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(54) **Method of determining fluid fractions in a wellbore**

(57) A method and system are provided for determining component fractions of a stream of multiphase fluid including hydrocarbon gas and liquid. The stream flows in a wellbore extending into an earth formation. The method comprises (a) closing the wellbore to contain the stream of multiphase fluid between a lower containment member and an upper containment member, (b) allowing

the components of the stream to separate by gravity whereby a body of hydrocarbon gas and a body of a liquid is formed, (c) determining a depth level of an interface between the body of hydrocarbon gas and the body of liquid, and (d) determining the component fractions from the respective depth levels of said containment members, and the depth level of said interface.

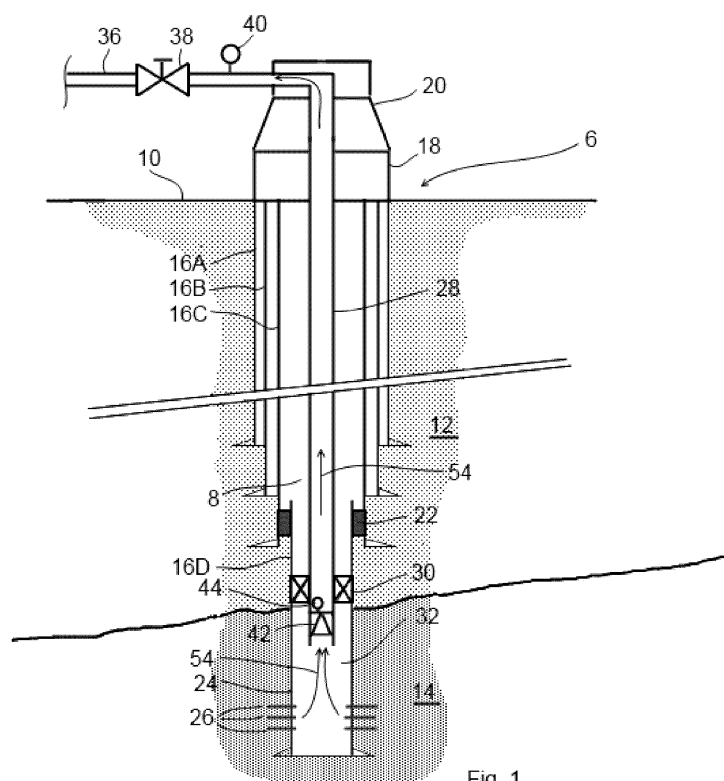


Fig. 1

Description

[0001] The present invention relates to a method of determining component fractions of a stream of multiphase fluid including hydrocarbon gas and liquid, the stream flowing in a wellbore.

[0002] Hydrocarbon gas which is produced from an earth formation in a wellbore generally flows in a multiphase stream, typically comprising natural gas, water and some gas condensate. In order to obtain information regarding the flow rates of the individual fluid components, a test separator is commonly used to separate the components of the multiphase stream. The information may be used to allow production from the wellbore or from a group of wellbores to be optimised. The test separator may be a permanent separator or a mobile test separator. On most wellbore locations no permanent separators are present, and mobile separator visits may be prohibitively expensive in terms of time, space, resources and/or budget.

[0003] US-2009/0107218-A1 discloses a method of testing a wellbore using a mobile test separator having a separator unit mounted on a wheeled trailer movable between sites. The separator unit separates a well production stream into a liquid production stream and a gas production stream.

[0004] It is an object of the invention to provide an improved method for determining component fractions of a stream of multiphase fluid.

[0005] The invention provides a method of determining component fractions of a stream of multiphase fluid including gas and liquid, the stream flowing in a wellbore extending into an earth formation, the method comprising:

- closing the wellbore to contain a part of the stream of multiphase fluid between a first containment member, which is arranged at a first level, and a second containment member, which is arranged at a second level;
- allowing the components of the part of the stream of multiphase fluid to separate due to gravity, whereby a body of gas and a body of liquid is formed;
- determining an interface level of an interface between the body of gas and the body of liquid; and
- determining the component fractions from the first level and the second level of said containment members, and the interface level of said interface.

[0006] The method uses the wellbore itself as a test separator, thereby obviating the need for a permanent or mobile test separator at the well site. Moreover, the method of the invention enables the fluid component fractions to be determined in combination with other wellbore intervention work such as reservoir pressure and production profile surveillance. The method of the invention reduces costs, requires less time and resources, and is more practical. These advantages are even more pronounced in offshore wellbores including normally unmanned satellite wells.

[0007] The invention also relates to a system for determining component fractions of a stream of multiphase fluid including gas and liquid, the stream flowing in a wellbore extending into an earth formation, the system comprising:

- a first containment member, which is arranged at a first level, and a second containment member, which is arranged at a second level, for closing the wellbore to contain a part of the stream of multiphase fluid between the first containment member and the second containment member;
- level determining means for determining an interface level of an interface between a body of gas and a body of liquid resulting from separation of the components of the part of the stream of multiphase fluid due to gravity in between the first containment member and the second containment member; and
- fraction determining means for determining the component fractions from the first level and the second level of said containment members, and the interface level of said interface.

[0008] To prevent leakage of the contained fluid back into the earth formation, suitably the first or lower containment member allows passage of fluid in upward direction and prevents passage of fluid in downward direction. For example, the lower containment member may comprise a valve selected from a B-type wire line plug and a standing valve.

[0009] The first containment member is suitably arranged above an inlet section of the wellbore where the stream of multiphase fluid flows into the wellbore.

[0010] The level of the interface between the bodies of hydrocarbon gas and liquid (which may comprise water and/or gas condensate) may be determined by measuring a fluid pressure in the body of hydrocarbon gas and measuring a fluid pressure in the body of liquid. The interface level may be determined from the fluid pressure measurements and the specific gravities of the hydrocarbon gas and the liquid.

[0011] Suitably the fluid pressure in the body of liquid is measured using a pressure measuring device provided to the lower containment member.

[0012] To store the pressure measurement data, the pressure measuring device advantageously includes data storage means, and the method further comprises storing the pressure data measured with the pressure measuring device in the data storage means.

[0013] In a practical embodiment the first containment member is retrievably arranged in the wellbore, wherein the method further comprises retrieving the lower containment member together with the pressure measuring device to surface and reading the pressure data from the data storage means.

[0014] Suitably the fluid pressure in the body of hydrocarbon gas is measured at or near the earth surface.

[0015] The lower containment member is advantageously arranged in a lower portion of a production tubing that is used for transporting the stream of multiphase fluid to surface.

[0016] The body of liquid normally comprises water from the earth formation. If a body of gas condensate is formed above the body of water, the method suitably further comprises determining an interface between the bodies of water and gas condensate by determining a static pressure gradient in the bodies of water and gas condensate using a pressure gauge lowered into the wellbore on wire line.

[0017] The invention will be described hereinafter in more detail and by way of example, with reference to the drawings in which:

Fig. 1 shows an embodiment of a wellbore system for application of the method of the invention, during gas production;

Fig. 2 shows the wellbore system after shut-in;

Fig. 3a shows a fluid pressure profile in the wellbore system during gas production; and

Fig. 3b shows an example of a fluid pressure profile in the wellbore system after shut-in.

[0018] In the detailed description and the figures, like reference numerals relate to like components.

[0019] Fig. 1 shows a wellbore system 6 whereby a wellbore 8 extends from surface 10 through an earth formation 12 and into a reservoir layer 14 containing, for instance, hydrocarbons. The reservoir layer 14 may typically be located at a depth of, for example, 3 to 10 km. The wellbore 8 may be lined with casings 16A-C and a liner 16D arranged in a nested arrangement. The casings 16A-C extend from a wellhead 18 at surface into the wellbore 8. A Christmas tree 20 is provided on top of the wellhead 18. The liner 16D is suspended from casing 16C by a liner hanger 22 arranged at a down hole location, and extends from there to the reservoir layer 14. A lower portion 24 of the liner 16D is provided with perforations 26 to allow hydrocarbon gas from the reservoir layer 14 to enter the wellbore 8.

[0020] A production tubing 28 extends from wellhead 18 and Christmas tree 20 through the interior of casing 16C and liner 16D, into the lower liner portion 24. The production tubing 28 is internally provided with a sub-surface safety valve (not shown) that is controlled by a hydraulic control line extending from surface 10 into the well along the outside of the production tubing 28. The sub-surface safety valve is located at a depth of, for example, approximately 100 m, and is adapted to close the production tubing in the event of an emergency well control situation. A production packer 30 is provided between the production tubing 28 and the liner 16D to seal an inlet portion 32 of the wellbore from the remaining portion of the wellbore. The production tubing 28 is at surface fluidly connected to a conduit 36 for transporting hydrocarbon gas that is produced from the reservoir layer 14 via the production tubing 28 to surface.

[0021] A valve 38 is provided at the Christmas tree to close the conduit 36 and thereby to shut-in the wellbore 8. A pressure gauge 40 is provided downstream of the valve 38 for measuring fluid pressure in the production tubing 28 at or near surface.

[0022] A one-directional valve 42 that allows passage of fluid in upward direction and prevents passage of fluid in downward direction is arranged near a downhole end section of the production tubing 28. The one-directional valve 42 may be arranged in a landing profile (not shown) of the production tubing 28 and may be retrievable to surface by wire line. A downhole pressure gauge 44 may be arranged on or near the one-directional valve 42. Said pressure gauge 44 may be provided with a data storage memory (not shown) for storing pressure data measured with the gauge 44.

[0023] Fig. 2 shows the well system 6 after shut-in of the wellbore 8. Herein the valve 38 is closed. Due to gravity, a column of liquid 46 will form in a downhole portion of the production tubing 28, i.e. above the one-directional valve 42, and a column of hydrocarbon gas 48 will form in the uphole portion of the production tubing.

[0024] Figs. 3a, 3b show diagrams of fluid pressure p versus depth d in the wellbore 8, indicating pressure profile 50 when the well is producing and pressure profile 52 after shut-in of the wellbore. It should be noted that depth d refers to the true vertical depth which may differ from the along-hole depth. TVD_1 represents the true vertical depth at which the one-directional valve 42 is positioned. TVD_2 represents the true vertical depth of the interface between the liquid column 46 and the gas column 48 in the production tubing 28. Furthermore, FBHP is the flowing bottom hole pressure, P_{res} is the fluid pressure in the reservoir layer 14, P_{top} is the fluid pressure in the production tubing at surface level after shut-in, and P_b is the fluid pressure at level TVD_2 as measured by downhole pressure gauge 44.

[0025] During use of the system 6, the valve 38 is open and a stream of multiphase fluid 54 containing hydrocarbon gas and water flows from the reservoir layer 14 via the perforations 26 into the lower portion of the wellbore 8 and from there through the production tubing 28 to surface. The fluid pressure in the wellbore 8 versus depth is represented by pressure profile 50 (Fig. 3a).

[0026] When it is desired to determine the fluid component fractions of the multiphase stream, the valve 38 is closed whereby the wellbore 8 becomes shut-in. The fluid that is contained in the production tubing 28 after shut-in between

the one-directional valve 42 and the valve 38 thereby no longer flows to surface, and the fluid components separate by virtue of their different specific gravities. The one-directional valve 42 prevents passage of fluid in direction. As a result the water column 46 and the gas column 48 are formed in the contained portion of the production tubing 28. The fluid pressure in the contained portion of the production tubing after shut-in is represented by pressure profile 52 (Fig. 3b).

[0027] In order to determine the depth level TVD_2 of the water column 46 it is considered that the fluid pressure in the water column and the fluid pressure in the gas column vary linearly with depth. Therefore the pressure profile 52 after shut-in has a linear section 58 for the water column and a linear section 60 for the gas column. The gradient of linear section 58 is defined by the specific gravity of water SG_w , and the gradient of linear section 60 is defined by the specific gravity of hydrocarbon gas SG_g .

[0028] The fluid pressure P_b at the lower end of the water column is measured by the downhole pressure gauge 44, and the fluid pressure P_{top} at the upper end of the gas column is measured by the valve 38. The measured fluid pressure P_b is stored in the data storage of the pressure gauge 44. When the measurements are finalised, the one-directional valve 42 together with the pressure gauge 44 is retrieved to surface through the production tubing 28 on wire line, where after the measured value of P_b is read from the data storage.

[0029] The fluid pressure P_b is the sum of P_{top} and the pressure from the weight of the water column 46 and the gas column 48, therefore:

$$P_b = P_{top} + TVD_2 \cdot SG_g + (TVD_1 - TVD_2) \cdot SG_l$$

from which it follows:

$$TVD_2 = (TVD_1 \cdot SG_l - P_b + P_{top}) / (SG_l - SG_g)$$

[0030] The liquid-gas ratio LGR of the multiphase stream equals the ratio of the volume of the water column 46 to the volume of the gas column 48 in the production tubing. The latter ratio equals $(TVD_1 - TVD_2)/TVD_2$ for a uniform diameter of the production tubing.

[0031] Therefore the liquid-gas ratio LGR of the multiphase stream is determined as:

$$LGR = (TVD_1 - TVD_2) / TVD_2.$$

LGR is generally reported as volume of liquid (m^3) per volume of gas (m^3) at standard conditions which usually implies 1 bara pressure. Hence the actual volume of gas in above expression is to be converted to standard conditions to arrive at LGR . Rough conversion may be done by dividing the gas volume in the well by the average of P_{top} and P_b (bara).

[0032] If the production tubing, or other element in which the water and gas are contained, is of non-uniform diameter the liquid-gas ratio is determined in substantially similar manner however taking into account such non-linear diameter when expressing the volume ratio into TVD_1 and TVD_2 .

[0033] In case the multiphase stream also contains gas condensate, a relatively small column of gas condensate will form on top of the water column. The interface between the gas condensate and water can be further established by determining a static pressure gradient in the bodies of liquid and gas condensate using a pressure gauge. Said pressure gauge may be introduced in the wellbore by wire line.

[0034] In an alternative embodiment of the method or system of the invention, the interface between the body of hydrocarbon gas and the body of liquid may be determined using acoustic level detection.

[0035] The present invention is not limited to the embodiments thereof as described above. Therein, various modifications are conceivable within the scope of the appended claims. Features of respective embodiments may for instance be combined.

Claims

1. A method of determining component fractions of a stream of multiphase fluid including gas and liquid, the stream flowing in a wellbore extending into an earth formation, the method comprising:

- closing the wellbore to contain a part of the stream of multiphase fluid between a first containment member, which is arranged at a first level, and a second containment member, which is arranged at a second level;
- allowing the components of the stream of multiphase fluid to separate due to gravity, whereby a body of gas and a body of liquid is formed;
- determining an interface level of an interface between the body of gas and the body of liquid; and
- determining the component fractions from the first level and the second level of said containment members, and the interface level of said interface.

2. The method of claim 1, wherein the first containment member allows passage of fluid in upward direction and prevents passage of fluid in downward direction.

3. The method of claim 2, wherein the first containment member comprises a valve selected from a B-type wire line plug and a standing valve.

4. The method of any one of claims 1-3, wherein the stream of multiphase fluid flows into the wellbore at an inlet section of the wellbore, and wherein the first containment member is arranged above the inlet section.

5. The method of any one of claims 1-4, wherein the step of determining an interface level comprises:

- measuring a fluid pressure in the body of gas; and
- measuring a fluid pressure in the body of liquid.

6. The method of claim 5, wherein the fluid pressure in the body of liquid is measured using a pressure measuring device provided at or near the first containment member.

7. The method of claim 6, wherein the pressure measuring device includes data storage means, and wherein the method further comprises storing pressure data measured using the pressure measuring device in the data storage means.

8. The method of claim 7, wherein the first containment member is retrievably arranged in the wellbore, and wherein the method further comprises the step of retrieving the first containment member together with the pressure measuring device to surface and reading the pressure data from the data storage means.

9. The method of any one of claims 5-8, wherein the fluid pressure in the body of gas is measured at a location at or near the earth surface.

10. The method of any one of claims 1-9, wherein the stream of multiphase fluid flows into a production tubing positioned in the wellbore, and wherein the first containment member is arranged in a downhole end section of the production tubing.

11. The method of any one of claims 1-10, wherein the body of liquid comprises a body of water.

12. The method of claim 11, wherein the step of allowing the components of the stream of multiphase fluid to separate includes:

- forming a body of water; and
- forming a body of gas condensate above the body of water; the method further comprising the step of:

determining a fluid interface level between the body of water and the body of gas condensate by determining a static pressure gradient in the body of water and in the body of gas condensate using a pressure gauge introduced in the wellbore.

13. A system for determining component fractions of a stream of multiphase fluid including gas and liquid, the stream

flowing in a wellbore extending into an earth formation, the system comprising:

- a first containment member, which is arranged at a first level, and a second containment member, which is arranged at a second level, for closing the wellbore to contain a part of the stream of multiphase fluid between the first containment member and the second containment member;
- level determining means for determining an interface level of an interface between a body of hydrocarbon gas and a body of liquid resulting from separation of the components of the part of the stream of multiphase fluid due to gravity in between the first containment member and the second containment member; and
- fraction determining means for determining the component fractions from the first level and the second level of said containment members, and the interface level of said interface.

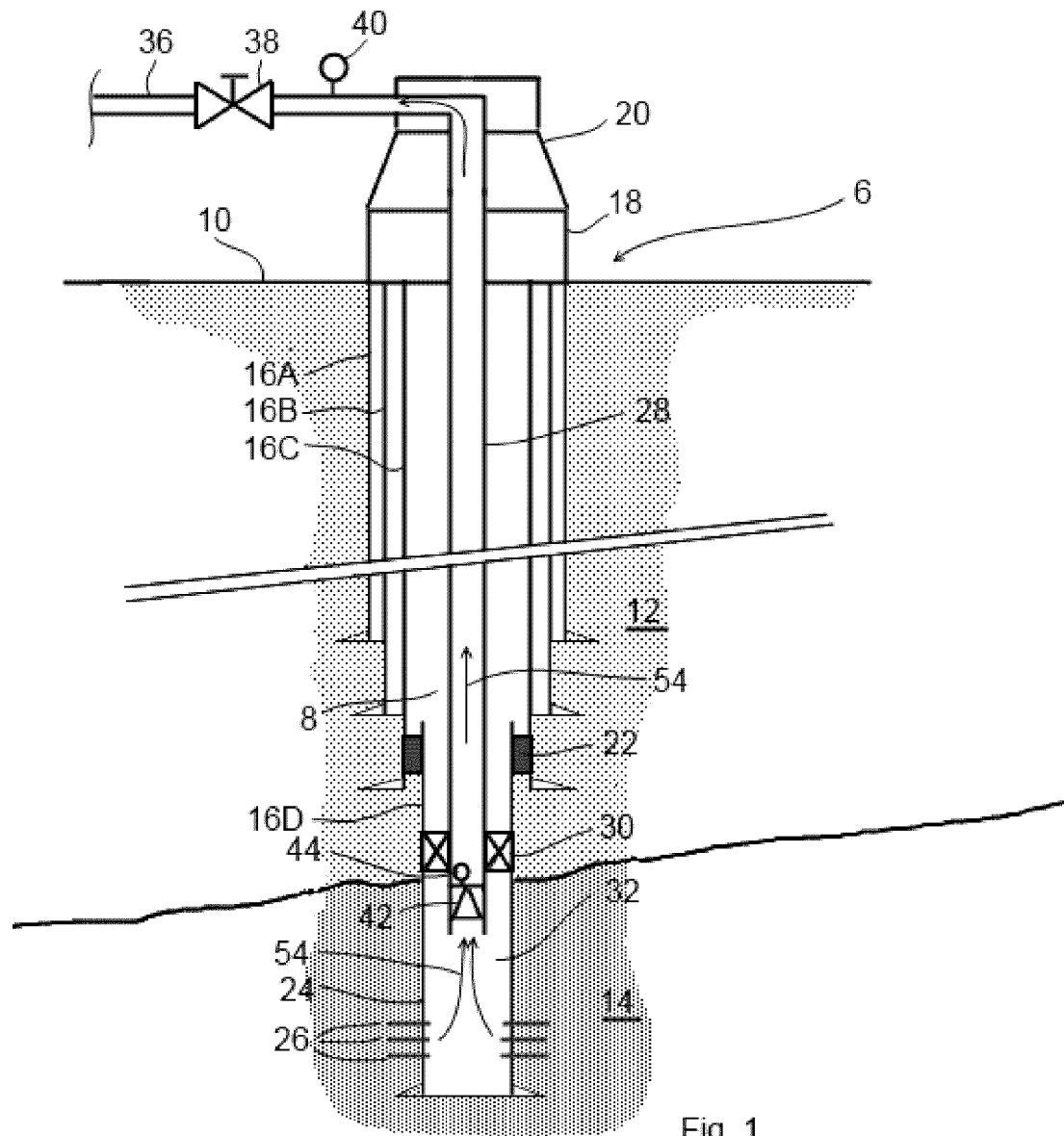
14. The system of claim 13, wherein the first containment member is adapted to allow passage of fluid in upward direction and to prevent passage of fluid in downward direction.

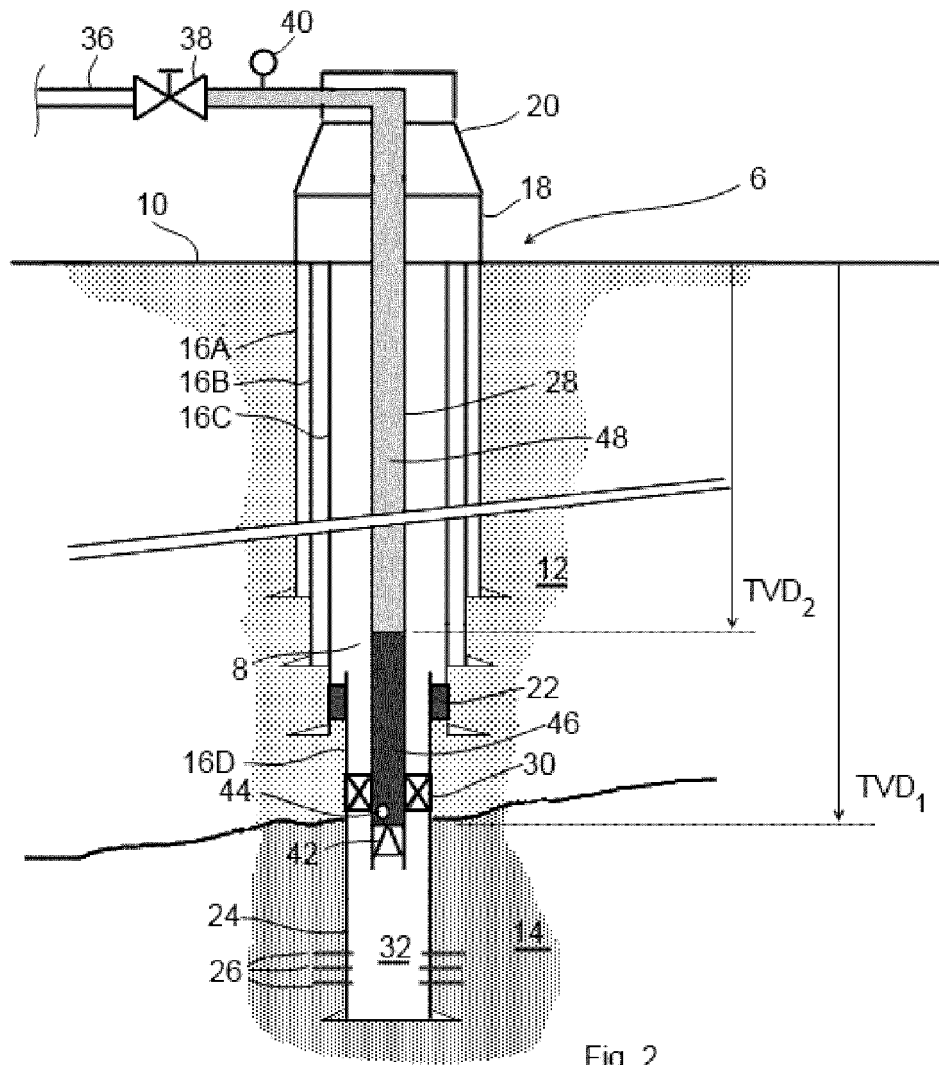
15. The system of claim 14, wherein the first containment member comprises a valve selected from a B-type wire line plug and a standing valve.

16. The system of any one of claims 13-15, wherein the stream of multiphase fluid flows into the wellbore at an inlet section of the wellbore, and wherein the first containment member is arranged above the inlet section.

17. The system of any one of claims 13-16, wherein the level determining means comprise a pressure gauge for measuring a fluid pressure in the body of gas and a pressure gauge for measuring a fluid pressure in the body of liquid.

18. The system of claim 17, wherein the pressure gauge for measuring a fluid pressure in the body of liquid is arranged at or near the first containment member.





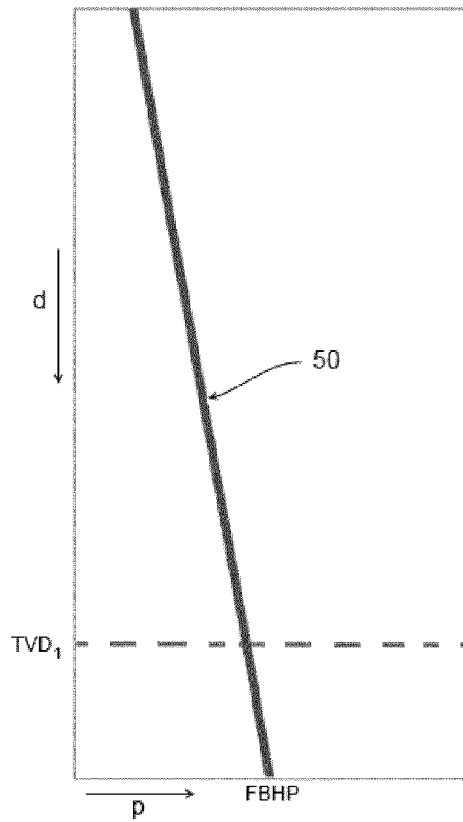


Fig. 3a

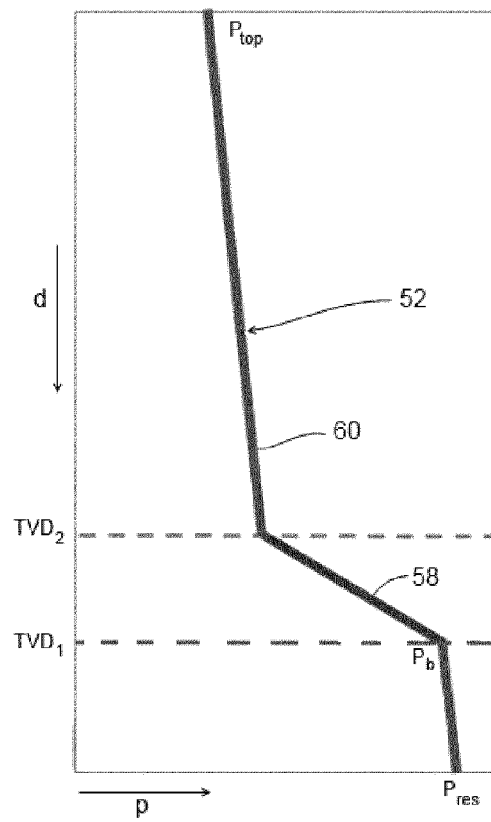


Fig. 3b



EUROPEAN SEARCH REPORT

 Application Number
 EP 13 16 3882

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	* column 3, lines 28-33 * * column 3, line 63 - column 4, line 4 * * column 10, lines 1-20 *	13-18	
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Y	* page 3, lines 33-52 * * page 5, lines 3-12 *	13-18	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 28 August 2013	Examiner Manolache, Iustin
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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