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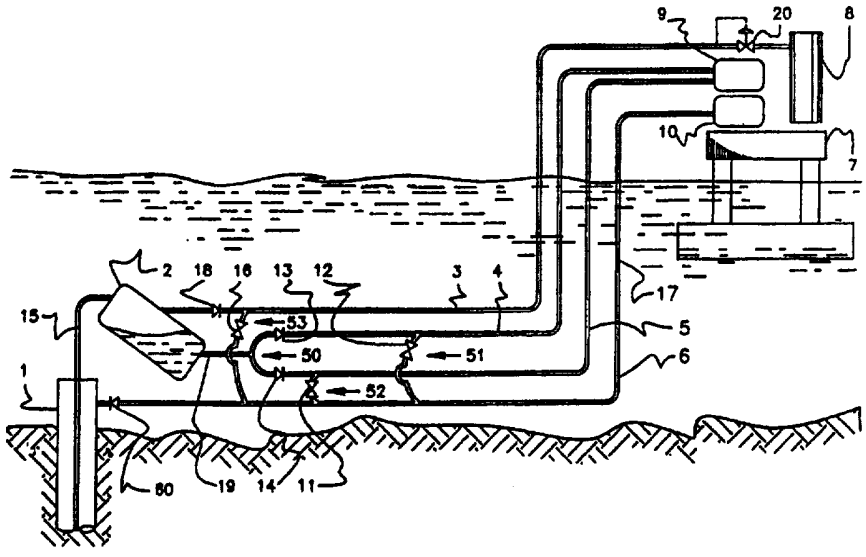


(57) Abstract

A subsea primary separating vessel (2, 22) is installed close to the wellhead (1, 31) of an oil producing well to effect primary separation of the liquid and gas phases of the fluids produced. A line (3, 23) connected to the top of the separating vessel allows separated gas to flow to a gathering vessel (8, 28) located at any gathering centre. At least one flow line (4, 5, 24) connects the lower part of the separating vessel to a vessel (9, 29) located at any gathering centre. When the volume of liquid phase which separates out within the at least one flow line begins to exert a back pressure which adversely affects production from the well, high pressure gas can be injected into the flow line(s) for a specific period of time in order to promote the flow of liquid gas to the vessel (9, 29). If it is desired that flow efficiency should be increased, a mechanical interface driven by the high pressure gas may be used to encourage flow of the liquid phase.

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# "METHOD AND EQUIPMENT FOR OFFSHORE OIL PRODUCTION WITH PRIMARY GAS SEPARATION AND FLOW USING THE INJECTION OF HIGH PRESSURE GAS"

This invention relates to a method and equipment to assist the flow, up to the surface, of hydrocarbon mixtures containing a high gas concentration. It may be applied to a single offshore oil well or to an undersea gathering line (manifold) which receives production from various wells for subsequent delivery.

In the flow of oil, as occurs in undersea production lines, large pressure head losses occur due mainly to the large simultaneous flows of gas and oil, and which give rise to great shear stresses in the flow.

In the technique of deep offshore production another factor which gives rise to high pressure gradients is the great difference in level between the wellhead and the platform, which very frequently makes it necessary to use extensive vertical pipes to deliver the products to the surface; such pipes are known to those skilled in the art as "risers".

These factors result in high pressures at the wellhead or in the undersea gathering line (manifold), significantly reducing production.

The object of this invention is to provide equipment and a method to assist flow of the multiphase production from an oil producing well to any gathering station.

It is a further object of this invention to promote the primary separation of the liquid and gas phases of fluids produced by an oil producing well and to encourage flow of these two separated phases along separate flow lines to a gathering station.

A subsea primary separating means is used to perform a primary separation between the liquid and gas phases right on the ocean bed. Where the separating means is a separating vessel the gas phase is carried away to the gathering station by a line connected to the top of the primary separating vessel and the liquid phase is carried by at least one line connected to the lower part of the primary separating vessel.

High pressure gas is injected into the flow line at intervals to encourage

flow of the liquid phase settling out in this line to the gathering station.

The liquid phase is caused to flow to a gathering station through at least one flow line. U-shaped pipes connect the high pressure gas line to the flow lines so that high pressure gas can be injected into the flow line for a required period of time.

This volume of high pressure gas makes it possible for the liquid phase which has collected in the line to flow to the gathering centre. Check valves installed in the flow lines prevent the high pressure gas from entering the primary separating means.

If it is desired to increase the flow efficiency, a mechanical interface may be used to push the liquid phase separating out in the flow line to the gathering centre. In this case the high pressure line must be provided with means to allow the mechanical interface to be inserted at the launching point and with means to allow the mechanical interface to travel along within the high pressure line and into the flow line. The flow line must in turn have means to receive the mechanical interface without interrupting production.

Thus one aspect of the present invention provides equipment for offshore oil production with primary gas separation and flow, by means of high pressure gas injection; characterized in that it comprises :- a subsea primary separating means which receives the production from an offshore oil well delivered from a wellhead through a flow line; a separated gas flow line which connects the upper part of the primary separating means to a collecting vessel located at a gathering centre; at least one flow line which connects the lower part of the subsea primary separating means to a gathering centre; and a U-shaped pipe length which is fitted with a shut-off valve and connects said at least one flow line to a high pressure gas line which is fitted with a check valve near to the point where the high pressure gas line connects to the wellhead to avoid back flow of gas originating from the annulus of the well; wherein said at least one flow line has a check valve located between the subsea primary separating means and the point of connection to said U-shaped pipe length in order to prevent the injected high pressure gas from exerting a back pressure

which would adversely affect production from the oil producing well.

The flow line for the separated gas may include a pressure control valve, which makes it possible to control the level of the liquid phase of fluid produced which collects in the subsea primary separating means.

If it is necessary to remove any accumulations of condensate within the flow line for the separated gas, the high pressure gas line can be connected to it, this making it possible for a travelling mechanical interface device, which causes the condensed fluids to flow to the gathering station, to pass through the separated gas line. In this case the shut-off valve in the U-shaped pipe length must be a clear-flow valve, and a check valve must be fitted to prevent the high pressure gas from passing into the primary separating means.

Another aspect of the invention provides a method for offshore oil production with primary gas separation and flow by the injection of high pressure gas characterized in that it comprises the following steps:

a) Closing a shut-off valve in a U-shaped pipe length which connects flow lines to a high pressure gas line;

b) Allowing the fluids produced by the well to flow through a flow line from a wellhead to a subsea primary separating means where primary separation between the liquid and gas phases takes place,

c) Separating out the liquid phase in the lower part of the subsea primary separating means and also allowing it to accumulate in said flow lines;

d) When the back pressure exerted by the fluid accumulated in the flow lines begins to rise, adversely affecting production, then opening a shut-off valve in said U-shaped pipe length which connects the high pressure gas line to the flow line, and maintaining it open for a predetermined period in order to allow a volume of high pressure gas to pass within the flow line;

e) Using a check valve fitted in the flow line close to the point of connection between the flow line and the U-shaped pipe length to prevent the injected high pressure gas from exerting any back pressure which would affect production from the well;

f) Using the injected high pressure gas then to cause flow, to a gathering centre, of the liquid phase which has accumulated in the flow line; and

g) After closing the shut-off valve which was previously open, allowing the liquid phase again to accumulate in the flow line into which the high pressure gas was injected, thus completing performance of the method.

The characteristics of this invention will be better understood from the following detailed description, which is given merely by way of example, taken together with the associated drawings which are referred to below and which form an integral part of this description.

Figure 1 is a diagrammatic representation of an application of the method and equipment according to this invention in which two lines are used for the delivery of the production flow.

Figure 2 is a diagrammatic representation of the method and equipment according to this invention in which a single line is used for delivery of the production flow.

Figure 1 shows a diagrammatic representation of an embodiment of the equipment according to this invention, in which two lines 4 and 5 are used to effect flow of the liquid phase of the fluids produced by an offshore oil well to a gathering centre. In this embodiment the fluids are collected in a surge tank 9 located on a platform 7 serving as the gathering centre.

A wellhead 1 is connected through a flow line 15 to the top of an undersea separating means, shown in Figure 1 as a subsea primary separating vessel 2, the function of the separating means being to effect primary separation of the liquid and gas phases of the fluids produced by the offshore oil well.

A high pressure gas line 6 connects the annulus of the offshore well to a compressed gas supply system 10, which in this embodiment is located on the platform 7. A check valve 60 is fitted in the high pressure gas line 6, close to the wellhead 1. The purpose of this check valve is to avoid any back flow of gas leaving the annulus.

The high pressure gas line 6 is normally used to inject gas used for the artificial lifting of the produced fluids into the annulus of a production well, a

technique known by those skilled in the art as gas lift.

A flow line 19 connects the lower part of the subsea primary separating vessel 2 to a gathering device which in this embodiment is a U-shaped pipe length 50 which has one of its ends connected to the flow line 4 and the other connected to the flow line 5. Flow lines 4 and 5 have check valves 13 and 14 respectively fitted close to the points of connection with the U-shaped pipe length 50.

A flow line 3 for separated gas is connected to the top of the subsea primary separating vessel 2, and this line 3 is also connected to a collecting vessel 8 which in this embodiment is located on the platform 7. The gas which separates out in the subsea primary separating vessel 2 should preferably pass through this separated gas flow line 3.

A pressure control valve 20 fitted in separated gas flow line 3 will also be seen in Figure 1. This valve, which is optional and may be located at any point in the line, is designed to control the flow of separated gas to the collecting vessel 8 in accordance with parameters determined by the operating conditions.

A U-shaped pipe length 51, which is fitted with a clear-flow shut-off valve 12, connects the high pressure gas line 6 to the flow line 4. A U-shaped pipe length 52 which is fitted with a clear-flow shut-off valve 11 connects high pressure gas line 6 to flow line 5. The term clear-flow valve is intended to denote a valve which, when fully open, can pass a mechanical interface or pig therethrough.

Figure 1 also shows a U-shaped pipe length 53 which also has a clear-flow shut-off valve 16 and connects the high pressure gas line 6 to the separated gas flow line 3. Its use is optional, as will be shown below. If it is used, then a check valve 18 must be fitted in the separated gas flow line 3 near to the point where it connects with the U-shaped pipe length 51.

Figure 2 shows a diagrammatic representation of another embodiment of the equipment according to this invention, in which only one line 24 is used to encourage flow, to a gathering centre, of the liquid phase of the fluids produced by an offshore oil well. In this embodiment the fluids are collected by

a surge tank 29 located on a platform 27.

A wellhead 31 is connected by a flow line 21 to the top of a subsea separating means, which is shown in the Figure 2 as a subsea primary separating vessel 22 and whose function is to promote primary separation of the liquid and gas phases of the fluids produced by the offshore oil well.

A high pressure gas line 26 connects the annulus of the offshore well to a compressed gas supply system 30, which in this embodiment is located on platform 27. A check valve 70 is fitted to high pressure gas line 26 close to the wellhead 31. The function of this check valve is to avoid any back flow of gas from the annulus.

As in the previous embodiment, the high pressure gas line 26 is normally used to inject the gas used for artificial lifting of the produced fluids into the annulus of the producing well.

A flow line 24 connects the bottom part of subsea primary separating vessel 22 to surge tank 29.

The top of the subsea primary separating vessel 22 is connected to a flow line 23 for separated gas, which is in turn connected to a collecting vessel 28, which in this embodiment is located on the platform 27. Gas which separates out in the subsea primary separating vessel 22 should preferably pass through this separated gas flow line 23.

Figure 2 also shows a pressure control valve 39 fitted to the separated gas flow line 23. This valve, which is optional, may be located at any point in the line and is used to control the flow of separated gas to the collecting vessel 28 in accordance with parameters previously defined by the operating conditions.

A U-shaped pipe length 35, which is fitted with a clear-flow shut-off valve 47, connects the high pressure gas line 26 to the flow line 24.

A U-shaped pipe length 36, which also has a clear-flow shut-off valve 37, connects the high pressure gas line 26 to the separated gas flow line 23. Its use is optional, as will be shown below. If it is used, a check valve 38 must then be fitted to separated gas flow line 23 close to the point of connection with U-shaped pipe length 36.

The method according to this invention is described below step by step:

a) The clear-flow shut-off valves (11, 12 - Figure 1) (47 - Figure 2) of the U-shaped pipe lengths (52, 51 - Figure 1), (35 - Figure 2), which connect flow lines (4, 5 - Fig. 1) (24 - Fig. 2) to high pressure gas line (6 - Fig. 1) (26 - Fig. 2) are closed;

b) The fluids produced by the well flow through the flow line (15 - Fig. 1) (21 - Fig. 2) from wellhead (1 - Fig. 1) (31 - Fig. 2) to the subsea primary separating vessel (2 - Fig. 1) (22 - Fig. 2) where primary separation between the liquid and gas phases takes place;

c) The liquid phase separates out in the bottom part of the subsea primary separating vessel (2 - Fig. 1) (22 - Fig. 2) and also accumulates in the flow lines (19, 4, 5 - Fig. 1) (24 - Fig. 2). As the liquid phase accumulates in the lengths of the flow line which are horizontal or have only a small gradient, the back pressure exerted by that volume of fluids on the production from the well will be small,

d) When the back pressure exerted by the volume of fluids accumulated in the flow lines (19, 4, 5 - Fig. 1)(24 - Fig. 2) begins to increase and to adversely affect production from the well, then a clear-flow shut-off valve (11, 12 - Fig. 1) (47 - Fig. 2) of the U-shaped pipe length (52, 51 - Fig. 1) (35 - Fig. 2) which connects the high pressure gas line (6 - Fig. 1) (26 - Fig. 2) to the flow line (4, 5 - Fig. 1) (24 - Fig. 2) opens for a predetermined period so as to allow a volume of high pressure gas to pass into that flow line; a check valve (13, 14 - Fig. 1) (25 - Fig. 2) fitted in the flow line (4, 5- Fig. 1) (24 - Fig. 2) close to the point of connection between this and the U-shaped pipe length (52, 51 - Fig. 1) (35 - Fig. 2) prevents the injected high pressure gas from exerting any back pressure which affects the production of the well.

e) The injected high pressure gas then promotes flow of the liquid phase which has accumulated in flow line (4, 5 - Fig. 1) (24 - Fig. 2) to the gathering centre,

f) After closing of the clear-flow shut-off valve which was previously open

the liquid phase will again accumulate in the flow line (4, 5 - Fig. 1) (24 - Fig. 2) into which the high pressure gas was injected, thus completing performance of the method.

One possibility for increasing the efficiency of flow of the liquid phase driven by the high pressure gas is to use a mechanical interface (17 - Fig. 1) (34 - Fig. 2) to prevent direct contact between the high pressure gas and the liquid phase, because this direct contact of two miscible fluids can cause a reduction in the volume delivered.

If such mechanical interfaces are used, means must be used to launch and to receive these interfaces at the location where they are manoeuvred into position. These means are not described here as they do not form an integral part of the invention and also because they are widely known to those skilled in the art.

It is also necessary that means must also be used to allow passage of such a mechanical interface from the high pressure gas line to the U-shaped pipe length into which it must travel. Merely by way of example it is suggested in this situation that the device disclosed in our Brazilian patent PI9601401-6 should be used. Nevertheless, any other type of device which satisfactorily performs the task may be used.

Figure 1 shows a mechanical interface 17 within the high pressure gas line 6. Likewise, in Figure 2 a mechanical interface 34 may be seen in the high pressure gas line 26.

The use of more than one flow line to deliver liquid phase to the gathering centre, as illustrated in the embodiment proposed in Figure 1, has the advantage that it allows the liquid phase to accumulate at all times in at least one of the flow lines while the other (or others) is (are) receiving injected high pressure gas, and vice versa. It will be understood that the limiting number of flow lines used will be determined by geometrical reasons (space) and economic reasons (cost/benefit ratio).

This feature makes it possible to use a smaller primary separating vessel because, if only one flow line is used as in the embodiment proposed in Figure

2, the primary separating vessel will have to be dimensioned to have the capacity to accept the extra volume of produced fluids which will be prevented from flowing along the flow line during the period while the flow line is pressurized by the injected high pressure gas.

It is recommended that the optional pressure control valve (20 - Fig. 1) (39 - Fig. 2) should be fitted in the separated gas flow line (3 - Fig. 1) (23 - Fig. 2). This valve makes it possible to control, in accordance with previously determined limits, the level of the liquid phase of the produced fluid accumulating in the subsea primary separating vessel (2 - Fig. 1) (22 - Fig. 2) because the valve opens or closes, depending on whether the gas pressure increases or decreases, this making it possible to keep the level of the fluid phase in the subsea primary separating vessel (2 - Fig. 1) (22 - Fig. 2) within desirable limits.

There is always the possibility that the separation of the liquid and gas phases which occurs inside the subsea primary separating vessel (2 - Fig. 1) (22 - Fig. 2) is incomplete, or that separating out of the liquid phase occurs as a result of special flow conditions when the separated gas is subsequently passing through the flow line (3 - Fig. 1) (23 - Fig. 2) for separated gas.

In such circumstances it is desirable that this liquid phase should be removed, because it causes serious problems. It is therefore suggested that a U-shaped pipe length (53 - Fig. 1) (36 - Fig. 2) should be fitted to connect the high pressure gas line (6 - Fig. 1) (26 - Fig. 2) to separated gas flow line (3 - Fig. 1) (23 - Fig. 2) which makes it possible to launch into that flow line a travelling mechanical interface device driven by high pressure gas,in order to remove liquid phase from the inside of the separated gas flow line. Merely by way of example the device disclosed in EP-A-0581616 may be used for this purpose.

If the length of pipe mentioned in the foregoing paragraph is used it will be necessary to fit a check valve (18 - Fig. 1) (38 - Fig. 2) between the subsea primary separating vessel (2 - Fig. 1) (22 - Fig. 2) and the point at which the U-shaped pipe length (53 - Fig. 1) (36 - Fig. 2) connects with the separated gas flow line (3 - Fig. 1) (23 - Fig. 2), to prevent high pressure gas from passing into

the primary separating vessel.

It is pointed out that in this situation it will also be necessary to have means for launching and receiving the travelling interface devices at the location where they are manoeuvred into position. It will also be necessary to have devices which will allow the mechanical interface to pass from the high pressure gas line to the U-shaped pipe length as already described previously.

It is important to note that when the gas which has separated out in the subsea primary separating vessel (2 - Fig. 1) (22 - Fig. 2) reaches the surface it is available for use as a raw material for the gas compression process which is used to remove the liquid phase from the flow lines, and this makes the process typically cyclical and easy to control.

In the embodiments illustrated in Figures 1 and 2 it is suggested that the gathering centre for the produced fluids, the separated gas gathering vessel, and the gas compression system are concentrated at a single location, namely on a platform. This example is however merely indicative, as these installations may be located anywhere else, and may or may not be concentrated at a single point. Thus the location suggested for these installations in this description cannot in any way be regarded as a factor restricting the invention.

## CLAIMS

1. Equipment for offshore oil production with primary gas separation and flow, by means of high pressure gas injection; characterized in that it comprises:- a subsea primary separating means (2; 22) which receives the production from an offshore oil well delivered from a wellhead (1; 31) through a flow line (15; 21); a separated gas flow line (3; 23) which connects the upper part of the primary separating means (2; 22) to a collecting vessel (8; 28) located at a gathering centre (7; 27); at least one flow line (4, 5; 24) which connects the lower part of the subsea primary separating means (2; 22) to a gathering centre; and a U-shaped pipe length (51, 52; 35) which is fitted with a shut-off valve (12, 11; 47) and connects said at least one flow line (4, 5; 24) to a high pressure gas line (6; 26) which is fitted with a check valve (60; 70) near to the point where the high pressure gas line (6; 26) connects to the wellhead (1; 31) to avoid back flow of gas originating from the annulus of the well; wherein said at least one flow line (4, 5; 24) has a check valve (13, 14; 25) located between the subsea primary separating vessel (2; 22) and the point of connection to said U-shaped pipe length (51, 52; 35) in order to prevent the injected high pressure gas from exerting a back pressure which would adversely affect production from the oil producing well.

2. Equipment according to Claim 1, characterized in that it includes a further U-shaped pipe length (53; 36) which has a clear-flow shut-off valve (16; 37) and is able to connect said high pressure gas line (6; 26) to said separated gas flow line (3; 23) and which allows a travelling mechanical interface driven by high pressure gas to pass from the high pressure gas line (6; 26) to the separated gas line (3; 23) for removing any liquid phase which may have separated out within the separated gas line (3; 23); and in that a check valve (18; 38) is fitted in the separated gas flow line (3; 23) close to the point of connection with said further U-shaped pipe length (53; 36).

3. Equipment according to either of Claims 1 and 2, characterized in that a pressure control valve (20; 39) is provided in the separated gas flow line (3;

23) in order to allow control of the pressure of the gas in that flow line.

4. A method for offshore oil production with primary gas separation and flow by the injection of high pressure gas; characterized in that it comprises the following steps:

a) Closing a shut-off valve (11, 12; 47) in a U-shaped pipe length (52, 51; 35), which connects flow lines (4, 5; 24) to a high pressure gas line (6; 26);

b) Allowing the fluids produced by the well to flow through a flow line (15; 21) from a wellhead (1; 31) to a subsea primary separating means (2; 22) where primary separation between the liquid and gas phases takes place,

c) Separating out the liquid phase in the lower part of the subsea primary separating means (2; 22) and also allowing it to accumulate in said flow lines (4, 5; 24);

d) When the back pressure exerted by the volume of fluids accumulated in the flow lines (4, 5; 24) begins to rise, adversely affecting production, then opening a shut-off valve (11, 12; 47) in said U-shaped pipe length (52, 51; 35) which connects the high pressure gas line (6; 26) to the flow line (4, 5; 24), and maintaining it open for a predetermined period in order to allow a volume of high pressure gas to pass within the flow line;

e) Using a check valve (14, 13; 25) fitted in the flow line close to the point of connection between the flow line and the U-shaped pipe length (52, 51; 35) to prevent the injected high pressure gas from exerting any back pressure which would affect production from the well;

f) Using the injected high pressure gas to cause flow, to a gathering centre (7; 27), of the liquid phase which has accumulated in the flow line (4, 5; 24); and

g) After closing the shut-off valve which was previously open, allowing the liquid phase again to accumulate in the flow line into which the high pressure gas was injected, thus completing performance of the method.

5. A method according to Claim 4, characterized by releasing a mechanical

interface (17; 34) into the flow line (4, 5; 24) and driving it by high pressure gas is used to cause the fluid phase in the flow lines (4, 5; 24) to flow to the gathering centre (7; 27).

6. A method according to claim 4 or claim 5, wherein the liquid phase separated out in step (c) accumulates in lengths of the flow lines which are horizontal, or which have a small gradient, so the back pressure exerted by that volume of fluids on the production from the well is small,

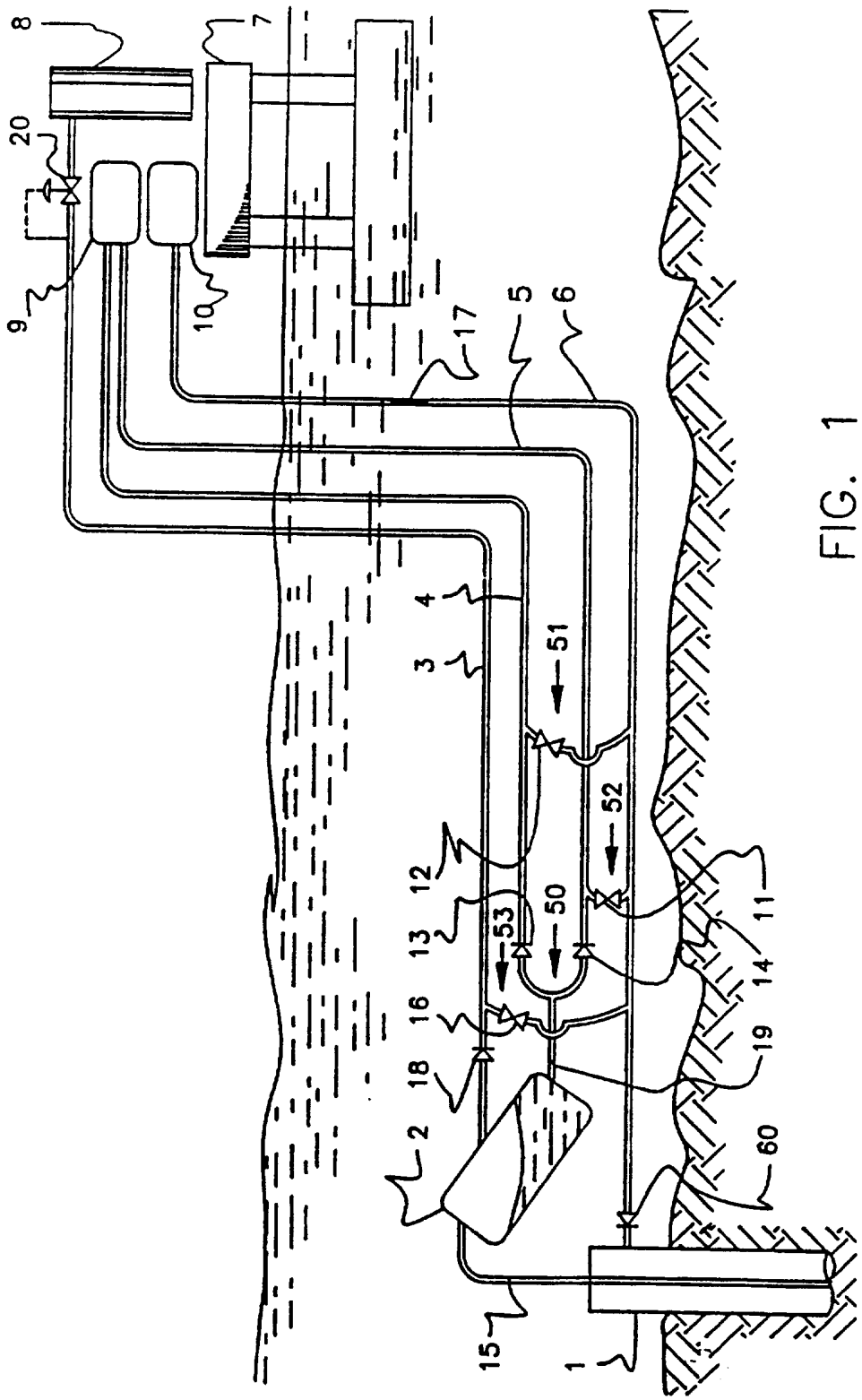


FIG. 1

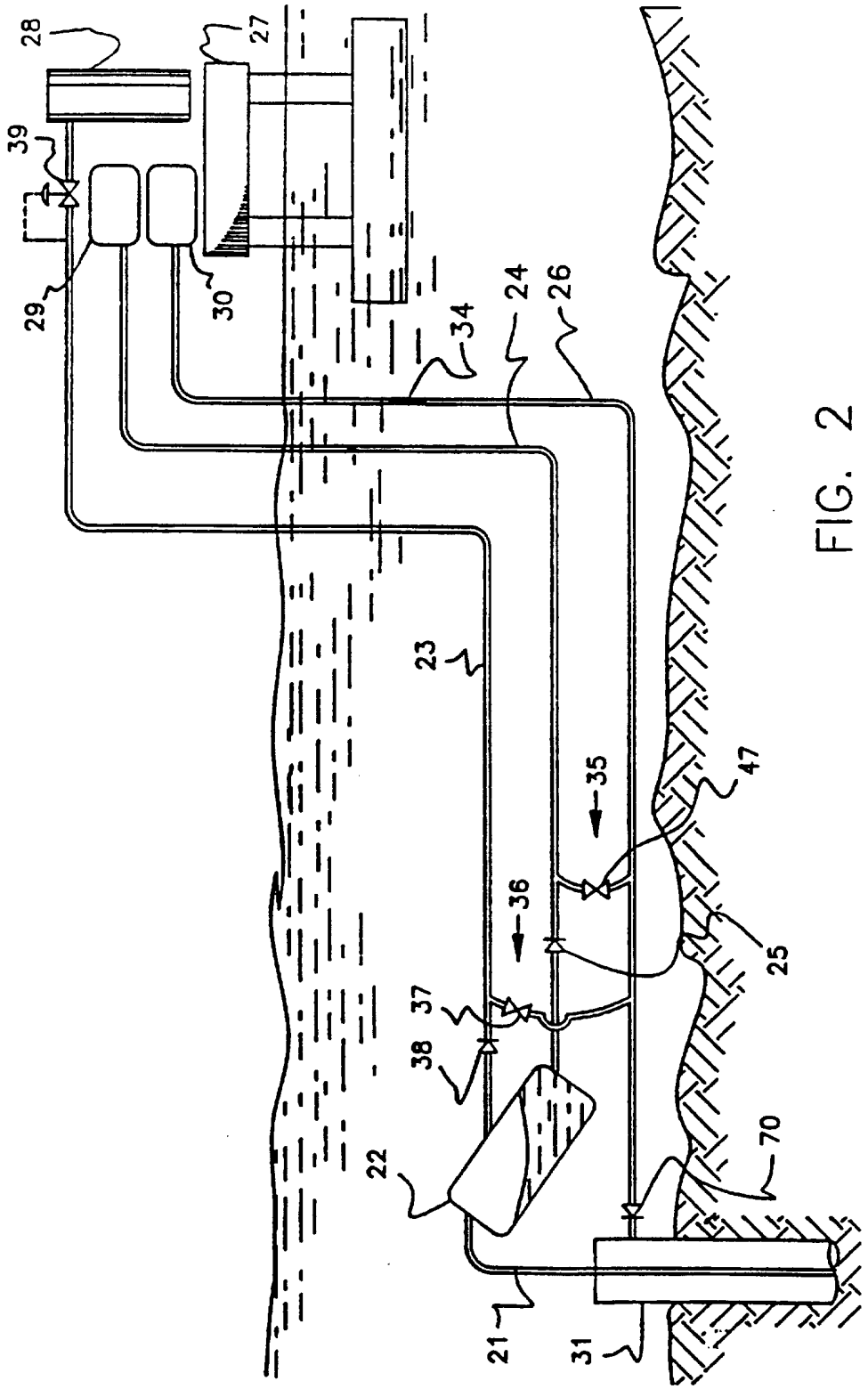


FIG. 2

# INTERNATIONAL SEARCH REPORT

Inter. .onal Application No
PCT/GB 97/01200

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 E21B43/01 E21B43/12

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)
IPC 6 E21B

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5 460 227 A (SIDRIM FERNANDO ANTONIO C) 24 October 1995<br>see abstract<br>see column 4, line 23-59<br>see figure 1<br>--- | 1,4 |
| A | US 5 199 496 A (REDUS CLIFFORD L ET AL) 6 April 1993<br>see abstract<br>see column 2, line 6-65<br>see figure 1<br>--- | 1,4 |
| A | EP 0 579 497 A (COOPER IND INC) 19 January 1994<br>see page 2, column 1, line 1-21<br>see page 3, column 3, line 48 - page 4, column 6, line 37<br>see figures 1-5<br>---<br>-/-- | 1,4 |

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

[X] Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 5 November 1997 | 07. 11. 97 |
| **Name and mailing address of the ISA**<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | **Authorized officer**<br>Schouten, A |

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# INTERNATIONAL SEARCH REPORT

Inte. ional Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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