



## PLANT FOR SEPARATING A MIXTURE OF OIL, WATER AND GAS

The present invention relates to a plant for separating at separation pressure a mixture of oil, water and gas into its components.

5 Such a separation plant normally comprises a supply conduit provided with a pressure reduction valve to allow during normal operation reducing the pressure of the mixture from a high pressure to the separating pressure and a plurality of interconnected separator vessels. The separator vessels are sufficiently large to get a good  
10 separation.

A disadvantage of such a plant is that in case of a shut down the separator vessels have to be emptied. To this end the separation plant should be connected to a pressure relief and blowdown system including a flare, so  
15 that the vapours and liquids can be conducted to the flare.

It is an object of the invention to provide a separation plant that does not have separator vessels, but consists of pipes so that the plant has a small  
20 inventory and therefore does not need a pressure relief and blowdown system.

In accordance with the invention there is provided a plant for separating a mixture of oil, water and gas produced from a well, the plant comprising:

- 25 - a first in-line separator for separating the mixture into a gas stream substantially free of liquid and a liquid stream substantially free of gas, the first in-line separator being provided with an inlet conduit for supplying the mixture to the first in-line separator;
- 30 - a second in-line separator for separating the liquid stream into an oil stream substantially free of water and

a water stream substantially free of oil, the second in-line separator being provided with an inlet conduit for supplying the liquid stream to the second in-line separator;

5           wherein each in-line separator comprises a chamber for separating the respective fluid stream supplied to the in-line separator, said chamber having an internal diameter substantially equal to the internal diameter of the respective inlet conduit of the in-line separator.

10           Separation of the fluid stream in the chamber can take place on the basis of gravitational forces, centrifugal forces, or a combination of gravitational and centrifugal forces. However it is preferred that the chamber is a swirl chamber having means for inducing a  
15           swirling motion to the respective fluid stream supplied to the in-line separator so as to separate the fluid stream by centrifugal forces exerted to the fluid stream.

          By virtue of the feature that the internal diameter of the swirl chamber is substantially equal to the  
20           internal diameter of the respective inlet conduit of the in-line separator, it is achieved that the fluid content of the plant (referred to as: inventory) is not substantially greater than the internal volume of the piping of the plant. Thus in case of a temporary shut-  
25           down of the plant, no large volume of gas is present in the plant. As a result there is no need to relieve the internal pressure from the plant during such shut-down, and consequently there is no need to flare any remaining gas from the plant. Furthermore, since the in-line  
30           separators are of a diameter comparable to the diameter of the piping of the plant, the separators can be designed according to a pipeline-code instead of a vessel-code as for conventional separators. This implies that the plant is significantly lighter than conventional

plants which include conventional, gravity based, separators.

In case of an offshore well, it is preferred that the plant is positioned on the seabed, thereby obviating the need for an offshore platform to process the produced hydrocarbon fluid.

Suitably the plant is mounted on a skid provided with means for lifting the skid and transporting the skid. Such arrangement allows the plant to be moved from one well to another well after the production of hydrocarbon fluid from said one well has declined to a level whereby further production is no longer economical.

It is preferred that the inlet conduit of the first in-line separator is in fluid communication with a single well for the production of hydrocarbon fluid. Such arrangement allows the plant to be very light, and obviates the need to provide commingling facilities for commingling hydrocarbon fluid from different wells.

The invention will now be described in more detail with reference to the accompanying drawings, wherein

Figure 1 shows schematically and not to scale an on-shore embodiment of the present invention; and

Figure 2 shows schematically and not to scale a subsea embodiment of the present invention.

Reference is now made to Figure 1, showing schematically an on-shore plant 1 for separating at separating pressure a mixture of oil, water and gas into its components.

The separation plant 1 comprises a first in-line separator 2 for separating gas from the mixture to obtain a substantially gas-free liquid and a gas having a reduced liquid content. The first in-line separator 2 has an inlet 3 adapted to be connected to a supply conduit 5 and separate outlets 7 and 9 for gas and liquid, respectively.

The separation plant 1 further comprises means 10 for removing the gas having a reduced liquid content from the outlet for gas 7 of the first in-line separator 2.

5 The separation plant 1 further comprises a second in-line separator 12 for separating water from the substantially gas-free liquid to obtain a substantially oil-free water and a substantially water-free oil. The second in-line separator 12 has an inlet 15 that is in fluid communication with the outlet for liquid 9 of the first in-line separator 2 and separate outlets 18 and 19  
10 for water and oil, respectively.

The separation plant 1 further comprises separate means 25 and 27 for removing the substantially oil-free water and the substantially water-free oil from the  
15 outlets 18 and 19 for water and oil of the second in-line separator 12.

An example of an in-line separator is a dual-tube horizontal oil and gas separator as described in Petroleum Engineering Handbook, edited by H B Bradley,  
20 SPE.

The separation plant 1 is connected to a supply conduit 5, which extends from a wellhead 30 pertaining to a well 31 in an underground formation 33. The wellhead 30 is provided with a suitable shut-in valve 35.

25 In the embodiment as shown in Figure 1, the inlet 15 of the second in-line separator 12 is in direct fluid communication with the outlet for liquid 9 of the first in-line separator 2.

In an alternative embodiment, the plant 1 further  
30 comprises an in-line demulsifier (not shown) having an inlet that is in direct fluid communication with the outlet for liquid of the first in-line separator and an outlet that is in direct fluid communication with the inlet of the second in-line separator. An example of an

in-line demulsifier is an electrostatic or an ultrasonic coalescer.

The means 10 for removing the gas having a reduced liquid content is suitably a sealless compressor 40. The sealless compressor 40 is arranged together with its electric motor 41 in a closed housing 45. The compressor 40 has a suction end 46 that is connected by means of a conduit 47 the outlet for gas 7 of the first in-line separator 2. The compressor 40 has a discharge end 48 that is connected to a pipeline 49. During normal operation, the compressor 40 raises the pressure of the gas from separation pressure to pipeline pressure.

The means for removing the substantially oil-free water 25 is a canned water pump, which is a pump 50 arranged in a closed housing 52. The pump 50 has a suction end 53 and a discharge end 56. The suction end 53 is in direct fluid communication with the outlet for water 18 of the second in-line separator 12 via conduit 57. The substantially oil-free water is passed away through conduit 59, which is connected to the discharge end 56, to a suitable storage place (not shown). Alternatively the water is passed to an injection well to inject the water into an underground reservoir.

The means for removing the substantially water-free oil 27 is a canned oil pump, which is a pump 60 arranged in a closed housing 62. The pump 60 has a suction end 63 and a discharge end 66. The suction end 63 is in direct fluid communication with the outlet for oil 19 of the second in-line separator 12 via conduit 67. The substantially water-free oil is passed through conduit 69 to a suitable storage and handling facility (not shown).

Suitably, the plant according to the present invention further comprises a pressure reduction valve (not shown) to reduce the pressure of the mixture from a high pressure to the separating pressure, which pressure

reduction valve is arranged between the supply conduit 5 and the inlet 3 of the first in-line separator 2.

Suitably, the pressure reduction valve is part of an over-pressure protection system as described in

5 International patent application publication

No. 03/038 325. Such an over-pressure protection system comprises a conduit section extending between a pressure reduction valve and a low-pressure fluid handling system, a shut-off valve provided with an actuator arranged in

10 the conduit section, pressure sensors arranged one on either side of the shut-off valve in the conduit section,

a safety control system that communicates with the actuator and the pressure sensors and produces a signal when it detects a high pressure in the conduit section,

15 and a self-diagnostic system for checking the shut-off valve and the pressure sensors that communicates with the actuator, the pressure sensors and the safety control system, which self-diagnostic system produces a signal

when it detects a failure in either the shut-off valve or the pressure sensors or both.

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It will be understood that the plant of the present invention can as well be used offshore, for example on an offshore platform. However, because the separation plant according to the present invention does not need to have a flare, it can be suitably used on the sea floor for an underwater wellhead.

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Reference is now made to Figure 2, showing schematically an subsea plant 201 for separating at separating pressure a mixture of oil, water and gas into its components. The subsea plant for separating at separating pressure a mixture of oil, water and gas is located on the sea floor 270 below the sea level 271.

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The separation plant 201 comprises a first in-line separator 202 for separating gas from the mixture to obtain a substantially gas-free liquid and a gas having a

35

reduced liquid content. The first in-line separator 202 has an inlet 203 adapted to be connected to a supply conduit 205 and separate outlets 207 and 209 for gas and liquid, respectively.

5           The separation plant 201 further comprises means 210 for removing the gas having a reduced liquid content from the outlet for gas 207 of the first in-line separator 202.

10           The separation plant 201 further comprises a second in-line separator 212 for separating water from the substantially gas-free liquid to obtain a substantially oil-free water and a substantially water-free oil. The second in-line separator 212 has an inlet 215 that is in fluid communication with the outlet for liquid 209 of the  
15           first in-line separator 2 and separate outlets 18 and 19 for water and oil, respectively.

          The separation plant 201 further comprises separate means 225 and 227 for removing the substantially oil-free water and the substantially water-free oil from the  
20           outlets 218 and 219 for water and oil of the second in-line separator 212.

          An example of an in-line separator is a dual-tube horizontal oil and gas separator as described in Petroleum Engineering Handbook, edited by H B Bradley,  
25           SPE.

          The separation plant 201 is connected to a supply conduit 205, which extends from a wellhead 230 pertaining to a well 231 in an underground formation 233. The wellhead 230 is provided with a suitable shut-in  
30           valve 235.

          In the embodiment as shown in Figure 2, the inlet 215 of the second in-line separator 212 is in direct fluid communication with the outlet for liquid 209 of the first in-line separator 202.

In an alternative embodiment, the plant 201 further comprises an in-line demulsifier (not shown) having an inlet that is in direct fluid communication with the outlet for liquid of the first in-line separator and an outlet that is in direct fluid communication with the inlet of the second in-line separator. An example of an in-line demulsifier is an electrostatic or an ultrasonic coalescer.

The means 210 for removing the gas having a reduced liquid content is suitably a sealless compressor 240. The sealless compressor 240 is arranged together with its electric motor 241 in a closed housing 245. The compressor 240 has a suction end 246 that is connected by means of a conduit 247 the outlet for gas 207 of the first in-line separator 202. The compressor 240 has a discharge end 248 that is connected to a pipeline 249. During normal operation, the compressor 240 raises the pressure of the gas from separation pressure to pipeline pressure.

The means for removing the substantially oil-free water 225 is a canned water pump, which is a pump 250 arranged in a closed housing 252. The pump 250 has a suction end 253 and a discharge end 256. The suction end 253 is in direct fluid communication with the outlet for water 218 of the second in-line separator 212 via conduit 257. The substantially oil-free water is passed away through conduit 259, which is connected to the discharge end 256, to a suitable storage place (not shown). Alternatively the water is passed to an injection well to inject the water into an underground reservoir.

The means for removing the substantially water-free oil 227 is a canned oil pump, which is a pump 260 arranged in a closed housing 262. The pump 260 has a suction end 263 and a discharge end 266. The suction end 263 is in direct fluid communication with the outlet

for oil 219 of the second in-line separator 212 via conduit 267. The substantially water-free oil is passed through conduit 269 to a suitable storage and handling facility (not shown).

5           The seabed embodiment of the present invention contains an additional feature and that is that the plant further includes a fluid header 280 having a first inlet 281, a second inlet 282 and a single outlet 283. The discharge end 248 of the sealless compressor 210 is  
10 in fluid communication with the first inlet 281 of the header 280, and the discharge end 266 of the canned oil pump 227 is in direct fluid communication with the second inlet 282. The fluid header 280 has one outlet 283 that is debouching into a pipeline (not shown). The pipeline  
15 transports the combined oil and gas stream. The advantage of the header 280 is that only a single pipeline is needed to transport the hydrocarbons to shore, where oil and gas are separated.

          In order to remove condensable components, such as  
20 water and C<sub>3</sub><sup>+</sup> components from the gas, so that the dew point of the gas is below a temperature that is determined by the conditions at the sea floor, the separation plant suitably further includes a gas-conditioning device. The gas-conditioning device is  
25 suitably a supersonic gas-conditioning device as described in a feature article by F Okimoto and J M Brouwer in World Oil, August 2002, Vol. 223, No. 8.

          The gas conditioning device can be arranged upstream  
of the means 210 for removing the gas having a reduced  
30 liquid content, or it can be arranged downstream of the means 210 for removing the gas having a reduced liquid content. In the upstream arrangement (shown with dashed lines having reference numeral 290u) the inlet of the gas-conditioning device is in direct fluid communication  
35 with the outlet for gas 207 of the first in-line

- 10 -

separator 202, and the outlet is in direct fluid communication with the suction end 246 of the compressor 240. Moreover, in this case the discharge end 248 of the compressor 240 is in direct fluid communication with the first inlet 281 of the header 280. The liquid separated by the gas conditioning device 290u is passed through a conduit (not shown) to the conduit 257 that runs to the suction end 253 of the water pump 250. In the downstream embodiment (shown with dashed lines having reference numeral 290d), the inlet of the gas-conditioning device is in direct fluid communication with the discharge end 248 of the compressor 240 and the outlet of the gas-conditioning device is in direct fluid communication with the first inlet 281 of the header 280. In this case the outlet for gas 207 of the first in-line separator 202 is in direct fluid communication with the suction end 246 of the compressor 240. The liquid separated by the gas conditioning device 290d is passed through a conduit (not shown) to the conduit 259 that runs from the discharge end 256 of the water pump 250.

In the embodiment shown in Figure 2, the inlet 215 of the second in-line separator 212 is in direct fluid communication with the outlet for liquid 209 of the first in-line separator 202. Alternatively, the plant 201 further comprises an in-line demulsifier (not shown) having an inlet that is in direct fluid communication with the outlet for liquid 209 of the first in-line separator 202 and an outlet that is in direct fluid communication with the inlet 215 of the second in-line separator 212.

Suitably, the plant according to the present invention further comprises a pressure reduction valve (not shown) to reduce the pressure of the mixture from a high pressure to the separating pressure, which pressure reduction valve is arranged between the supply

conduit 205 and the inlet 203 of the first in-line separator 202. Suitably, the pressure reduction valve is part of an over-pressure protection system as described in International patent application publication  
5 No. 03/038 325. Such an over-pressure protection system comprises a conduit section extending between a pressure reduction valve and a low-pressure fluid handling system, a shut-off valve provided with an actuator arranged in the conduit section, pressure sensors arranged one on  
10 either side of the shut-off valve in the conduit section, a safety control system that communicates with the actuator and the pressure sensors and produces a signal when it detects a high pressure in the conduit section, and a self-diagnostic system for checking the shut-off  
15 valve and the pressure sensors that communicates with the actuator, the pressure sensors and the safety control system, which self-diagnostic system produces a signal when it detects a failure in either the shut-off valve or the pressure sensors or both.

20 In the above, the plant according to the invention was connected to a wellhead. However, alternatively the plant can be connected to a collecting station in which fluids from several wells come together.

C L A I M S

1. A plant for separating a mixture of oil, water and gas produced from a well, the plant comprising:

- a first in-line separator for separating the mixture into a gas stream substantially free of liquid and a liquid stream substantially free of gas, the first in-line separator being provided with an inlet conduit for supplying the mixture to the first in-line separator;

- a second in-line separator for separating the liquid stream into an oil stream substantially free of water and a water stream substantially free of oil, the second in-line separator being provided with an inlet conduit for supplying the liquid stream to the second in-line separator;

wherein each in-line separator comprises a chamber for separating the respective fluid stream supplied to the in-line separator, said chamber having an internal diameter substantially equal to the internal diameter of the respective inlet conduit of the in-line separator.

2. The plant according to claim 1, wherein said chamber is a swirl chamber having means for inducing a swirling motion to the respective fluid stream supplied to the in-line separator so as to separate the fluid stream by centrifugal forces exerted to the fluid stream.

3. The plant according to claim 1 or 2, wherein the second in-line separator is in direct fluid communication with the first in-line separator via the inlet conduit of the second in-line separator.

4. The plant according to claim 1 or 2, wherein the inlet conduit of the second in-line separator is provided with an in-line demulsifier having an inlet in direct fluid communication with the first in-line separator and

an outlet in direct fluid communication with the second in-line separator.

5 5. The plant according to any one of the claims 1-4, further comprising means for removing the gas stream from the plant, including a seal-less compressor for raising the pressure of the gas stream to pipeline pressure, the compressor having a suction end in fluid communication with a gas outlet of the first in-line separator.

10 6. The plant according to claim 5, further comprising means for removing the oil stream from the plant, including a canned oil pump having a suction end in fluid communication with an oil outlet of the second in-line separator.

15 7. The plant according to claim 6, further comprising a fluid header having a first inlet in fluid communication with a discharge end of the seal-less compressor, a second inlet in fluid communication with a discharge end of the canned oil pump, and a single outlet in fluid communication with a remote facility for receiving oil and gas from the plant.

20 8. The plant according to any one of claims 1-7, further comprising means for removing the water stream from the plant, including a canned water pump having a suction end in fluid communication with a water outlet of the second in-line separator.

25 9. The plant according to any one of the claims 1-8, further comprising a pressure reduction valve for reducing the pressure of the mixture from a high pressure to a separating pressure, the pressure reduction valve being arranged between the well and a mixture inlet of the first in-line separator.

30 10. The plant according to any one of claims 1-9, wherein the plant is positioned on the seabed.

11. The plant according to any one of claims 1-10,  
wherein the plant is mounted on a skid provided with  
means for lifting the skid and transporting the skid.
12. The plant according to any one of claims 1-11,  
5 wherein the inlet conduit of the first in-line separator  
is in fluid communication with a single well for the  
production of hydrocarbon fluid.
13. The plant substantially as described hereinbefore,  
with reference to the accompanying drawings.

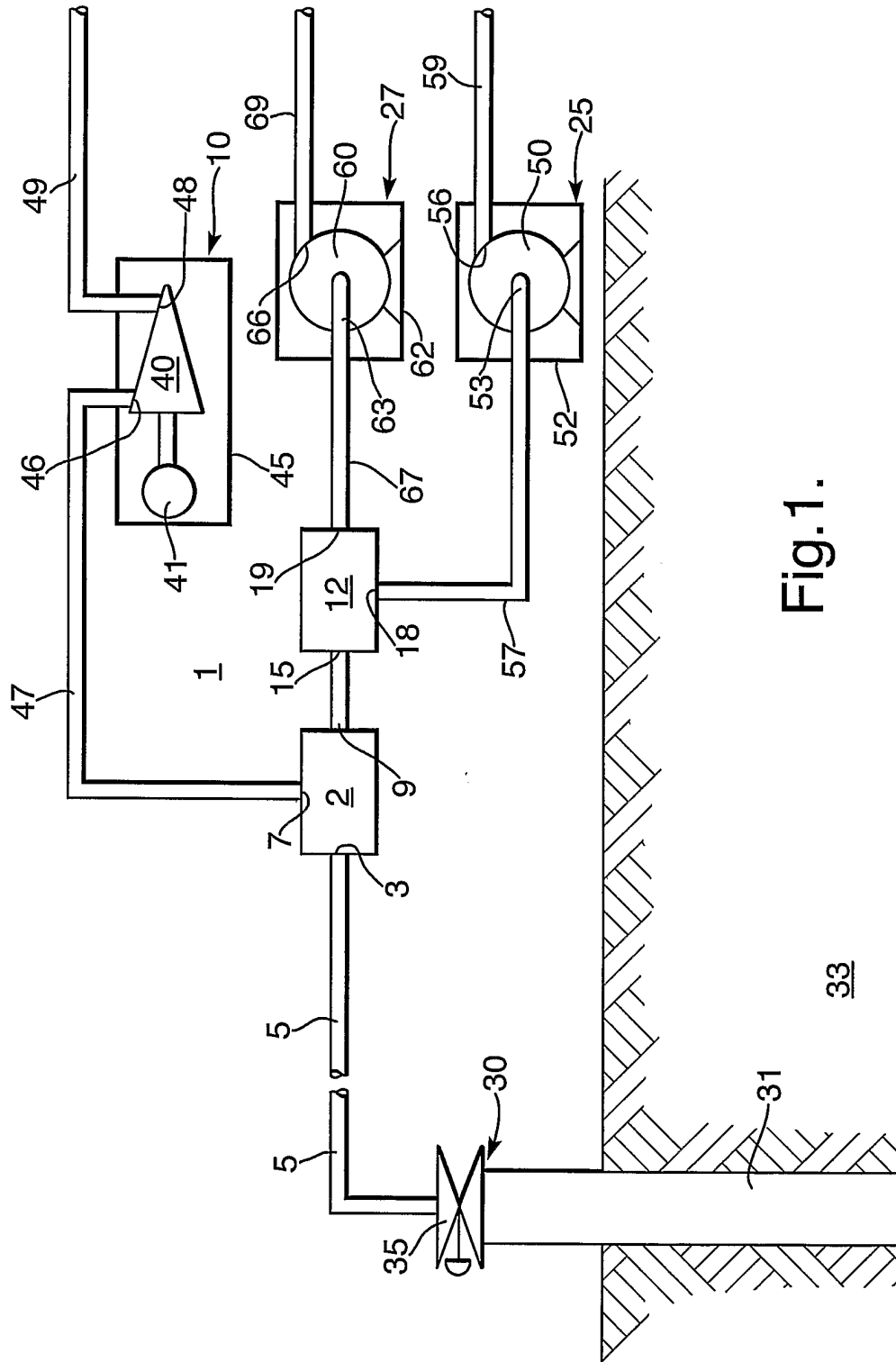


Fig.1.

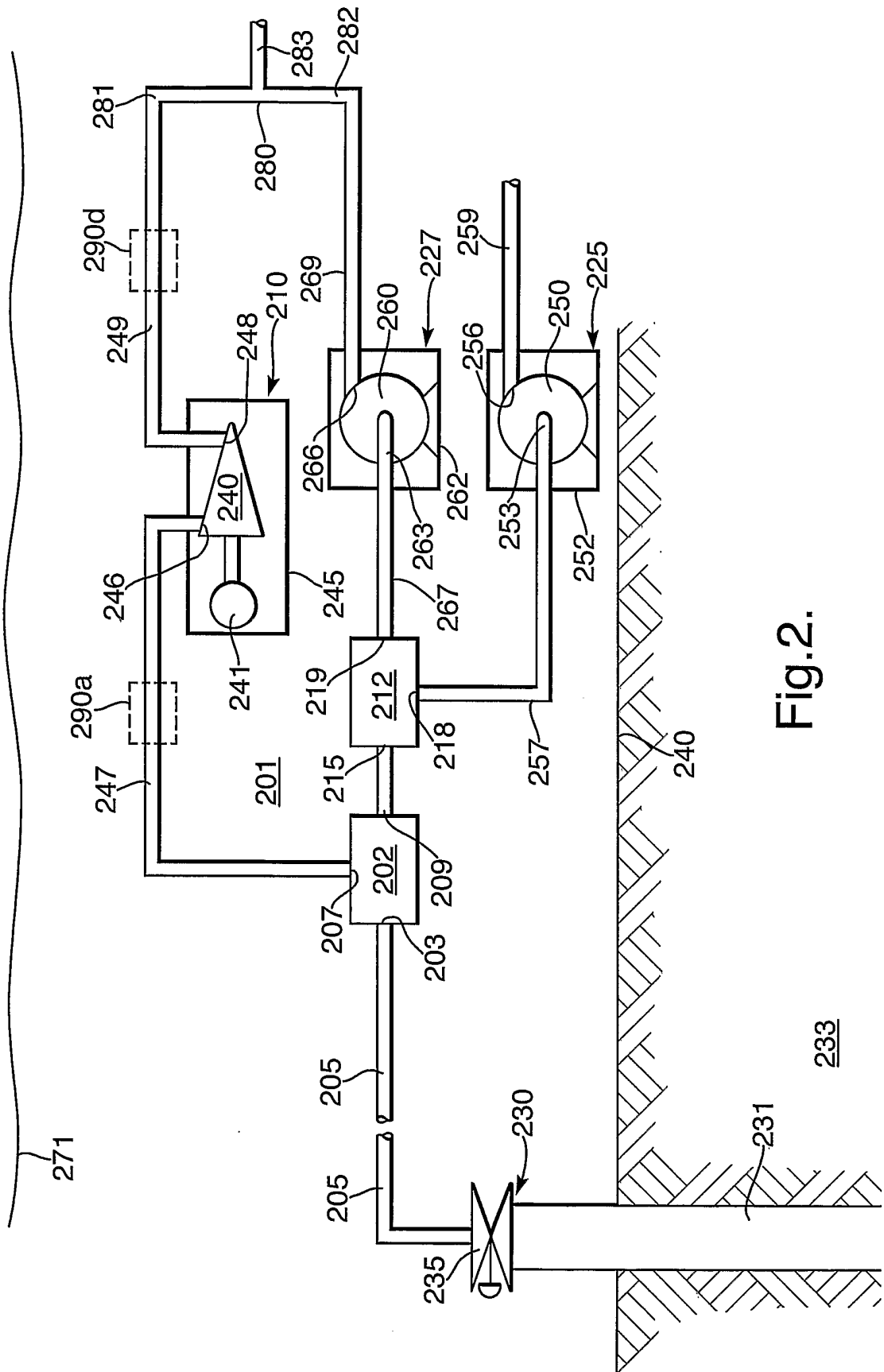


Fig.2.

**INTERNATIONAL SEARCH REPORT**

International Application No  
PCT/EP2005/053663

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 B01D19/00 E21B43/34 B01D17/02

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 7 B01D 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)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 197 095 B1 (HADFIELD DAVID A ET AL) 6 March 2001 (2001-03-06) column 6, line 49 - column 8, line 38; claims 34-40; figure 1	1-13
A	GB 2 222 961 A (BRITISH OFFSHORE ENG TECH) 28 March 1990 (1990-03-28) page 3, line 1 - page 4, line 13; claims 1-3	1-13
A	US 2003/111230 A1 (OLSON DAVID L ET AL) 19 June 2003 (2003-06-19) paragraphs '0017! - '0023!; figures 1A, 3	1-13
A	US 5 302 294 A (SCHUBERT MARK F ET AL) 12 April 1994 (1994-04-12) column 6, line 5 - line 42; claim 1; figure 2	1
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Further documents are listed in the continuation of box C.

Patent family members are listed in 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 document but published on or after the international filing date
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- \*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

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Fourgeaud, D

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/EP2005/053663

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 2003/217956 A1 (MOHSEN ABDUL HAMEED ET AL) 27 November 2003 (2003-11-27) paragraph '0030!; figure 1 -----	1-13

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No PCT/EP2005/053663
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