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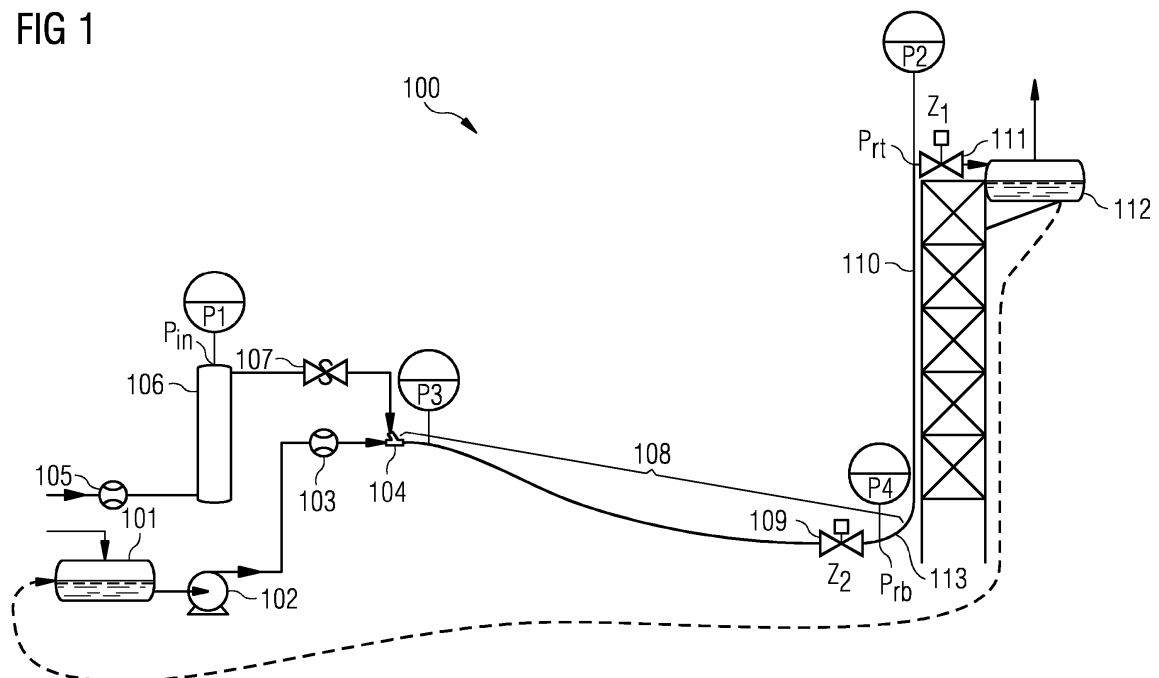
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(54) **Pipeline-riser system and method of operating the same**

(57) A pipeline-riser system (100) is provided which comprises a pipeline portion (108), an anti-slug valve (109), and a riser portion (110), wherein the pipeline por-

tion is connected to the riser portion at a joining point (113); and wherein the anti-slug valve is arranged in proximity to the joining point.

FIG 1



Description

Field of invention

[0001] The present invention relates to a pipeline-riser system, in particular to a pipeline-riser system comprising an anti-slug valve. Moreover, the invention relates to a method of operating a pipeline-riser system. Furthermore, the invention relates to a program element to and a computer readable medium.

Art Background

[0002] In the field of offshore oil production often pipeline-riser systems are used. In particular, at offshore oil-fields, subsea pipelines are used to transport the multiphase mixture of oil, gas and water from producing wells to the processing facilities. Several kilometers of pipeline run on the seabed ending with risers to top-side platforms. Therefore, in new field developments, multiphase transport technology and flow assurance become more important. Especially, depleted reservoirs have low pressures to push the fluid along the pipeline, and they are prone to flow instabilities. Liquids tend to accumulate at places with lower elevation, and can block the gas flow in the pipe. In low flow rate conditions, this blockage leads to a slugging flow regime called terrain slugging.

[0003] If the oscillating frequencies or the corresponding wavelengths of slugs are comparable to the length of the riser, the flow condition is called "severe slugging" or "riser-slugging". The severe-slugging flow is also characterized by large oscillatory variations in pressure and flow rates. The oscillatory flow condition in offshore multiphase pipelines is undesirable and an effective solution is needed to suppress it. One way to prevent this behavior is reducing the opening of a choke valve arranged at the top-side of the riser. However, this conventional solution increases the back pressure of the valve, and it reduces the production rate from the oil wells. The recommended solution to maintain a non-oscillatory flow regime together with the maximum possible production rate is active control of the topside choke valve. Measurements such as pressure, flow rate or fluid density are used as the controlled variables and the top-side choke valve is the manipulated variable. However, existing anti-slug control systems are typically not robust in practice and the closed-loop system becomes unstable after some time, because of inflow disturbances or plant changes.

[0004] Thus, there may be a need for providing a pipeline-riser system showing a low probability of slugging and a method of operating the same.

Summary of the Invention

[0005] This need may be met by a pipeline-riser system, a method of operating a pipeline-riser system, a program element to and a computer readable medium according to the independent claims. Further embodi-

ments are described in the dependent claims.

[0006] According to an exemplary aspect a pipeline-riser system is provided which comprises a pipeline portion, an anti-slug valve, and a riser portion, wherein the pipeline portion is connected to the riser portion at a joining point; and wherein the anti-slug valve is arranged in proximity to the joining point.

[0007] In particular, the pipeline-riser system may be an undersea pipeline-riser system, e.g. for offshore oil production. For example, the pipeline section is arranged upstream of the riser portion. In particular, the anti-slug valve may be arranged in the pipeline portion, the riser portion or at the joining point which is different to the known arrangement of anti-slug valves which are typically located at the topside platform. For example, the anti-slug valve may form the joining point or may be arranged at a base of the riser portion.

[0008] According to another exemplary aspect a method of slug controlling in a pipeline-riser system comprising an anti-slug valve arranged in proximity to a joining point of a pipeline portion and a riser portion of the pipeline-riser system is provided, wherein the method comprises controlling the anti-slug valve by a control signal generated based on a measured signal indicative for a flow of a fluid through the pipeline-riser system.

[0009] According to an exemplary aspect a program element is provided, which, when being executed by a processor, is adapted to control or carry out a method according to an exemplary aspect.

[0010] According to an exemplary aspect a computer-readable medium is provided, in which a computer program is stored which, when being executed by a processor, is adapted to control or carry out a method according to an exemplary aspect.

[0011] The term "pipeline portion" may particularly denote a portion of a tube system adapted to convey fluids, e.g. natural gas, crude oil or a multiphase fluid and which is arranged substantially horizontal or following the contour of the terrain, e.g. a subsea floor. A pipeline portion has to be distinguished from a riser portion of a pipeline-riser system.

[0012] The term "riser portion" may particularly denote a portion of the tube system which is arranged substantially vertical or at least does not follow a contour of the terrain. In particular, the riser portions may be that portions of a subsea tube arrangement, which are adapted to convey crude oil from the sea level to the surface, e.g. by pumping up the crude oil or multiphase fluid.

[0013] The term "anti-slug valve" may particularly denote a valve which is adapted or suitable to reduce or avoid slugging in a conveying pipeline-riser system. In particular, the anti-slug valve may be controllable or may have a preset throughput of a fluid, e.g. crude oil.

[0014] The term "proximity to the joining point" may particularly denote a point which is closer to the joining point than to other prominent points, like the top of the well where the pipeline section is connected to the well or the upper or top-side of the riser where the riser is

connected to an outlet or to a further pipeline. That is, the anti-slug valve may particularly be arranged closer to the joining point than to the well head of a subsea well and/or a top-side of the riser portion.

[0015] Surprisingly the inventors have found out by experiments using a test rig and performing simulations that an anti-slug valve while arranged before or at the beginning of a riser portion, in which riser slugging occurs, allows for reducing or even eliminating slugging during conveying of fluids through the pipeline-riser system.

[0016] Experiments have shown that anti-slug valves at the two positions, i.e. in proximity to the joining point and at the top-side of the riser provide a substantially equal operation range. Thus, it may be possible to provide a more robust anti-slug control and/or a more robust slug control and therefore an improved oil production when providing an anti-slug valve at or close to the joining point of the pipeline portion and the riser portion. Furthermore, the provision of an anti-slug valve at the joining point of the (subsea) pipeline portion and the riser portion may allow for using a common top-side (choke) valve for other controlling than slugging control, e.g. for absolute flow rate control or safety and shutdown purposes, and thus may allow for a production optimization.

[0017] Next further embodiments of the pipeline-riser system will be described. However, these embodiments also apply to the method of operating a pipeline-riser system, to the program element and to the computer readable medium.

[0018] According to an exemplary embodiment of the pipeline-riser system the anti-slug valve comprises a control interface adapted to receive control signals.

[0019] In particular, the control signal may be suitable or may be adapted to modify or change a throughput of the anti-slug valve, e.g. by increasing or decreasing an aperture of the anti-slug valve, for example formed by a choke valve or the like. By providing a controllable anti-slug valve it may be possible to even further increase the anti-slugging control and/or to provide a higher rate of crude oil production or conveying through the pipeline-riser system.

[0020] According to an exemplary embodiment the pipeline-riser system further comprises a processing unit, wherein the processing unit is adapted to generate control signals adapted to control a throughput of the anti-slug valve. In particular, the processing unit may be a computer or computer unit.

[0021] According to an exemplary embodiment the pipeline-riser system further comprises a sensor unit arranged in connection to the pipeline-riser system and adapted to measure values of flow parameters.

[0022] In particular, the flow parameters may be a pressure, flow rate of a fluid flowing through the pipeline-riser system or a fluid density. By using these parameters a suitable control signal may be achievable since these parameters describe at least partially the flowing regime and flowing behavior of the multiphase fluid.

[0023] According to an exemplary embodiment of the

pipeline-riser system the sensor unit is arranged downstream of the anti-slug valve. In particular, the sensor unit may thus measure the values of flow parameters at a position downstream of the anti-slug valve.

[0024] According to an exemplary embodiment of the pipeline-riser system the anti-slug valve is arranged at a position having a distance to the joining point, wherein the distance is smaller than five lengths of the riser portion.

[0025] In particular, the distance may be smaller than three lengths of the riser portion, more particular smaller than one length or even smaller than half the length of the riser portion. Preferably the distance may be smaller than a fifth of the length of the riser portion, more preferably smaller than a tenth of the length of the riser portion. The length of the riser portion may particularly be defined from the joining point to the surface of the sea or to a further joining point at which a further horizontal pipeline section is attached to the riser portion.

[0026] According to an exemplary embodiment of the pipeline-riser system the anti-slug valve is arranged at a position having a distance to the joining point which is lower than 1000 m. In particular, the distance may be in the range of 0 m to 500 m, more particularly in the range of 0 m to 250 m or, even more particularly in the range of 0 m to 100 m, most particular in the range between 0 m and 50 m or even in the range between 0 m and 10 m or in the range between 0 m and 5 m.

[0027] According to an exemplary embodiment of the pipeline-riser system a ratio of a volume of the pipeline portion from the anti-slug valve to the joining point and a volume of the riser portion is below ten.

[0028] The ratio of volumes may be another possibility to define the distance or proximity. In particular, the ratio may be below 7, more particular below 5, even more particular below 2.5. Preferably the ratio may be between 0 and 1 or even between 0 and 0.5.

[0029] Next further embodiments of the method of operating a pipeline-riser system will be described. However, these embodiments also apply to the pipeline-riser system, to the program element and to the computer readable medium.

[0030] According to an exemplary embodiment the method further comprises measuring values of a process parameter which is indicative of the flow of a fluid through the pipeline-riser system.

[0031] For example, the respective measured values may be included in the measured or measurement signal. In particular, the measured variables may be a pressure or a timely behavior of pressure of the fluid flowing through the pipeline, a volumetric flow rate or mass flow rate, a flowing rate, an oscillation frequency of timely variation of a pressure. All these variables may be measured in particular from the subsea pipeline, i.e. from the pipeline portion or at the top-side of the riser portion or section.

[0032] According to an exemplary embodiment the method further comprises generating the control signal based on the measured signal. For example, the control

signal may be generated by a control unit and/or processing unit, like a computer.

[0033] In particular, a gist of an exemplary embodiment may be seen in providing an anti-slug valve for an undersea pipeline-riser system, wherein the anti-slug valve comprises a control interface and is adapted to be mounted between an undersea pipeline of the pipeline-riser system and a riser of the pipeline-riser system. The anti-slug valve may be arranged close to the joining point of a pipeline portion and a riser portion of the pipeline-riser system, e.g. in particular, before the riser section in which a riser slugging occurs. It has been found out that although the anti-slug valve is thus arranged before or at least at the beginning of the riser section it may be possible to decrease the probability of riser slugging and/or the amount of riser slugging.

[0034] In particular, the anti-slug valve may be a choke valve. The term "anti-slug valve" may particularly denote a valve, e.g. a choke valve, which is adapted to control a flow through a pipeline, in particular, to prevent or at least reduce the probability of an oscillatory flow regime. In particular, the anti-slug valve may be adapted to be controlled by a control signal, wherein the controlling may be provided by increasing or decreasing a flow rate through the anti-slug valve, e.g. by opening or closing an aperture of the anti-slug valve.

[0035] The aspects defined above and further aspects of the present invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to the examples of embodiment. The invention will be described in more detail hereinafter with reference to examples of embodiment, but to which the invention is not limited.

Brief Description of the Drawings

[0036]

Fig. 1 shows a simplified experimental set-up.

Fig. 2 shows a schematic piper-riser system for simulation.

Fig. 3 shows some simulation results.

Detailed Description

[0037] The illustration in the drawing is schematically. It is noted that in different figures, similar or identical elements may be provided with the same reference signs or with reference signs, which are different from the corresponding reference signs only within the first digit.

[0038] Fig. 1 shows a simplified experimental set-up. In particular, Fig. 1 shows a simplified pipeline-riser system 100 comprising a fluid reservoir 101 for simulating an oilfield for example. The fluid reservoir is connected via a pump 102 (simulating the pressure the crude oil in the oil field is exposed to) and a water flow meter 103 to

a mixing point 104. Furthermore, an air flow meter 105 is connected to an air buffer tank 106 having a pressure of P_1 or P_{in} . The air buffer tank 106 is connected to the mixing point 104 via a safety valve 107 and is used in the experiment to simulate gas expansion of a very long pipeline (corresponding to a real pipeline-riser system). The mixing point 104 corresponds in principle to the well head of a real offshore pipeline-riser system. At the mixing point the water/air fluid has a pressure of P_3 and is pumped through a pipeline portion or section 108 which is arranged substantially horizontal. Close or at the other end of the pipeline portion 108 a subsea valve 109 is arranged which may form an anti-slug valve of the experimental set-up. At the subsea valve 109 the multiphase (water/air) fluid has a pressure of P_{rb} (pressure at riser bottom) or P_4 .

[0039] In the experimental set-up of Fig. 1 a riser of the pipeline-riser system 100 is formed by a framework structure to which the riser portion 110 is attached for simulating the riser portion of a real pipeline-riser system. The riser portion 110 and the pipeline portion 108 are joined at a joining point 113. At top of the framework structure a top-side valve 111 is connected to the riser 110 simulating a common top-side valve which is typically used for slugging control. At the top-side the multiphase fluid has a pressure of P_{rt} (pressure at riser top) or P_2 . After the top-side valve the multiphase fluid is conveyed to a separator 112 in which the air phase is separated from the water phase which is recycled and conveyed back to the water reservoir 101.

[0040] Fig. 2 shows a schematic piper-riser system for simulation. In particular, the schematic pipeline-riser system 200 may be used in a simulation of the experimental set-up of Fig. 1 and forms a well-pipeline-riser model. In the simulation, e.g. a simulation with the known OLGA tool a reservoir 201 is defined which has a pressure of P_{bh} (pressure at bottom hole). Furthermore, a well 213 is defined simulating a real well and connected at the upper end to a wellhead valve 214 at which a pressure of P_{wh} (pressure at wellhead) is present. The wellhead valve 214 may form a first anti-slug valve which is analysed in simulation and is thus also labelled Z_3 in Fig. 2. After the wellhead valve 214 the pressure of the multiphase fluid is described by P_{in} (pressure at inlet). The wellhead valve 214 is connected to a pipeline portion 208 which is simulated to be substantially horizontal. At a joining point 215 a subsea valve or riser-base valve 209 is arranged and at which the multiphase fluid pressure is described by P_{rb} (pressure at riser bottom). The subsea valve 209 may be used as an anti-slug valve and is thus also labelled by Z_2 . Furthermore, a riser 210 is defined in the simulation at the top-side of which a top-side valve 211 is defined. A pressure at the top-side valve 211 is described by P_{rt} (pressure at riser top). The top-side valve 211 may also be used as an anti-slug valve and is thus also labelled by Z_1 .

[0041] In the simulation in particular the above described pressure values (P_{bh} , P_{wh} , P_{in} , P_{rb} and P_{rt}) may

be used as control variables.

[0042] Fig. 3 shows some simulation results as a comparison of the effects of a slugging control using a top-side valve (left side of Fig. 3) and subsea valve (right side of Fig. 3) by showing the so called bifurcations diagrams, describing the steady-state and the dynamics of this system. In particular, Fig. 3 shows the results of a simulation used to compare a simplified simulation model to experiments and simulations using the OLGA model. Fig. 3A shows the pressure P_{in} at the inlet of the pipeline vs. the top-side valve opening (Z_3) in percent. Fig. 3B shows the pressure P_{rt} at the top of riser vs. the top-side valve opening (Z_3) in percent. Fig. 3C shows the pressure P_{in} at the inlet of the pipeline vs. the subsea valve opening (Z_2) in percent. Fig. 3D shows the pressure P_{rt} at the top of riser vs. the subsea valve opening (Z_2) in percent.

[0043] In the whole Fig. 3 the simplified model (thin solid lines; 301, 302, 303) is compared to the experiments (bold solid lines; 304, 305, 306) and the OLGA model (dashed lines; 307, 308, 309). In Figs. 3A and 3B (top-side valve used for slugging control), the system has a stable (non-slug) flow when the topside valve opening Z_3 is smaller than 15%, and it switches to slugging flow conditions for $Z_3 > 15\%$. In each of the Figs. 3A and 3B three lines for each of the three experiment/models for slugging conditions are shown. They represent the minimum (301 for experiment, 304 for simple model and 307 for OLGA model) of the oscillations, the maximum (302 for experiment, 305 for simple model and 308 for OLGA model) of the oscillations and the steady-state (303 for experiment, 306 for simple model and 309 for OLGA model). The steady-state at slugging condition ($Z_3 > 15\%$) is unstable, but it can be stabilized by using control.

[0044] In Figs. 3C and 3D (subsea valve used for slugging control), the system has a stable (non-slug) flow when the subsea valve opening Z_2 is smaller than 8%, and it switches to slugging flow conditions for $Z_2 > 8\%$. In each of the Figs. 3C and 3D as well three lines for each of the three experiment/models for slugging conditions are shown. They represent the minimum (301 for experiment, 304 for simple model and 307 for OLGA model) of the oscillations, the maximum (302 for experiment, 305 for simple model and 308 for OLGA model) of the oscillations and the steady-state (303 for experiment, 306 for simple model and 309 for OLGA model). The steady-state at slugging condition ($Z_2 > 8\%$) can be stabilized by using control. Thus according to the simulations the critical valve opening for the subsea valve is $Z_2 = 8\%$ as shown in Fig. 3C and Fig. 3D. With the OLGA model it was more difficult to capture both steady-state and the dynamics for the subsea choke valve at the same time. However, by adjusting the coefficient of discharge of the subsea valve it was possible to get the critical valve opening correct.

[0045] Summarizing, the experimental results and the two models all show that by using a subsea valve arranged close to the basis of a riser portion in a pipeline-riser system may be a suitable candidate for anti-slug

control or as an anti-slug valve which at least show similar results as the use of a top-side valve for slugging control. By using the subsea valve for slugging control a common top-side valve may be used for different control or adjusting processes, e.g. for absolute flow rate control or safety and shutdown purposes, and thus may allow for a production optimization.

[0046] It should be noted that the term "comprising" does not exclude other elements or steps and "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

Claims

1. A pipeline-riser system (100) comprising:
 - a pipeline portion (108);
 - an anti-slug valve (109); and
 - a riser portion (110);
 - wherein the pipeline portion (108) is connected to the riser portion (110) at a joining point (113); and
 - wherein the anti-slug valve (108) is arranged in proximity to the joining point (113).
2. The pipeline-riser system (100) according to claim 1, wherein the anti-slug valve (109) comprises a control interface adapted to receive control signals.
3. The pipeline-riser system (100) according to claim 1 or 2, further comprising a processing unit, wherein the processing unit is adapted to generate control signals adapted to control a throughput of the anti-slug valve.
4. The pipeline-riser system (100) according to any one of the claims 1 to 3, further comprising:
 - a sensor unit arranged in connection to the pipeline-riser system (100) and adapted to measure values of flow parameters.
5. The pipeline-riser system (100) according to claim 4, wherein the sensor unit is arranged downstream of the anti-slug-valve.
6. The pipeline-riser system (100) according to any one of the claims 1 to 5, wherein the anti-slug valve (109) is arranged at a position having a distance to the joining point (113), wherein the distance is smaller than five lengths of the riser portion (110).
7. The pipeline-riser system (100) according to any one of the claims 1 to 6, wherein the anti-slug valve (109)

is arranged at a position having a distance to the joining point (113) which is lower than 1000 m.

8. The pipeline-riser system (100) according to any one of the claims 1 to 7, wherein a ratio of a volume of the pipeline portion from the anti-slug valve to the joining point and a volume of the riser portion is below ten. 5

9. A method of slug controlling in a pipeline-riser system (100) comprising an anti-slug valve (109) arranged in proximity to a joining point (113) of a pipeline portion (108) and a riser portion (110) of the pipeline-riser system (100), wherein the method comprises: 10 15

controlling the anti-slug valve (109) by a control signal generated based on a measured signal indicative for a flow of a fluid through the pipeline-riser system (100). 20

10. The method according to claim 9, further comprising:

measuring values of a process parameter which is indicative of the flow of a fluid through the pipeline-riser system (100). 25

11. The method according to claim 9 or 10, further comprising: 30

generating the control signal based on the measured signal.

12. A program element, which, when being executed by a processor, is adapted to control or carry out a method according to any one of the claims 9 to 11. 35 40

13. A computer-readable medium, in which a computer program is stored which, when being executed by a processor, is adapted to control or carry out a method according to any one of the claims 9 to 11. 45 50 55

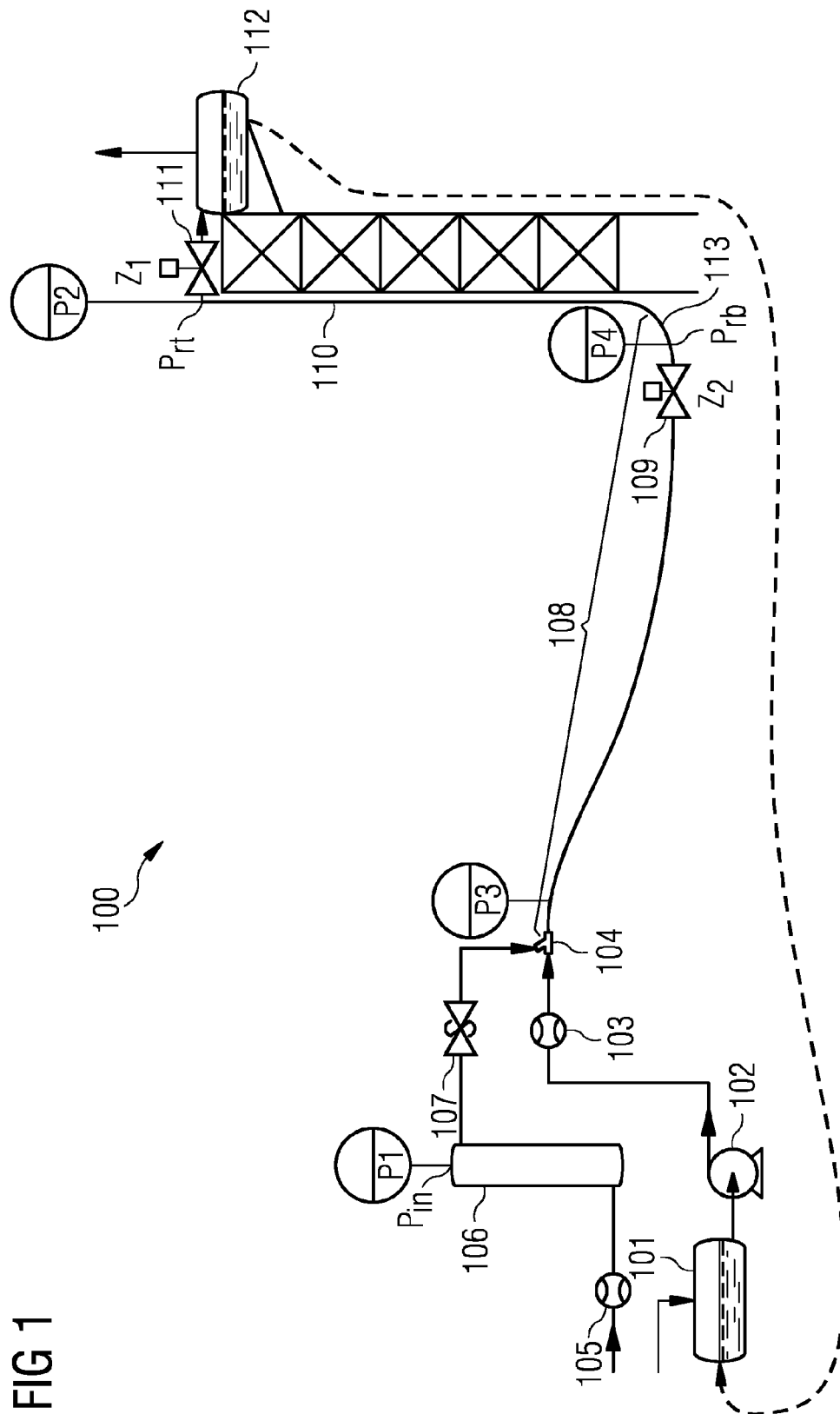


FIG 1

FIG 2

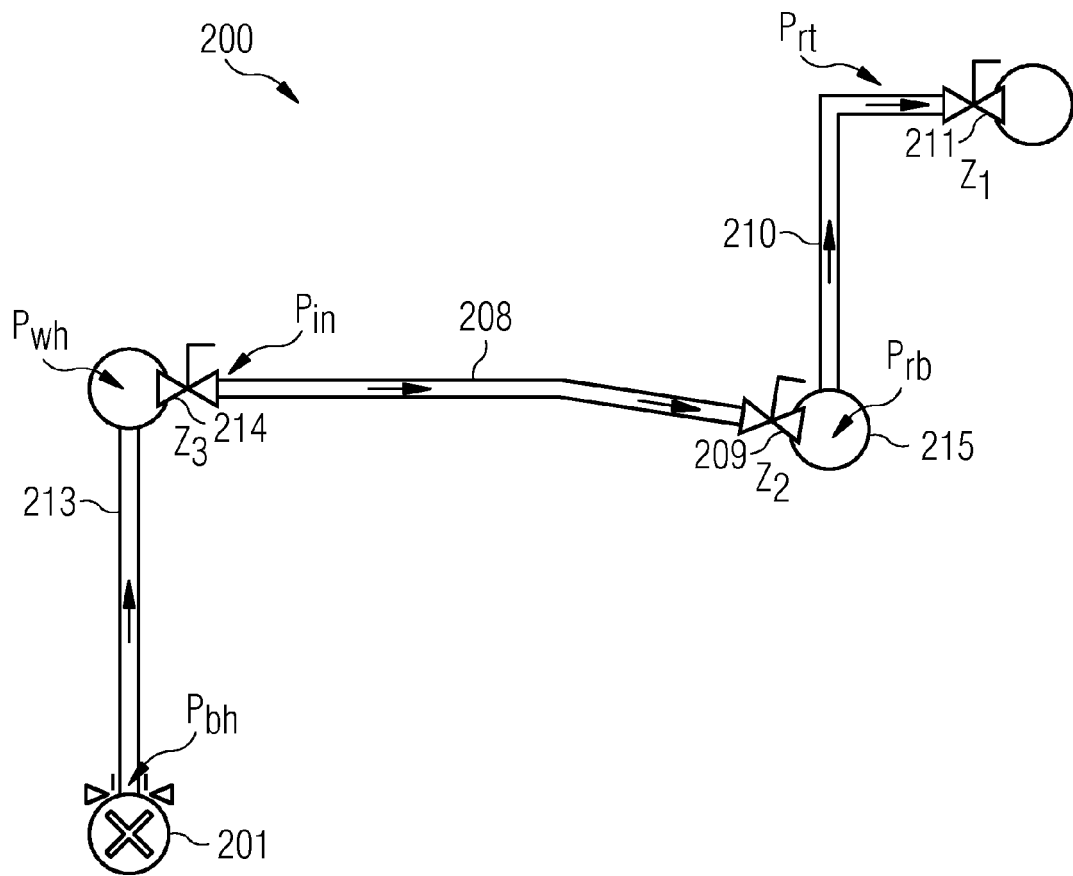


FIG 3A

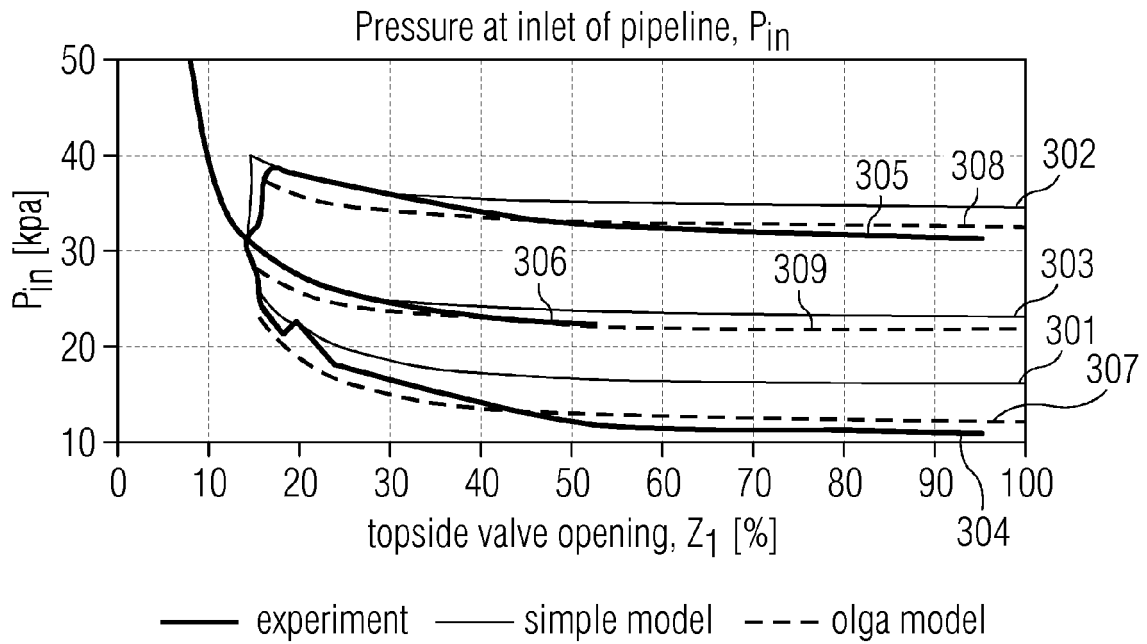


FIG 3B

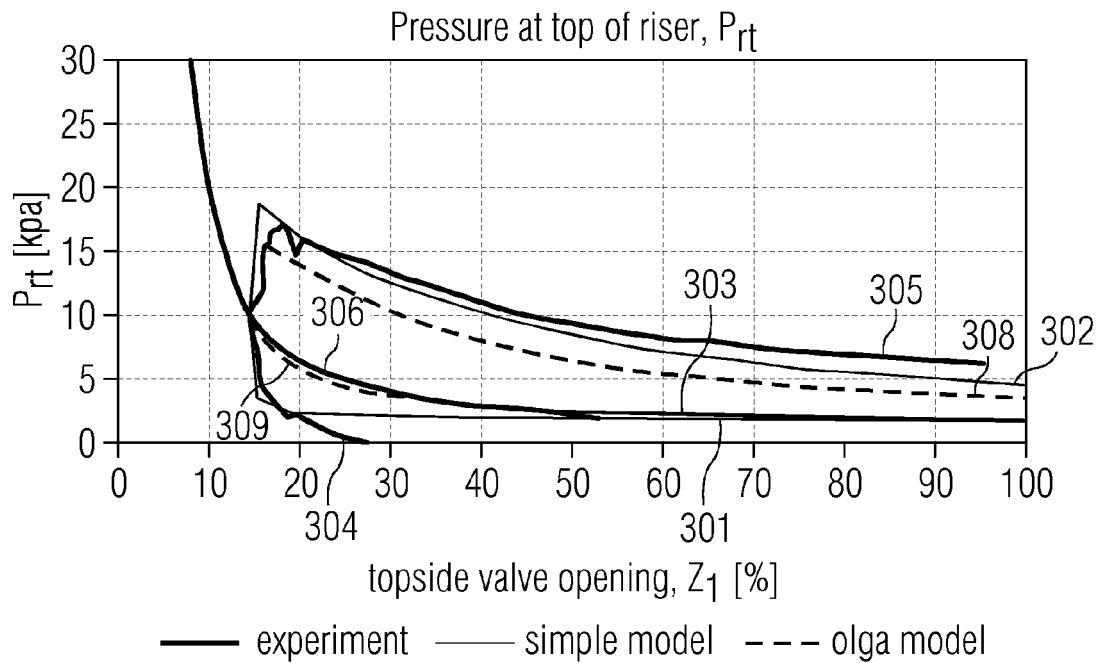


FIG 3C

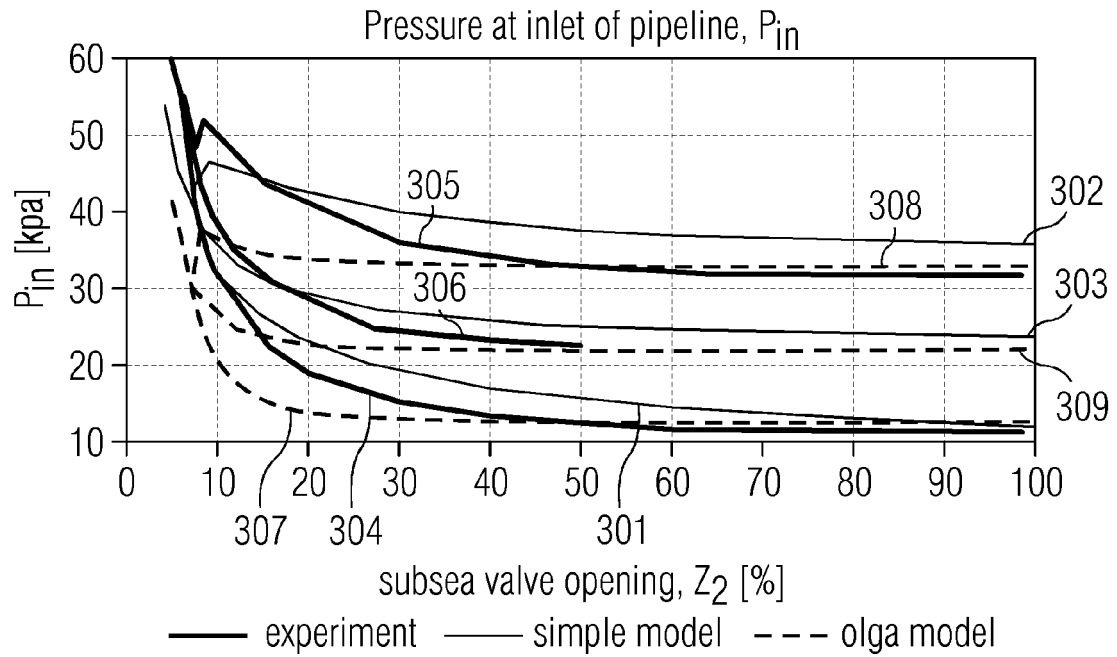
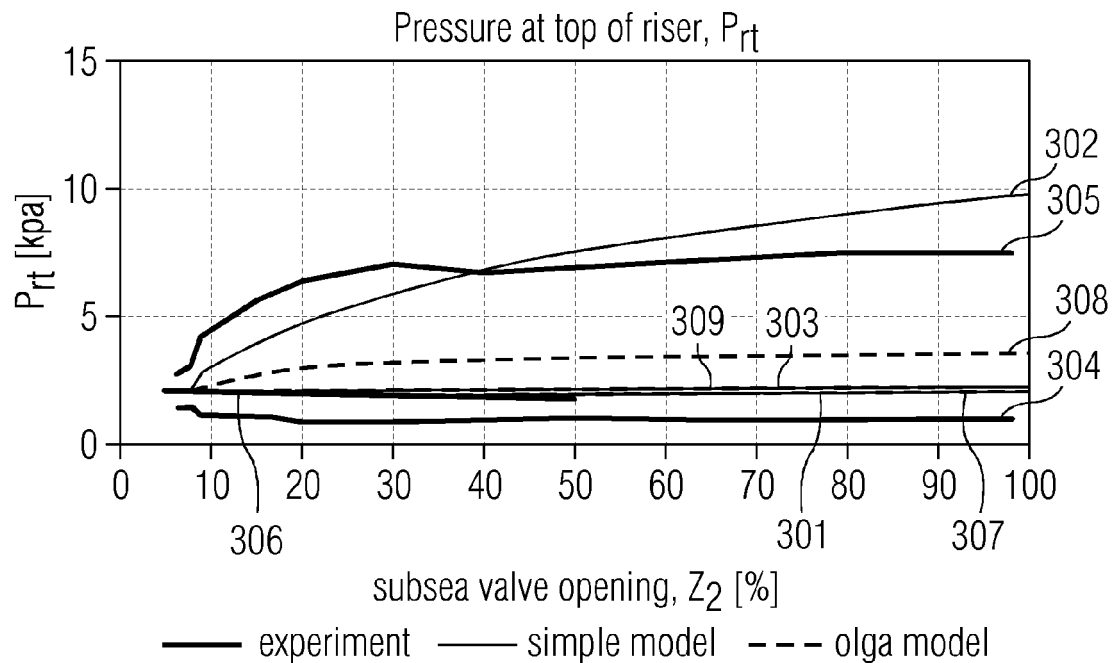


FIG 3D





EUROPEAN SEARCH REPORT

Application Number
EP 13 17 4514

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	Mats Lieungh: "Stabilizing Slug Control Using Subsea Choke Valve", 7 June 2012 (2012-06-07), XP055093244, Retrieved from the Internet: URL:http://urn.kb.se/resolve?urn=urn:nbn:se:ntnu:diva-18525 [retrieved on 2013-12-13] * page 39 - page 45 *	1-13	INV. E21B43/12 E21B43/01
X	JAHANSHAH E ET AL: "Anti-slug control experiments using nonlinear observers", 2013 AMERICAN CONTROL CONFERENCE, IEEE, 17 June 2013 (2013-06-17), pages 1056-1062, XP032476135, ISSN: 0743-1619 ISBN: 978-1-4799-0177-7 [retrieved on 2013-08-14] * the whole document *	1-13	
X	Esmail Jahanshahi: "Anti-slug control experiment", 24 April 2013 (2013-04-24), pages 1-5, XP055093249, Retrieved from the Internet: URL:www.nt.ntnu.no/users/skoge/.../Slug-rig-Instruction%20Manual2.docx‎ [retrieved on 2013-12-13] * the whole document *	1-13	TECHNICAL FIELDS SEARCHED (IPC) E21B
X	US 2010/132800 A1 (JAMALUDDIN ABUL K M [MY] ET AL) 3 June 2010 (2010-06-03) * paragraph [0014]; figure 1 * * paragraph [0038] *	1-13	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 13 December 2013	Examiner Dantine, Patrick
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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