gas separator is mounted in the flowline jumper.

Fig. 1

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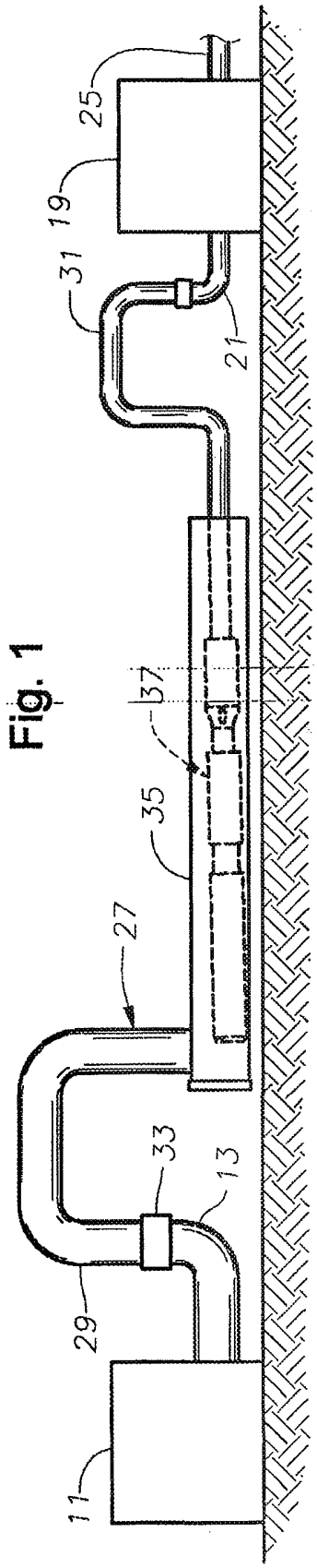


Fig. 1

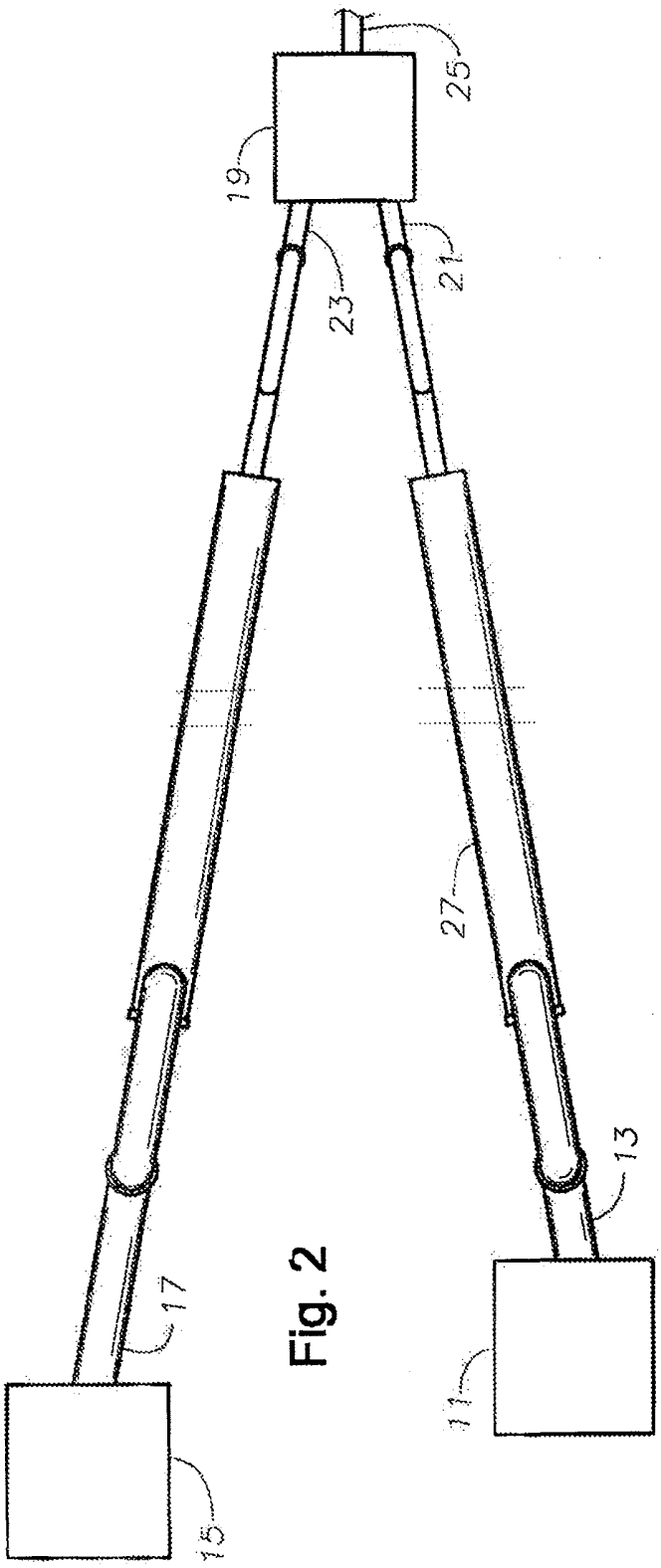


Fig. 2

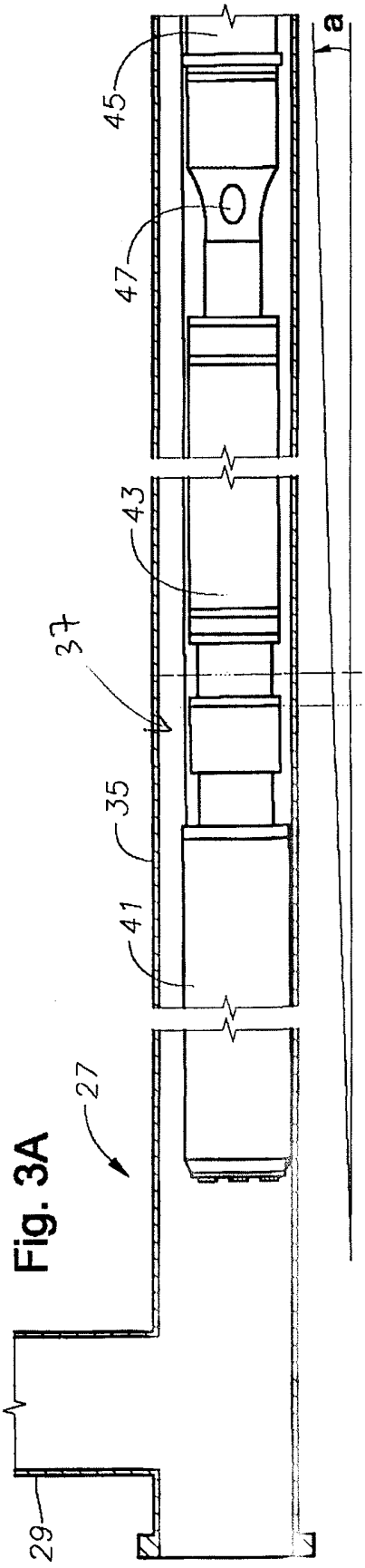


Fig. 3A

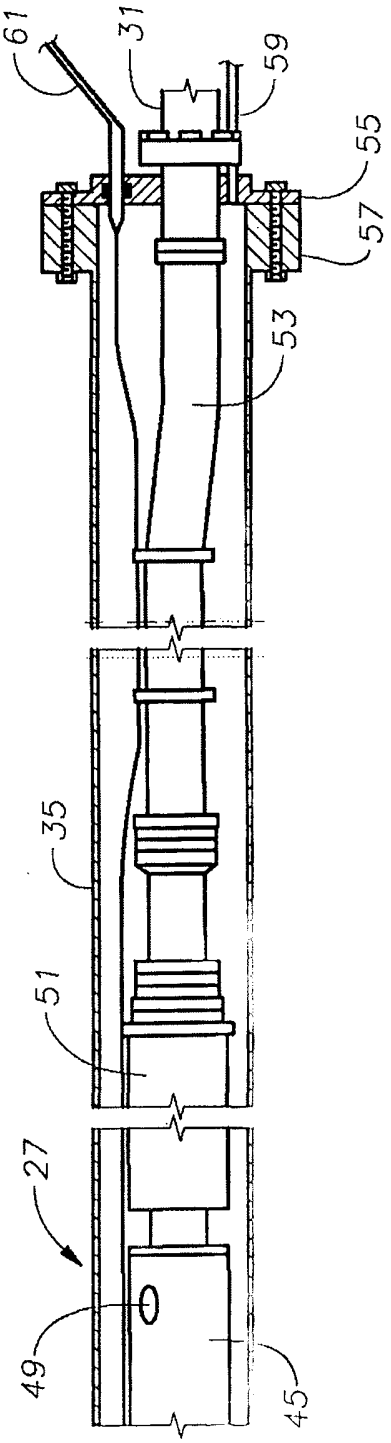


Fig. 3B

# SUBSEA FLOWLINE JUMPER CONTAINING ESP

## Field of the Invention

This invention relates in general to subsea well production systems, and in particular to flowline jumpers connecting multiple subsea production trees with a manifold.

## Background of the Invention

Offshore hydrocarbon production wells may be located in water thousands of feet deep. Some wells have inadequate internal pressure to cause the well fluid to flow to the sea floor and from the sea floor to a floating production vessel at the surface. Though not extensively used yet, various proposals exist to install booster pumps at the sea floor to boost the pressure of the well fluid.

US Patent 7,150,325 discloses installing a submersible rotary pump assembly in a caisson at the sea floor. The caisson has an inlet connected to a production unit, such as a subsea production tree, and an outlet leading to a second production unit, such as a manifold. The pump assembly is located within a capsule in the caisson in a manner that allows the capsule, with the pump therein, to be installed and retrieved from the caisson with a lift line. That solution has its merits, but does require constructing a caisson or using an abandoned well.

Flowline jumpers are commonly employed to connect various sea floor production units to each other. A flowline jumper is a pipe having connectors on its ends for connection to inlets and outlets of the production units. It is known to install a flowline jumper by lowering it from a vessel on a lift line and using a remote operated vehicle (ROV) to make up the connections. Flowline jumpers may have U-shaped ends with the connectors on downward extending legs for stabbing into receptacles of the production units. Generally, a flowline jumper is simply a communication pipe and contains no additional features for enhancing production.

According to the present invention there is provided a subsea pumping apparatus as defined by claim 1.

The subsea production system of this invention includes a pump flowline jumper having connectors at upstream and downstream ends for connection between first and second production receptacles on the sea floor. One receptacle

may be on one subsea structure, such as on a tree assembly, and the other on another subsea structure, such as a manifold. Alternately, the receptacles may be located on the same subsea structure, such as on a base positioned between two subsea structures. A submersible pump assembly is mounted within the pump flowline jumper prior to installing the flowline jumper. The pump flowline jumper with the pump assembly contained therein is lowered on a lift line and connected to the first and second receptacles.

Preferably, the portion of the pump flowline jumper containing the pump assembly is inclined with the upstream end at a lower elevation than the downstream end. A gas separator is installed within the pump flowline jumper upstream of the pump assembly for separating gas prior to entry into the pump assembly. The gas separator optionally may contain only a separator and not a pump. In that instance, the separated liquid is delivered to the inlet of the pump flowline jumper.

In the preferred embodiment, the pump assembly comprises an electrical motor that drives a rotary pump, such as a centrifugal or progressing cavity pump. Preferably the motor is located upstream from the pump so that the well fluid flowing into the flowline jumper flows over the motor before entering the pump.

In a preferred embodiment the pump flowline jumper has a substantially straight intermediate section in which the pump assembly is located. An inverted generally U-shaped section is located on each end of the intermediate section, having an upward extending leg and a downward extending leg. Connectors of the flowline jumper are located on the downward extending legs.

Optionally a second pump flowline jumper may be connected in parallel with the first pump flowline jumper. The second jumper has a second submersible pump assembly mounted therein and is retrievable independently of the first pump flowline jumper. If a separate gas separator flowline jumper is used, the separated liquid could be fed in parallel to inlets of the first and second pump jumpers.

## Brief Description of the Drawings

Figure 1 is a schematic side view illustrating part of a subsea production system, with a flowline jumper in accordance with this invention being installed.

Figure 2 is a side elevational view of the system of Figure 1., with the flowline jumper installed.

Figure 3 is an enlarged sectional view illustrating an electrical submersible pump assembly installed within the flowline jumper of Figures 1 and 2.

Detailed Description of the Invention

Referring to Figure 1, a subsea production unit 11 located on a sea floor is schematically illustrated. Unit 11 has an outlet receptacle 13 for flowing fluid to an inlet receptacle 17 of a second subsea unit 15. Units 11, 15 may be a variety of equipment, including subsea production trees, flowline end termination units, production line end termination units, manifolds and the like.

A flowline jumper 19 is shown being lowered into a position connecting unit 11 to unit 15. Flowline jumper 19 has a length sized for the spacing between units 11, 15. Flowline jumper 19 has an intermediate straight portion 21 located between two end portions. In this example, each end portion has a configuration of an inverted U, having an upward extending leg 23 joined to a downward extending leg 25. A connector 27 is mounted to each downward extending leg 25 for connecting to outlet 13 and inlet 17. Preferably connectors 27 are conventional and hydraulically actuated by an ROV 29.

Flowline jumper 19 is installed by lowering it on a lift line 31 from a vessel (not shown). Lift line 31 may have a leveling assembly such as a spreader bar 33 to maintain downward extending legs 25 at substantially the same elevation while lowering. When installed, as shown in Figure 2, intermediate section 21 is preferably inclined with its upstream end at a lower elevation than its downstream end. The angle of inclination 35 may vary.

Referring to Figure 3, intermediate section 21 of flowline jumper 19 contains a pump assembly, which in this example is an electrical submersible pump (ESP) 37. ESP 37 boosts the pressure of the fluid flowing into flowline jumper 19 from unit 11 and delivers the fluid to unit 15 (Fig. 2). ESP 37 is mounted in jumper 19 by supports and includes an electrical motor 41 that is typically a three-phase AC motor. Alternately, motor 41 could be a hydraulically driven motor. Motor 41 is filled with a dielectric fluid for lubricating and cooling. A seal section 43 is connected to motor 41 for sealing the lubricant within motor 41 and equalizing the pressure

difference between the lubricant and the well fluid pressure in the interior of jumper 19.

A gas separator 45 is connected to seal section 43 and has an intake 47 for receiving well fluid flowing into flowline jumper 19. Gas separator 45 may be employed if the well produces a sufficient quantity of gas along with the liquid so as to impede the efficiency of ESP 37. Gas separator 45 preferably has a rotary separator within it that separates liquid from gas and discharges the gas out a gas outlet 49 into the interior of flowline jumper 19.

Gas separator 45 is connected to a rotary pump 51, typically a centrifugal pump, but it could be other types, such as a progressing cavity pump. Centrifugal pump 51 contains a large number of stages, each stage containing an impeller and a diffuser. Motor 41 rotates the impellers to cause fluid to flow from gas separator 45 into pump 51 and out through a discharge tube 53. The discharge pressure is isolated from the intake pressure. In this embodiment, the isolation discharge tube 53 extends sealingly into a flange 57 of flowline jumper 19 and has a collar 55 secured to flange 57. Other devices to isolate discharge to isolate discharge pressure from intake pressure could be used.

A gas outlet 59 leads from jumper 19 for the removal of separated gas collected in flowline jumper 19. Gas outlet 59 optionally may lead to unit 11 or unit 15 (Figure 2) where it may be delivered for further processing or re-injection back into one of the wells. Preferably, gas outlet 59 may be connected and disconnected with ROV 29 (Fig. 1).

In this embodiment, a power cable 61 extends alongside ESP 37 within flowline jumper 19 to motor 41. Power cable 61 has a wet-mate electrical connector on the exterior of jumper 37 for connection to a source of power, preferably subsea. When running or retrieving flowline jumper 19, ROV 29 (Fig. 1) may be used to connect and disconnect an electrical power line to the connector. Other electrical connector arrangements are feasible. If desired, jumper 19 may have a jacket of thermal insulation.

In operation, ESP 37 (Fig. 3) will be installed within flowline jumper 19 on a vessel. Referring to Figure 1, the entire assembly is then lowered into the sea with lift line 31 and spreader bar 33. With the assistance of ROV 29, legs 25 of flowline jumper 19 will land on outlet receptacle 13 of unit 11 and inlet receptacle 17 of unit 15. Hydraulic connectors 27 are actuated by ROV 29 to complete the connections. The well fluid will flow into flowline jumper 19, and ESP 37 boosts the pressure and

discharges the fluid into unit 15. If gas separator 45 is employed, it will separate gas prior to the entry of well fluid into pump 51. For maintenance or repair, the entire flowline jumper 19 will be released from outlet receptacle 13 and inlet receptacle 17 and the assembly brought to the surface. The ESP 37 contained therein can be readily withdrawn from jumper 19 on the vessel at the surface and serviced or replaced.

In another embodiment a bypass flowline jumper is connected in parallel with pump flowline jumper 19. The bypass jumper has one end connected to an outlet receptacle on unit 11 and another end connected to an inlet receptacle on unit 15. The bypass jumper does not contain a pump in this embodiment, rather it serves only as a conduit between units 11, 15. The bypass jumper may have curved ends that are formed at a radius sufficient to allow a pipeline pig to be pumped through for cleaning of the main flowline. A valve between the bypass jumper and the main flowline would normally be closed while ESP 37 in pump jumper 19 is operating. When ESP 37 is being retrieved for repair or replacement, the operator may allow flow to continue through the bypass jumper.

In addition to a bypass flowline jumper, a second pump flowline jumper may be connected in parallel with jumper 19 and the bypass jumper. In one example the second bypass jumper is aligned with the main flowline and located between pump jumper 19 and bypass jumper. A Y-shaped junction connects the ends of jumper 19 and bypass jumpers to main flowline 64 at each unit 11, 15.

The second pump jumper may be identical to the first pump jumper 19 and contain an identical ESP 37 or its ESP 37 may differ. The separate ESPs 37 in the flowline jumpers can be sized to provide different pressure boosts from each other to optimize production. Also, the speeds of the separate ESPs can be individually controlled to match the production from unit 11.

In one embodiment a subsea production tree is connected by a flowline to a pump assembly base located on the sea bed a short distance from the tree. A pump assembly base may support one or more retrievable flowline jumpers; in this example, it contains three, one of which is a gas separator jumper containing a gas separator. The gas separator jumper releasably couples by hydraulic connectors 27 (Fig. 1) to an inlet receptacle and an outlet receptacle, each of which is permanently mounted on the base. The gas separator may be a variety of types, and in this embodiment comprises a rotary separator driven by an electrical motor similar to gas separator 37 except it is not coupled directly to a pump. The gas separator has

an outlet that connects by a hydraulically actuated connector to a gas outlet line on the base. The gas outlet line leads from the base to additional equipment for further processing. Preferably, the connector for the gas outlet line is actuable by ROV 29 (Fig. 1).

The gas separator jumper outlet receptacle is connected to a conduit that is permanently mounted to the base. The conduit has an upstream end coupled to the flowline and a downstream end coupled to a flowline that leads to additional subsea equipment such as a flowline end termination or a manifold. An inlet receptacle is connected into the conduit downstream from the gas separator outlet receptacle. A pump flowline jumper having an ESP therein releasably couples by hydraulic connectors 27 (Fig. 1) to the inlet receptacle and to an outlet receptacle. The outlet receptacle is permanently mounted on the base and is connected into the conduit downstream of the inlet receptacle.

Another inlet receptacle is permanently mounted to the base and connected to the conduit. A second pump flowline jumper is releasably connected by hydraulic connectors 27 (Fig. 1) to the inlet receptacle and an outlet receptacle. The outlet receptacle connects to the conduit downstream from the first pump outlet receptacle. The second pump jumper has an ESP mounted therein and is in parallel with the pump jumper.

An isolation valve is located between each inlet receptacle and the conduit. An isolation valve is also located between each outlet receptacle and the conduit. Closing the isolation valves for one of the pump jumpers enables the jumper to be retrieved while flow continues from the flowline, through the conduit and to the downstream flowline. Similarly, an isolation valve is located between the flowline and the gas separator jumper inlet receptacle, and an isolation valve is located between the gas separator jumper outlet receptacle and the conduit. The valves allow retrieval of gas separator jumper while flow continues through the conduit.

In addition, the conduit has a control valve between the flowline and its junction with the gas separator outlet receptacle. Closing the control valve requires the flow from the tree to flow through the gas separator. The conduit has one or more control valves between the junction with the pump inlet receptacle and pump outlet receptacle. The control valves are normally closed and open only when the pump isolation valves are closed, which enables flow from the upstream flowline to continue to the downstream flowline.

A multi-phase flow meter may also be mounted on the base for ROV retrieval. The flow meter is shown connected into the conduit downstream of the gas separator so that it monitors flow after separation. Alternately, it could be located upstream of the gas separator. In addition, a choke may also be mounted for ROV retrieval on the base. The choke is a conventional device that has a variable orifice for creating a desired back pressure in the flowline by varying the cross-sectional flow area. The choke may be mounted to the conduit downstream of the pumps, or it could be located elsewhere. Additionally, a retrievable control pod containing electronic circuitry for controlling the ESPs and the motor of the gas separator could be mounted to the base. The control pod is connected to electrical wires leading to the various motors. Optionally, the control pod could control the various valves, whether they are electrically actuated or hydraulically actuated.

In the operation of this embodiment, the gas separator separates gas from the well fluid flowing through the flowline from the tree and discharges the gas through the gas outlet line. The gas separator discharges the remaining fluid to the conduit, which delivers the fluid in parallel to the inlet receptacles of the pumps. The pumps boost the pressure and discharge the fluid to the flowline. If any one of the gas separator, or pumps needs to be retrieved, this can be done while the remaining components continue to operate by shutting off the isolation valves and retrieving the jumper. One pump may continue operating while the other along with its jumper has been removed. One or both pumps may continue to operate while the gas separator and its jumper are removed and vice-versa. Both pumps and the gas separator can be bypassed by closing all of the isolation valves and opening the control valves. This arrangement allows a pipeline pig to be pumped through the upstream flowline, conduit and downstream flowline.

The invention has significant advantages, in each of the embodiments, the pump assembly can be retrieved for repair or replacement by using a lift line and an ROV to retrieve the entire jumper. A bypass jumper can be optionally added. Pumps can be mounted in parallel flowline jumpers so as to be independently retrievable.

While the invention has been shown in only a few of its forms, it should be apparent to those skilled in the art that it is not so limited but is susceptible to various changes without departing from the scope of the invention.

CLAIMS

1. A subsea pumping apparatus for pumping fluid from a first to a second receptacle of a subsea production system on a sea floor, the apparatus comprising:

a pump flowline jumper releasably connected by hydraulic connectors at upstream and downstream ends to the first and second receptacles;

a submersible pump assembly mounted within the pump flowline jumper, the pump assembly having an intake for receiving fluid flowing from the first receptacle and a discharge for flowing the fluid to the second receptacle;

wherein the pump flowline jumper with the pump assembly contained therein is retrievable from the first and second receptacles by releasing the hydraulic connectors and using a lift line to retrieve the jumper; and

wherein the pump assembly further comprises:

a gas separator within the pump flowline jumper upstream of the pump assembly for separating gas from the fluid prior to entry into the pump assembly, the gas separator discharging separated gas into the interior of the pump flowline jumper; and

a gas outlet extending from the pump flowline jumper.

2. The apparatus according to claim 1, wherein a portion of the pump flowline jumper containing the pump assembly is inclined with the upstream end at a lower elevation than the downstream end.

3. The apparatus according to claim 1, wherein the pump assembly comprises an electrical motor that drives a rotary pump.

4. The apparatus according to claim 1, wherein the pump assembly comprises an electrical motor and a centrifugal pump.

5. The apparatus according to claim 4, wherein the motor is located upstream from the pump so that the well fluid flowing into the flowline jumper flows over the motor before entering the pump.

6. The apparatus according to claim 1, wherein the pump flowline jumper comprises:

a substantially straight intermediate section in which the pump assembly is located;

an inverted generally U-shaped section on each end of the intermediate section, having an upward extending leg and a downward extending leg; and

the connectors at the upstream and downstream ends of the flowline jumper are located on the downward extending legs.

7. The apparatus according to claim 1, further comprising:

a second pump flowline jumper having remotely operable connectors for connection to receptacles that are in parallel with the first and second receptacles;

a second submersible pump assembly mounted in the second pump flowline jumper; and

wherein the second pump flowline jumper and second submersible pump assembly are retrievable independently of said first mentioned pump flowline jumper.

8. The apparatus according to claim 7, further comprising:

a gas separator flowline jumper having remotely operable connectors for connection to receptacles upstream of the first and second receptacles; and

a gas separator mounted in the gas separator flowline jumper for separating gas from the fluid flowing into the gas separator flowline jumper and delivering the remaining portion of the fluid in parallel to the pump assemblies in the pump flowline jumpers.

9. The apparatus according to claim 1, further comprising:

a bypass flowline jumper connected in parallel with said first mentioned pump flowline jumper in fluid communication with the first and second receptacles, the bypass flowline jumper having a through-bore to enable pipeline pigs to pass.

INTELLECTUAL PROPERTY OFFICE

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| **Application No:** | GB1117368.9 | **Examiner:** | Mr David Hotchkiss |
| **Claims searched:** | 1 - 9 | **Date of search:** | 7 November 2011 |

# Patents Act 1977: Search Report under Section 17

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance |
|---|---|---|
| A | - | US7314084 B2 (PETROLEO) Whole document |
| A | - | US2010/119380 A1 (SCHLUMBERGER) Whole document |

Categories:

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| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC$^{X}$ :

Worldwide search of patent documents classified in the following areas of the IPC

E21B; F04B

The following online and other databases have been used in the preparation of this search report

Online: WPI, EPODOC

**International Classification:**

| Subclass | Subgroup | Valid From |
|---|---|---|
| E21B | 0043/013 | 01/01/2006 |
| E21B | 0043/12 | 01/01/2006 |
| F04B | 0047/06 | 01/01/2006 |