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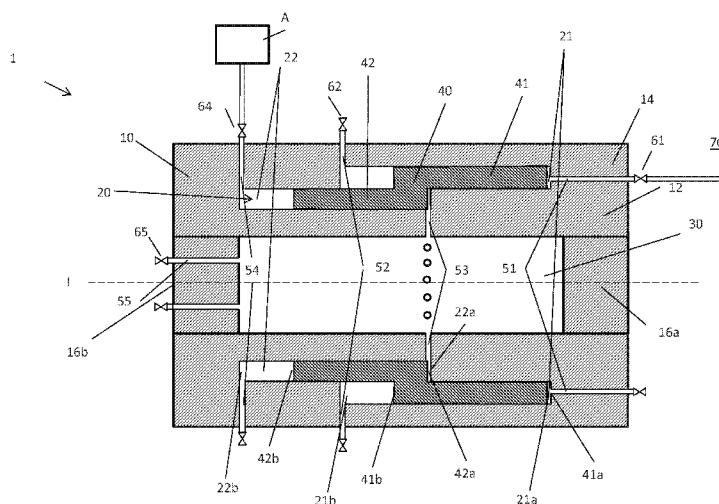


Fig. 1

(57) Abstract: The present invention relates to a subsea accumulator device (1) for supplying pressurized fluid to a subsea device (A). The accumulator device (1) comprises a housing device (10) comprising a piston compartment (20) and a pressurized compartment (30) and a piston device (40) axially displaceable within the piston compartment (20) between an initial state and an actuated state. The piston device (40) divides the piston compartment into a first (21a), a second (21b), a third (22a) and a fourth (22b) chamber, the piston device (40) having first, second, third and fourth piston surfaces (41a, 41b, 42a, 42b) facing the respective chambers (21a, 21b, 22a, 22b). The first chamber (21a) is in fluid communication with the environment (70) via a first line (51) and a first valve (81). The second chamber (21b) is an underpressure chamber. The third chamber (22a) is in fluid communication with the pressurized compartment (30) via a third line (53). The fourth chamber (22b) is in fluid communication with a fourth line (54) configured to be connected to the subsea device (A).



ACCUMULATOR

FIELD OF THE INVENTION

The present invention relates to a subsea accumulator device for actuating a subsea device.

5 BACKGROUND OF THE INVENTION

Subsea accumulators are used in subsea installations as a backup source of energy in case of a failure in the main energy supply. For example, in case of an emergency, the accumulator makes it possible to provide sufficient power to actuate a blowout preventer (BOP) in order to shut down a hydrocarbon well,
10 even if the main source of energy is malfunctioning.

One known conventional accumulator comprises a bladder filled with a high pressure actuation fluid which is connected to the subsea device in need of such actuation fluid in case of an emergency. The connection between the bladder and the subsea device is provided by a fluid line having a valve. Under
15 normal circumstances the valve is closed and the subsea device uses its main or primary energy source. In case of an emergency, the valve is opened and fluid flows from the bladder to the subsea device and actuates the subsea device.

Another known conventional accumulator comprises a piston and cylinder. In a first chamber located on a first side of the piston, a high pressure gas is provided. In a second chamber located on the opposite side of the piston, an
20 actuation fluid (liquid) is provided. The second chamber is connected to the subsea device via a fluid line having a valve. Again, upon actuation the valve is opened and the pressurized gas is allowed to expand, causing the piston to move and displace actuation fluid from the second chamber to the subsea device. It is
25 also known to connect further gas containers to the first chamber.

The disadvantages of the above solutions are that the size of such accumulators increases considerably when they are designed for depths exceeding 1500 m – 2000 m. In addition, the handling of accumulators on a vessel during deployment into the sea represents a safety issue, as the
30 accumulators contain a large volume of gas under high pressure.

An object of the invention is to provide a subsea accumulator for large depths which has a relatively low internal pressure during its handling topside.

SUMMARY OF THE INVENTION

The present invention relates to a subsea accumulator device for supplying pressurized fluid to a subsea device. The accumulator device comprises a housing device which includes a piston compartment and a pressurized compartment, and a piston device which is axially displaceable within the piston compartment between an initial position and an actuated position. The piston device divides the piston compartment into first, second, third and fourth chambers, and the piston device has first, second, third and fourth piston surfaces facing the respective chambers. The first chamber is in fluid communication with the environment via a first line and a first valve. Hence, seawater may enter the first chamber when the first valve is opened. The second chamber is an underpressure chamber. The third chamber is in fluid communication with the pressurized compartment via a third line. The fourth chamber is in fluid communication with a fourth line which is configured to be connected to the subsea device.

In the initial state of the piston device the pressurized compartment is filled with a pressurized gas. The filling operation may take place topside or subsea. The first valve is closed in the initial state and is open in the actuated state. In the initial state the fourth chamber is filled with a pressurized actuating fluid which is to be supplied to the subsea device. The fourth line is provided with a fourth valve, which may be referred to as an actuating fluid valve. Alternatively, the actuating fluid valve may be provided on the subsea device itself. The actuating fluid valve is closed in the initial state and is open in the actuated state. The second chamber may be a closed chamber, or it may be in fluid communication with a second line provided with a second valve.

The first and third chambers are provided on a first side of the piston device and the second and fourth chambers are provide on a second side of the piston device opposite the first side. The piston device comprises first and second sleeve-shaped piston sections fixed to each other, and the first sleeve-shaped piston section may have a diameter different from the diameter of the second sleeve-shaped piston section. The first and second piston surfaces are located on opposite ends of the first piston section and the third and fourth piston surfaces are located on opposite ends of the second piston section.

The pressurized compartment is provided within the housing device radially inside of the piston device. Alternatively, the pressurized compartment can be provided in a separate housing, external to the housing device.

The present invention also relates to a method for supplying pressurized fluid from a subsea accumulator device to a subsea device, wherein the subsea accumulator device comprises a housing device which includes a piston compartment and a pressurized compartment, and a piston device which divides the piston compartment into first, second, third and fourth chambers. The method comprises the steps of:

- providing the first chamber in fluid communication with the environment via a first line and a first valve;
- providing an underpressure in the second chamber;
- providing fluid communication between the pressurized compartment and the third chamber via a third line;
- filling the fourth chamber with an actuating fluid and pressurizing the actuating fluid, thereby displacing the piston device to an initial state;
- closing the first valve;
- closing a fourth valve provided in a fourth fluid line which is connected to the fourth chamber;
- positioning the accumulator device subsea; and
- connecting the accumulator device to the subsea device via the fourth line.

The accumulator device is configured to be brought to an actuated state by opening the first valve and the fourth valve, thereby allowing seawater to enter into the first chamber via the first line and allowing actuating fluid to exit from the fourth chamber, thereby allowing displacement of the piston device to its actuated state and hence supplying the subsea device with actuating fluid via the fourth line.

The step of connecting the accumulator device to the subsea device may be performed subsea. Alternatively, this step can be performed topside.

The step of providing an underpressure in the second chamber comprises the step of applying a suction force to a second line which is in fluid communication with the second chamber and closing a second valve which is provided in the second line. Alternatively, the second chamber can be closed

and sealed off when the piston is in the actuated position, in which event the underpressure in the second chamber is created when the piston device is moved from the actuated position to the initial position.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Embodiments of the invention will now be described in detail with reference to the accompanying drawings, in which:

 Figure 1 is a schematic cross sectional view of an embodiment of the accumulator device of the present invention shown in an initial state;

10 Figure 2a is a cross sectional view of the upper half of the piston device shown in Figure 1, further showing the forces acting on the piston device;

 Figure 2b is a perspective view of the piston device shown in Figure;

 Figure 3 is a schematic cross sectional view of the accumulator device of Figure 1 shown after actuation;

15 Figures 4a, 4b and 4c illustrate different configurations of the invention, wherein in Figure 4A the radius R3 is equal to the radius R2, in Figure 4b the radius R3 is smaller than radius R2, and in Figure 4c the radius R3 is larger than the radius R2;

20 Figure 5 is a table showing comparison data between a conventional bladder-type accumulator and the accumulator device of the present invention, which is referred to in Figure 5 as "PBA"; and

 Figure 6 is a table showing comparison data between a conventional "piston and cylinder with gas" accumulator and the accumulator device of the present invention, which is referred to in Figure 6 as "PBA".

DETAILED DESCRIPTION OF THE INVENTION

25 The subsea accumulator device of the present invention is shown schematically in Figure 1. The subsea accumulator device, which is indicated generally with the number 1, is provided for supplying pressurized fluid to a subsea device, indicated with the letter A.

30 The subsea device A may be any device which is used for safety shut downs of critical elements during drilling or workover operations, such as a blowout preventer (BOP), an emergency quick disconnect device (EQD), a weak link, or any other safety device which is operated with hydraulic fluid. The subsea device A is designed to be actuated when it receives a predetermined amount of pressurized fluid. Hence, some of the factors required to determine the size of

the accumulator device 1 will be the amount of fluid needed to actuate the subsea device A, the fluid pressure needed to actuate the subsea device 1, and the depth of the subsea device A and the accumulator device 1.

The accumulator device 1 comprises a housing device 10 and a piston device 40. The housing device 10 comprises a piston compartment 20 in which the piston device 40 is axially displaceable between an initial position or state and an actuated position or state. In Figure 1, the piston device 40 is shown in its first or initial (i.e., rightmost) position. In Figure 3, the piston device 40 is shown in its second or actuated (i.e., leftmost) position.

The housing device 10 further comprises a pressurized compartment 30. It should be mentioned that in the present embodiment the piston device 40 is substantially cylindrical, as will be described below with reference to Figure 2b. The pressurized compartment 30 is located centrally within the housing device 10, that is, the piston device 40 is positioned circumferentially around the compartment 30.

The piston device 40 divides the piston compartment 20 into four chambers: a first chamber 21a, a second chamber 21b, a third chamber 22a and a fourth chamber 22b. Correspondingly, the piston device 40 has four piston surfaces: a first piston surface 41a, second piston surface 41b, third piston surface 42a and fourth piston surface 42b, each of which faces a respective chamber 21a, 21b, 22a, and 22b.

As shown in Figure 1, the first chamber 21a is provided on the right of the piston device 40. The first chamber 21a is connected with the environment 70 via a first line or port 51 which is controlled by a first valve 61. When lowered into the sea, and by opening the first valve 61, the pressure in the first chamber 21a will be equal to the pressure of the seawater at the depth of the accumulator device 1. Hence, with reference to Figure 2a, the seawater will apply a first force F21a on the first piston surface 41a of the piston device 40 in a direction towards the actuated position. Accordingly, the first chamber 21a may be denoted as a seawater chamber or a hydrostatic chamber.

Referring again to Figure 1, the second chamber 21b is provided on the left of the piston device 40. The second chamber 21b is connected with the outside of the housing device 10 via a second line or port 52. A second valve 62 may be used to open or close the port 52. However, it is preferred that the port

52 be closed with a plug device. The purpose of this chamber will be explained more fully below. The second chamber 21b may be denoted as an underpressure chamber or a vacuum chamber.

The third chamber 22a is provided on the right of the piston device 40 as shown in Figure 1. The third chamber 22a is in fluid communication with the pressurized compartment 30 via a third line 53. Hence, the third chamber 22a may be denoted as a pressurized gas chamber.

A gas charge line 55 is provided in the housing device 10 for charging the pressurized compartment 30 with a pressurized gas. The gas charge line 55 is configured to be opened and/or closed by means of a gas charge valve 65, which is closed in both the initial state and the actuated state.

The fourth chamber 22b is provided on the left of the piston device 40 and is connected to a fourth fluid line or port 54. In the present embodiment, a valve 64 is provided for opening and closing the port 54.

Referring still to Figure 1, the housing device 10 may, for example, comprise an inner, substantially cylindrical mandrel device 12 having an axial through bore which forms the pressurized compartment 30. End caps 16a, 16b may be fixed in the respective ends of the through bore for enclosing the pressurized compartment 30. The housing device 10 may also comprise an outer housing 14 located radially outside of the mandrel device 12, in which case the piston compartment 20 is located radially between the mandrel device 12 and the outer housing 14.

As shown in Figure 2b, the piston device 40 comprises first and second sleeve-shaped piston sections 41, 42 which are fixed to each other. The first sleeve-shaped piston section 41 has a diameter D41 different from the diameter D42 of the second sleeve-shaped piston section 42. In Figure 2b the first piston section 41 is shown to have a larger diameter than the second piston section 42.

As described above, the first and third chambers 21a, 22a, and hence the first and third piston surfaces 41a, 42a, are provided on a first side of the piston device 40 (i.e., the right side as viewed in Figure 1), while the second and fourth chambers 21b, 22b, and hence the second and fourth piston surfaces 41b, 42b, are provided on a second side of the piston device opposite of the first side (i.e., the left side as viewed in Figure 1).

Figures 4a, 4b and 4c illustrate three different configurations of the accumulator device 1, with different relationships between the radii R1, R2, R3 and R4, and hence also between the piston areas A_s (area of piston surface 41a), A_v (area of piston surface 41b), A_g (area of piston surface 42a), and A_h (area of piston surface 42b).

In table 1 below, nine different configurations for the accumulator device 1 (referred to as "CPBA") are shown.

Table 1: Possible Configurations of the Accumulator Device

Type	Configuration	A_g/A_h	A_s/A_h
CPBA	1	1	1
CPBA	2	1	<1
CPBA	3	1	>1
CPBA	4	>1	1
CPBA	5	>1	<1
CPBA	6	>1	>1
CPBA	7	<1	1
CPBA	8	<1	<1
CPBA	9	<1	>1

Operation of the Accumulator Device

The operation of the accumulator device 1 will now be described. In the present embodiment the piston device 40 may be brought to its initial position topside and is then lowered into the sea together with the subsea device A.

Before use the accumulator device 1 must be charged. This is normally done topside before the accumulator device is lowered into the sea. Initially, the piston device 40 is moved to its second (i.e., leftmost) position, as shown in Figure 3. In this position of the piston device 40, the fourth line or port 54 is connected to a source of hydraulic fluid, the third line or port 53 is connected to a source of pressurized gas, valve 61 is open, and valve 62 is closed. The volume of the first chamber 21a is therefore filled with air at atmospheric pressure while the volume of the second chamber 21b is almost zero. Valve 64 is then opened to fill the fourth chamber 22b with hydraulic fluid to the desired working pressure, after which valve 64 is again closed. This action will displace the piston device 40 to the right and into its first or initial position (shown in Figure 1). Valve 65 is

then opened to fill the pressurized chamber 30 with gas to a desired operating pressure, after which valve 65 is again closed to trap the gas within this chamber.

As the piston device 40 is being displaced to the right by the hydraulic fluid filling the fourth chamber 22b, the air in the first chamber 21a is driven out as the volume of this chamber approaches zero. However, since the valve 62 is closed the second chamber 21b will be depressurized to an extent that the pressure inside this chamber will be near zero. Hence, with reference to Figure 2a, the second or underpressure chamber 21b will apply a second force F21b to the second piston surface 41b of the piston device 40 in a direction towards the second (i.e., leftmost) position of the piston device. Due to the relatively lower pressure in the second chamber 21b, the second chamber 21b may also be denoted as a vacuum chamber. However, the term "vacuum" does not imply that there is a perfect vacuum in the second chamber; it only implies that the pressure is sufficiently low to provide the above force F21b. Preferably, the pressure inside the second chamber 21b is lower than 101 kPa (1 atmosphere), for example 1 kPa – 10 kPa or even lower.

The valves 61, 64 and 65 can now be closed, at which point the accumulator device 1 is ready for use.

In an alternative embodiment the accumulator device 1 can be charged using the hydraulic line. A pump is connected to the fourth line or port 54 to supply pressurized hydraulic fluid into the fourth chamber 22b until it has reached the correct working pressure. This will also drive the piston device 40 to the first (i.e. rightmost) position.

In yet another alternative embodiment, the accumulator device 1 may be charged using the second chamber 21b. First, the piston device 40 is moved to its initial position, then a suction pump (not shown) is used to remove the air from the second chamber 21b, and then the second valve 62 is closed. Alternatively, the valve 62 is a one-way valve, allowing gas inside the second chamber to exit while moving the piston device 62 to the left, then, during the initialization, preventing gas from entering the second chamber 21b when the piston device 40 is moved to the right, thereby providing a low pressure inside the second chamber 21b.

The accumulator device 1 is then lowered into the sea and down to the seabed. Here, the subsea device A is connected to the accumulator device 1 via the fourth line 54.

When the subsea device A needs to be supplied with the actuation fluid, the accumulator device 1 is brought to the actuated state by opening the first valve 61 and the fourth valve 64, thereby allowing seawater to enter into the first chamber 21a via the first line 51 and allowing the actuating fluid to exit from the fourth chamber 22b through the fourth line 54. Preferably, the first valve 61 is opened before the fourth valve 64.

The first and fourth valves 61, 64 may, for example, be opened by means of a remotely operated vehicle (ROV).

The opening of the first and fourth valves 61, 64 causes a displacement of the piston device 40 to its second position, since, with reference to Figure 2a, the fourth force F22b is now smaller than the sum of the first, second and third forces F21a, F21b and F22a. As long as the subsea device A is receiving actuating fluid from the fourth chamber 22b, the piston device 40 will move towards the position shown in Figure 3.

Alternative embodiments

In an alternate embodiment, the piston device 40 may be brought to its initial state subsea, i.e., where the environment 70 is seawater. This may enable the accumulator to be recharged while in location subsea.

In yet an alternative embodiment, the accumulator device 1 could be connected to the subsea device A via the fourth fluid line 54 after lowering the accumulator device 1 to the subsea device A. In such a case, the fourth valve 64 may be provided as a part of the accumulator device 1. Alternatively, the fourth valve 64 may be provided as a part of the subsea device A.

In yet another alternative embodiment, the fourth line 54 may be separated into several branch lines, each having a valve. In this way, one accumulator device may serve as an energy source for more than one subsea device A.

In the embodiment described in Figure 1, the seawater chamber 21a and the underpressure chamber 21b are provided on opposite sides of the first sleeve-shaped piston section 41, and the pressurized gas chamber 22a and the actuation fluid chamber 22b are provided on opposite sides of the second sleeve-shaped piston section 42. In alternative embodiments, it is possible to provide

the seawater chamber 21a on the right side of the second sleeve-shaped piston section 42 and the pressurize gas chamber 22a on the right side of the first sleeve-shaped piston section 41, and/or to provide the underpressure chamber 21b on the left side of the sleeve-shaped second piston section 42 and the actuation fluid chamber 22b on the left side of the first sleeve-shaped section 41.

Normally a subsea accumulator must take into account the ambient pressure at its designed water depth. Hence the accumulator must be charged up not only to provide the necessary hydraulic pressure to the subsea device but also to the water depth. For example, if the subsea device requires a hydraulic pressure of 220 bar and the water depth is 3000 meters the accumulator must be charged up to 520 bar. The conventional accumulators must also be individually charged for the targeted water depths.

With the present invention, the ambient pressure in the first chamber 21a combined with the underpressure chamber 21b will almost cancel each other out so that it is only necessary to charge up the accumulator slightly above the requirement of the subsea device. The present invention also uses less hydraulic fluid, as can be seen in the tables shown in Figures 5 and 6.

In the preferred embodiment the ratio of the piston areas is one to one. However, a range of ratios is possible, as shown in Table 1 above. The ratio may be varied to suit different depths or to enhance the function of the accumulator device.

Referring now to Figure 5, for 5K to 3K accumulators (i.e., accumulators designed for precharge pressures between 5 kpsi – 3 kpsi), it can be seen that the precharge pressure for the accumulator device of the invention (which is referred to as "PBA") is 4285 psi, while the precharge pressure for a conventional accumulator is 8776 psi. Thus, the accumulator device of the present invention achieves a reduction of the precharge pressure of 50%. For 10K to 5K accumulators, the corresponding reduction of the precharge pressure is 17%.

Referring to Figure 6, the precharge pressure for the conventional accumulator is shown to be 4.2 kpsi, while the precharge pressure for the accumulator according to the invention is 2.7 psi. Also, the discharge volume is shown to be constant (=4.2 gal) for the present invention, while the discharge volume is reduced drastically, for deeper depths for the conventional accumulator.

CLAIMS

1. A subsea accumulator device (1) for supplying pressurized fluid to a subsea device (A), the subsea accumulator device comprising:

a housing device (10) comprising a piston compartment (20) and a pressurized compartment (30);

a piston device (40) axially displaceable within the piston compartment (20) between an initial state and an actuated state;

characterized in that,

the piston device (40) divides the piston compartment into a first chamber (21a), a second chamber (21b), a third chamber (22a) and a fourth chamber (22b), the piston device (40) having first, second, third and fourth piston surfaces (41a, 41b, 42a, 42b) facing the respective chambers (21a, 21b, 22a, 22b);

wherein the first chamber (21a) is in fluid communication with the environment (70) via a first line (51) and a first valve (61), the second chamber (21b) is an underpressure chamber, the third chamber (22a) is in fluid communication with the pressurized compartment (30) via a third line (53), and the fourth chamber (22b) is in fluid communication with a fourth line (54) which is configured to be connected to the subsea device (A).

2. The subsea accumulator device (1) according to claim 1, wherein the pressurized compartment (30) is filled with a pressurized gas in the initial state of the piston device.

3. The subsea accumulator device (1) according to any one of the above claims, wherein the first valve (61) is closed in the initial state of the piston device, and wherein the first valve (61) is open in the actuated state of the piston device.

4. The subsea accumulator device (1) according to claim 1 or 2, wherein the fourth chamber (22b) is filled with a pressurized actuating fluid in the initial state of the piston device, and wherein the fourth line (54) is provided with an actuating fluid valve (64).

5. The subsea accumulator device (1) according to claim 4, wherein the actuating fluid valve (64) is closed in the initial state of the piston device and is open in the actuated state of the piston device.

6. The subsea accumulator device (1) according to any one of the above claims, wherein the second chamber (21b) is in fluid communication with a second line (52) provided with a second valve (62).

7. The subsea accumulator device (1) according to any one of the above claims, wherein the first and third chambers (21a, 22a) are provided on a first side of the piston device (40) and the second and fourth chambers (21b, 22b) are provide on a second side of the piston device (40) opposite of the first side.

8. The subsea accumulator device (1) according to any one of the above claims, wherein the piston device (40) comprises first and second sleeve-shaped piston sections (41, 42) fixed to each other, and wherein the first sleeve-shaped piston section (41) has a diameter different from the diameter of the second sleeve-shaped piston section (42).

9. The subsea accumulator device (1) according to claim 8, wherein the first and second piston surfaces (41a, 41b) are located on opposite ends of the first piston section (41) and the third and fourth piston surfaces (42a, 42b) are located on opposite ends of the second piston section (42).

10. The subsea accumulator device (1) according to claim 8, wherein the pressurized compartment (30) is provided within the housing device (10) radially inside of the piston device (40).

11. A method for supplying pressurized fluid from a subsea accumulator device (1) to a subsea device (A), the subsea accumulator device (1) including a housing device (10) comprising a piston compartment (20) and a pressurized compartment (30) and having a piston device (40) dividing the piston compartment into a first chamber (21a), a second chamber (21b), a third chamber (22a) and a fourth chamber (22b), the method comprising the steps of:

providing the first chamber (21a) in fluid communication with the environment (70) via a first line (51) and a first valve (61);

providing an underpressure in the second chamber (21b);

providing fluid communication between the pressurized compartment (30) and the third chamber (22a) via a third line (53);

filling the fourth chamber (22b) with an actuating fluid and pressurizing the actuating fluid, thereby displacing the piston device (40) to an initial state,

closing the first valve (61);

closing an actuating valve (64) provided in a fourth line (54) into the fourth chamber (22b);

providing the accumulator device (1) subsea; and

connecting the accumulator device (1) to the subsea device (A) via the fourth line (54);

wherein the accumulator device (1) is configured to be brought to an actuated state by opening the first valve (61) and the fourth valve (64), thereby allowing seawater to enter into the first chamber (21a) via the first line (51) and allowing actuating fluid to exit from the fourth chamber (22b), thereby allowing a displacement of the piston device (40) to its actuated state and hence supplying the subsea device (A) with actuating fluid via the fourth line (54).

12. The method according to claim 11, wherein the step of connecting the accumulator device (1) to the subsea device (A) is performed subsea.

13. The method according to any one of claims 11 – 12, wherein the step of providing an underpressure in the second chamber (21b) comprises the step of applying a suction force to a second line (52) in fluid communication with the second chamber (21b) and closing a second valve (62) provided in the second line (52).

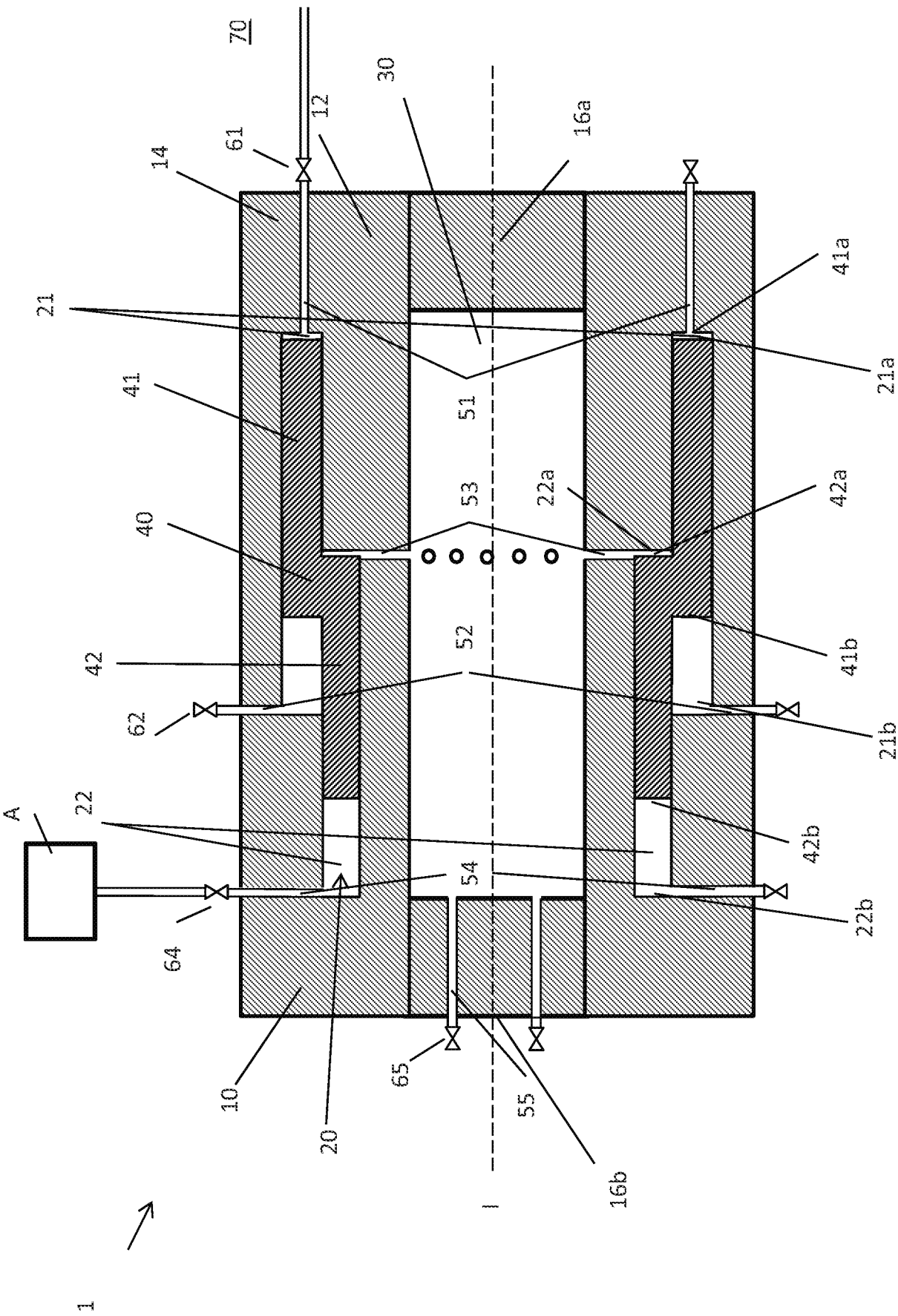


Fig. 1

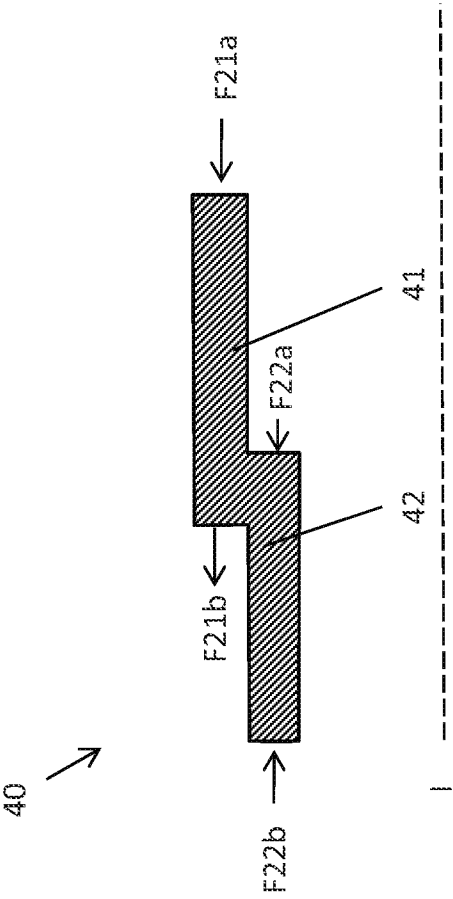


Fig. 2a

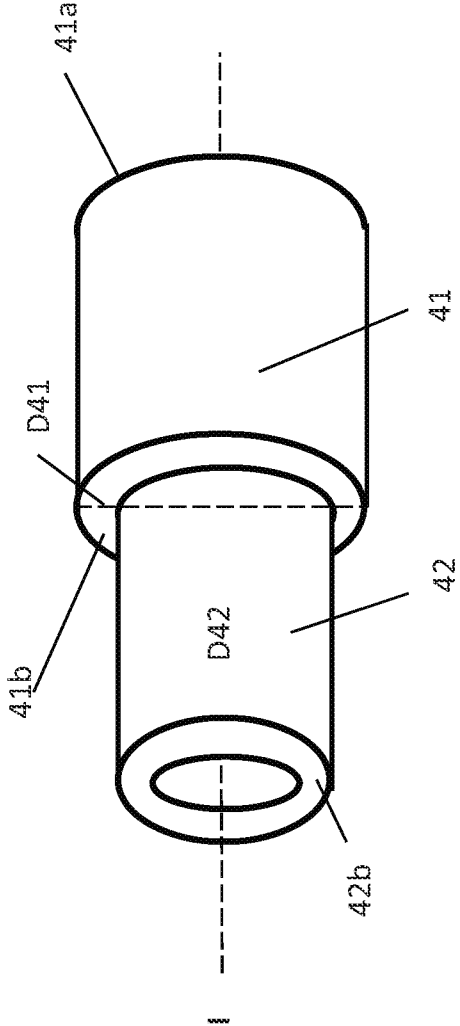


Fig. 2b

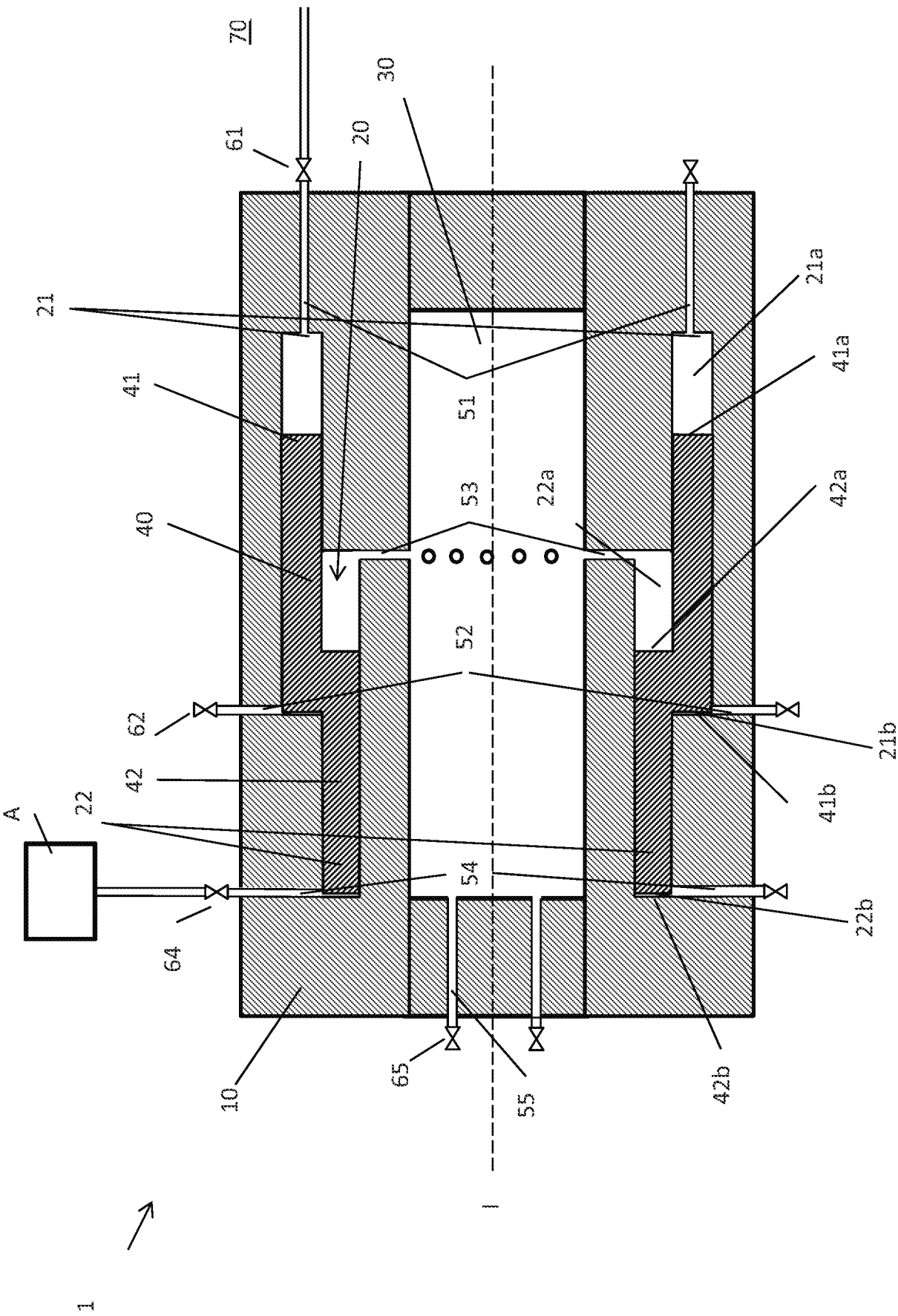
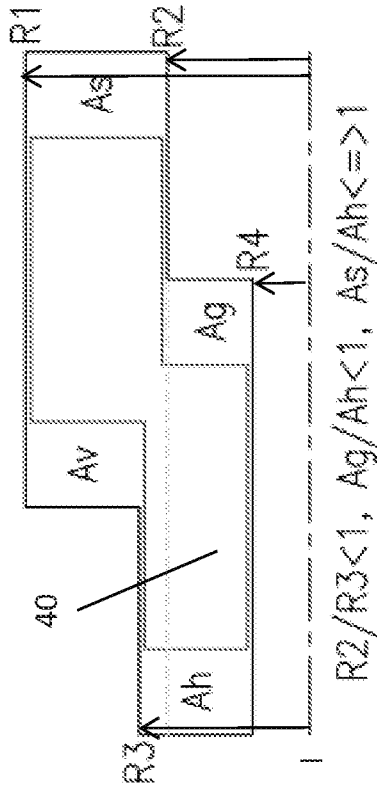
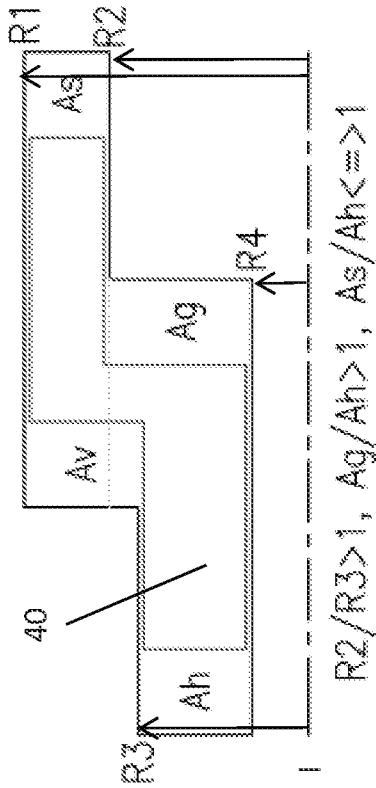
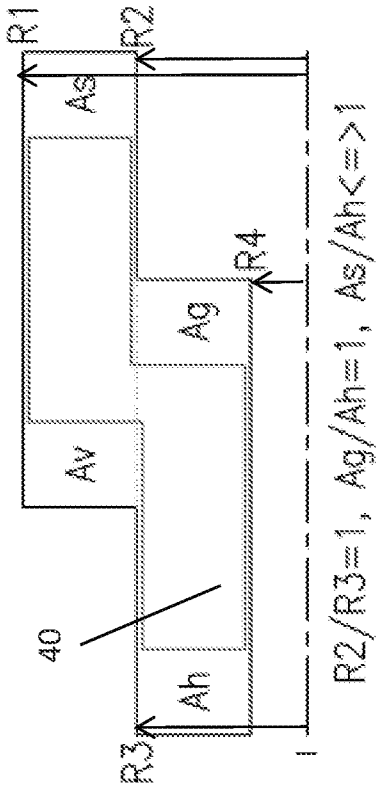
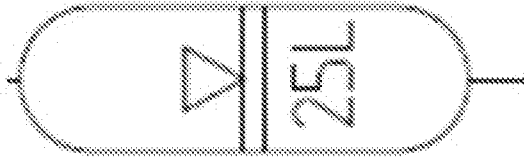


Fig. 3



Conventional vs. PBA for 5K & 10K Systems

- $V_{\text{Empty Gas}}$: 22 gal (83 L)
- MWPP: 10 ksi (689 bar)
- Depth: 10,000 ft (3048m)
- PBA Diameter and Length same as Conventional for comparison purpose

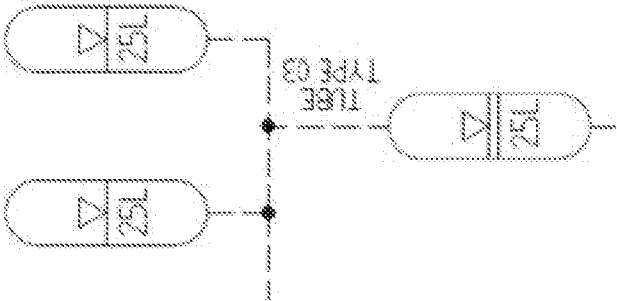


	5K to 3K		10K to 5K	
	Conv.	PBA	Conv.	PBA
Precharge (psi)	8776	4285	8776	7644
Discharge Vol (gal)	1.36	2.05	1.69	1.98
Discharge Difference	50%		17%	

Fig. 5

Conventional w/ Gas vs. PBA at Range of Depths

- $V_{Empty\ Gas}$: 150L (40 gal)
 - $V_{Swept\ Fluid}$: 50L (40 gal)
 - MWP: 5K (345 bar)
 - MOP: 2K (140 bar)
- PBA Diameter, Length, and Qty. same as Conventional w/ Gas for comparison purpose
 - Max precharge limited due to heating on deck



Depth (m)	Conv.+ Gas		PBA	
	$P_{precharge}$ (ksi)	$V_{discharge}$ (gal)	$P_{precharge}$ (ksi)	$V_{discharge}$ (gal)
2000	4.2 (max)	4.5	2.7	4.2
3000		2.0		
4000		0.3		
4500		0		

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/055024

A. CLASSIFICATION OF SUBJECT MATTER

INV. F15B1/24 E21B33/035 F15B1/02
ADD.

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)

F15B 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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/108008 A1 (BAUGH BENTON F [US]) 10 June 2004 (2004-06-10)	1-7
Y	the whole document	11-13
X	DE 10 2011 009276 A1 (HYDAC TECHNOLOGY GMBH [DE]) 26 July 2012 (2012-07-26)	1-7, 11-13
Y	the whole document	
Y	US 6 418 970 B1 (DEUL HANS HERMAN JACQUES [US]) 16 July 2002 (2002-07-16)	11-13
A	the whole document	
A	WO 2012/140178 A1 (SHELL INT RESEARCH [NL]; VAN WIJK JOHANNES [NL]) 18 October 2012 (2012-10-18)	1,11
	page 11 - page 12; figure 23	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

22 June 2016

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/055024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004108008 A1	10-06-2004	NONE	
DE 102011009276 A1	26-07-2012	DE 102011009276 A1	26-07-2012
		EP 2668403 A1	04-12-2013
		US 2013340421 A1	26-12-2013
		WO 2012100915 A1	02-08-2012
US 6418970 B1	16-07-2002	US 6418970 B1	16-07-2002
		WO 02103211 A1	27-12-2002
WO 2012140178 A1	18-10-2012	AU 2012241767 A1	26-09-2013
		EP 2697477 A1	19-02-2014
		US 2014034337 A1	06-02-2014
		WO 2012140178 A1	18-10-2012