

Subsea pumping system

The present invention relates to a pumping system for use in a remote location such as a subsea hydrocarbon extraction facility, comprising a source for high pressure
5 fluid and a fluid driven pump.

In many fields, the pressure of the hydrocarbon reservoir will decrease as the reservoir gets depleted. Therefore, to enable increased recovery of hydrocarbons, there has been an increased use of boosting equipment. One example of this are gas
10 lift systems. Another is the so-called ESP's that is electrical submersible pumps that are suspended in a hydrocarbon well to boost the pressure and enable hydrocarbons to be lifted to surface. The drawback of such installations is that each well needs a pump with the associated power supply and control system. Another drawback is that only liquid pumps are feasible in this situation since compressors are more
15 difficult to operate in wells.

There is therefore an increased interest in locating the boosting equipment on the seabed and pump well fluids collected from several wells. This also enables the use of separators so that each phase of the well fluids (gas, oil or water) can be
20 separated from each other and transported to different locations. For example can water be separated out from the well stream and reinjected into the ground, thus saving space and treatment equipment on the platform.

Added to this is the fact that new fields are found in deeper waters and further from
25 land. This requires long step out systems for power supply and control.

Many subsea process plants with process boosting require more pumps in addition to a main booster. Traditionally, subsea pumps are large, heavy and complex units that also require electric power supply and barrier oil supply provided over a long
30 distance. The electric system itself is highly complicated and costly, including for example penetrators, connectors, cable, transformers and motor control systems. If the host for electric power and barrier oil is a vessel or a platform, the pump supply systems will occupy highly valuable deck-area

Hydrocarbons coming from wells can be divided into several types, having mainly gas with some water or oil, having mainly oil with some water. In some instances there may be three phases, gas, oil and water. The well stream is separated into separate phases in a separator. The water may preferably be injected back into the
35 formation.

In applications with several separation stages, the separated process medium at the later stages must be commingled with the separated process medium at first stage.
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Since the process medium loses pressure throughout the separation stages, the later stages separated process medium must be boosted to reach the pressure of the first stage separated process medium. One current solution for boosting the pressure of the later stage separated process medium is to use an ejector that uses another pressurized medium as motion fluid.

5 However, the ejector solution has the disadvantages of low efficiency and mixing of motion fluid with the driven medium.

Conventional centrifugal or screw pumps have a limited tolerance to sand. Current solution is either to let the sand go through the pump and use very high grade materials and coatings, or
10 if the sand production is very high, the sand can be separated out upstream the pump and bypassed by means of an ejector. This ejector system is rather complex and requires high flow of motion fluid.

It is therefore a need for a different solution to boost a fluid subsea.

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The aim of the invention is to provide a simpler system that does not require dedicated supply of utilities (e.g. electric power and barrier fluid) from an external host, and hence will be more or less autonomous. It is also an aim of the invention to provide a system that is robust to sand and capable of pumping viscous sand slurries. This is achieved by using a subsea
20 available pressurized fluid as a motive fluid for the pump, that the pump is a reciprocating pump and that it comprises means for creating pressure pulses in the motive fluid for operation of the pump.

In an aspect of the invention, there is provided a subsea pumping system for use in a remote
25 location such as a subsea hydrocarbon production facility, comprising a source for high pressure fluid; a reciprocating or oscillating fluid driven pump, and a sequential valve able to transform a steady fluid pressure to a pulsating fluid pressure in a motive fluid for excitation of the fluid driven pump, the sequential valve is fitted in a branch pipeline between the source for high pressure fluid and the fluid driven pump, wherein the high pressure fluid in a
30 pipeline, used as a motive fluid for the fluid driven pump, is the hydrocarbon production produced from a well, and wherein the source for the motive fluid is a compressor using produced gas.

The working principle of the autonomous pump invention is to bleed off some process fluid from a high pressure space to a low pressure space. In the bleed-off line it shall be fitted a valve, or arrangement of valves (hereafter named sequencing valve) which working task is to transform a steady fluid pressure to a pulsating fluid pressure for excitation of a reciprocating or oscillating pump.

Preferably the reciprocating pump is a piston type, diaphragm type or hose diaphragm type. Especially diaphragm pumps and hose diaphragm pumps are robust to sand and particles.

- 10 The means for providing the reciprocating driving fluid is a sequential valve, preferably a rotating valve or a shuttle valve. It can also be an arrangement of several valves. One sequencing valve (or valve arrangement) can be made to operate one single pump or multiple pumps.
- 15 In one embodiment of the invention where there is sand in the well fluids, the sand is separated out in a de-sander and pumped using the reciprocating pump while the clean fluid is used as the motive fluid for the pump.

In one embodiment where the hydrocarbons are mainly gas, the motive fluid is gas that is pressurized in a compressor and the compressed gas is used as the motive fluid to power the pump for the liquid phase.

5 In another embodiment the hydrocarbons are mainly liquids. The hydrocarbons are separated into an oil phase and a water phase. The oil phase can then be used as the motive fluid to increase the pressure in the water line to enable reinjection of water into the formation. Or vice versa, pressurized water for water injection can be used as motive fluid for increasing the oil pressure for transport to an oil-reception
10 facility.

The invention shall now be described with reference to the accompanying drawings where

Fig. 1 is a principal sketch of the invention,
15 Fig. 2 is a drawing of a first embodiment of the invention comprising a compressor,
Fig. 3 is a drawing of a second embodiment of the invention comprising a compressor,
Fig. 4 is a drawing of a first embodiment of the invention comprising a liquid pump,
Fig. 5 is a drawing of a third embodiment of the invention,
20 Figs. 6 – 8 are drawings of different embodiments of sequential valves.

Referring first to Fig. 1 there is shown a sketch of the principle of the invention. A pump 12 is connected to a pipeline 13 to receive a fluid to be pressurized, for instance hydrocarbon stream from one or more wells (not shown). The pump is a
25 reciprocating pump preferably a hose diaphragm pump, a diaphragm pump or a piston pump. The pumped fluid is led to a pipeline 14 which transports the hydrocarbons to a receiving facility (not shown). Another pipeline 16 conveys a fluid of higher pressure than line 13. The fluid is led through a sequential valve 17 which in turn is connected to the pump 12 and delivers pulsed fluid to be the motive
30 fluid for the pump 12.

The high pressure fluid can be served from a remote facility. Reference can here be made to NO patent 323785 that describes a method for generating electricity in a subsea station. The high pressure fluid may be an injection fluid that is transported
35 from a land based facility that pressurizes the fluid to a higher pressure than what is needed for the well and the excess energy/pressure is drawn from this fluid.

In Fig. 2 there is shown a first embodiment of a practical use of the invention where the fluids produced from one or several subsea wells are separated into a first and
40 second fluid phase, where the first phase may be a gas and the second phase may be a liquid such a condensate, oil or water or combination of those. The hydrocarbons are transported through pipeline 20 to a separator 22. In the separator 22 the first

phase is separated from the second phase and the first phase is led through pipeline 23 to a compressor 24. The second phase is led through pipeline 30 to the reciprocating pump 32. In pump 32 the liquid is pressurized up and led into export pipeline 34. The compressor outlet is connected to a pipeline 25 for the high pressure first phase. A pipeline 26 branches off pipeline 25 to carry some of the first phase through sequential valve 27 and then back to the inlet pipe 23 upstream compressor 24. Alternatively the light fluid could after sequential valve 27 be led back to pipeline 20 or separator 22. The valve is arranged to set up an alternating high and low pressure pulse to drive the reciprocating pump. A reciprocating pump, works by pulsing the pressure outside of a diaphragm or piston to set up the pumping action. This arrangement is not describes further as such pumps are well known in the art. Examples of sequential valves will be shown later with reference to Figs. 6-8.

The first and second phases may be recombined downstream of the pump(s). In this case it is advantageous to pressurize the second phase to a higher pressure than the first phase, to facilitate recombination.

In Fig. 3 there is shown a second embodiment of the invention. In this case the produced fluids from the well are three phase fluids, i.e. gas oil and water. The hydrocarbons stream is led through pipeline 20 to a first separator 22 that separates the fluids into a gaseous phase that is led to pipeline 23 and a liquid phase that is led through pipeline 30. The gas is led through a compressor 24 and to the gas export pipeline 25. As in Fig. 2 a branch leads the high pressure gas through sequential valve 27 that sets up the pressure pulses for driving the reciprocating pump 32. The liquids that are separated out in first separator 22 is led to a second separator 40. This separates the oil from the water. The oil is led through pipeline 41 to reciprocating pump 32 which pressurizes up the oil and then through pipeline 42 and recombines the oil with the gas. The water is led through pipeline 44 to another pump 46 that pressurizes the water so that it can be injected into the formation.

In Fig. 4 there is shown yet another embodiment of the invention. In this case the fluids produced by the well(s) are also a three phase fluid but may be a two phase fluid, that is, oil and water. As in the other embodiments hydrocarbons from the well are transported through pipeline 20 to a first separator 22. This first separator 22 is only needed in the case where the well fluids contain gas. The gas is led through an export pipeline 52 to a remote facility. The liquids are led through pipeline 54 to a second separator 56 that separates the oil from water. The water is led through pipeline 58 to a pump 60 and then through pipeline 62. The pipeline 62 can lead to an injection well or to another facility. The oil is led trough pipeline 64 to reciprocating pump 66 and then to export pipeline 68. In the case of there being

gas in the well stream the gas and oil can be recombined downstream of the reciprocating pump. A pipe 70 branches off the pipeline 62 to convey pressurized fluid through sequential valve 27 and back through line 71 into pipeline 58 (the pump inlet). Similar to what is described earlier the high pressure fluids led through line 70 and sequential valve 27 sets up the pulses that make up the driving fluid for the reciprocating pump 66.

At times well fluids may contain particles such as sand. The sand can be very abrasive and it is normally not desirable to have sand in contact with rotary equipment, such as rotary pumps, since it can wear out the pump impellers and dynamic seals and bearings very quickly. Diaphragm pumps and hose diaphragm pumps are far more tolerant of particles since they do not have rotating parts, dynamic seals or bearings. In Fig. 5 there is therefore shown an embodiment where a well stream contains sand. The well fluids are transported from the well in pipeline 20 to a de-sander 80. The clean fluids are conveyed through pipeline 82 to pump 84 and to export pipeline 86. The sand slurry is conveyed through line 90 to a reciprocating pump 92. The pump 92 pressurizes the slurry to a pressure that is equal, or preferably a little higher, than in pipeline 86 and is recombined with the well fluids downstream of pump 84. A line 87 branches off pipeline 86 downstream of the pump and, as in the previous embodiments, are led through sequential valve 27 and then through line 87 back into pipeline 82 upstream of the pump. The sequential valve 27 sets up the pressure pulses that drive the reciprocating pump 92.

Figs. 6-8 show examples of a sequential valve that may be used in the invention. In Fig. 6 there is shown a high pressure line 101 with a first valve 102. After that there is a low pressure line 103 with valve 104. Between the valves 102 and 104 a line 105 leads to the reciprocating pump. The valves 102 and 104 are run in sequence corresponding with the pulsing of the reciprocating pump. The valves may be controlled electrically or hydraulically but ideally they are controlled by the fluid to create a fully autonomous system.

In Fig. 7 the sequential valve is a rotating valve with its rotational axis parallel with the pipeline axis. As the valve rotates it will in sequence convey high pressure fluid through bore 106 to the reciprocating pump or exhaust spent fluid through bore 108. The valve can be arranged with a fixed rotational speed that is synchronized with the oscillations of the pump or it can be mechanically linked to the pump.

In Fig. 8 the sequential valve is a rotating valve with its rotational axis perpendicular to the pipeline axis. The valve has a rotating vane 110 that sequentially opens for high pressure fluid to the pump and exhausts the spent fluids. The vane can be rotated with an electric motor but preferably is controlled either by the pump or by the pressurized fluid to create an autonomous system.

Another kind of valve that may be used is the kind called a shuttle valve. Also other types of valves and valve-arrangements may be fit for purpose.

- 5 To achieve a fully functional system there must be a set pressure differential between the pump strokes. The maximum discharge pressure is set by the process pressure supplied to autonomous pump drive in displacing sequence. This pressure can be increased by increasing main booster discharge pressure, e.g. by means of a restriction at main booster discharge, downstream the branch-off to autonomous
10 pump drive.

- The pump charging sequence requires a positive differential pressure between pumped medium in pump chamber and pump drive medium. This differential pressure can be increased either by increasing suction pressure to autonomous pump
15 (e.g. by increasing liquid column upstream pump), or by decreasing drive medium pressure.

- One method of achieving this is to increase pulsation pressure negative amplitude by creating low pressure discharge by means of a venturi arrangement. Pulsation
20 pressure negative amplitude can also be increased by means of an ejector incorporated in the sequencing valve or sequencing valve arrangement.

- By adjusting the restriction it will be possible to maintain the correct pressure differential between the high pressure and the low pressure. This pressure
25 differential can therefore be used to control the sequential valve. By adjusting the restriction the system will be able to handle changes in the composition of the well fluids.

- A charging sequence may be determined by the pressure on the pump inlet. If flow
30 should be regulated, initially the frequency on the valve must be regulated. However there is a possibility to achieve a self-regulating pump for compressor applications as the liquid column in the separator would determine how much the pump will be filled during a "charging" sequence.

- 35 The invention has been described with reference to some embodiments. A person skilled in the art will realize that there are several other ways of utilizing the invention. The reciprocating pump can for example be used for in a circuit for supplying cooling fluid to a compressor. It can also be used to set up a high pressure stream to purge a separator of accumulated sand. Also, more than one pump can be
40 installed in the system. In the case of having more than one pump it is preferable to control both pumps with one single sequential (rotating) valve.

CLAIMS

1. Subsea pumping system for use in a remote location such as a subsea hydrocarbon production facility, comprising
- 5 a source for high pressure fluid;
a reciprocating or oscillating fluid driven pump, and
a sequential valve able to transform a steady fluid pressure to a pulsating fluid pressure in a motive fluid for excitation of the fluid driven pump, the sequential valve is fitted in a branch pipeline between the source for high pressure fluid
- 10 and the fluid driven pump,
wherein the high pressure fluid in a pipeline, used as a motive fluid for the fluid driven pump, is the hydrocarbon production produced from a well, and wherein the source for the motive fluid is a compressor using produced gas.
- 15 2. The subsea pumping system according to claim 1, wherein the reciprocating pump is a diaphragm pump.
3. The subsea pumping system according to claim 1, wherein the reciprocating pump is a hose diaphragm pump.
- 20 4. The subsea pumping system according to claim 1, wherein the reciprocating pump is a piston pump.
5. The subsea pumping system according to claim 1, wherein the sequential valve
- 25 comprises an inlet valve and an outlet valve that is synchronized to provide the pulses.
6. The subsea pumping system according to claim 1, wherein the sequential valve comprises a rotating sequencing valve.
- 30 7. The subsea pumping system according to claim 6, wherein the rotating sequencing valve has a rotational axis parallel or transverse to a pipeline axis for the pipeline wherein the valve is arranged.
- 35 8. The subsea pumping system according to claim 1, further comprising at least one separator.