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(54) Title: A PRESSURE COMPENSATOR OF A SUBSEA INSTALLATION

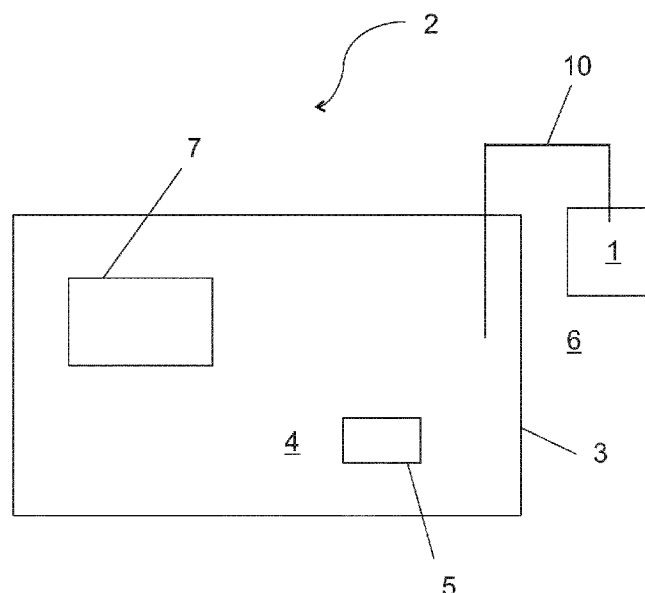


Figure 1

(57) Abstract: A pressure compensator (1) of a subsea installation (2), wherein the subsea installation (2) comprises a tank (3) comprising an insulation fluid (4) or other fluid. The pressure compensator (1) is in fluid communication with the tank (3). The pressure compensator (1) is configured to compensate volume variations of the insulation fluid (4) or the other fluid by performing an expansive and a contracting movement. The subsea installation (2) comprises means for heating (5) the insulation fluid (4) or the other fluid for reducing the volume variations of the insulation fluid (4) or the other fluid.

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
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A PRESSURE COMPENSATOR OF A SUBSEA INSTALLATION

FIELD OF THE INVENTION

[0001] The present invention relates to a pressure compensator of a subsea installation, and particularly to a pressure compensator of a subsea installation compensating volume variations of an insulation fluid or other fluid by performing an expansive and a contracting movement.

BACKGROUND OF THE INVENTION

[0002] Subsea installations are assemblies comprising several apparatuses used under water. Said assemblies can be installed for example on the bottom ground of a sea. As an example of said subsea installations power transformers used under water can be mentioned. Typically these power transformers comprise a tank filled with insulation and/or cooling fluid to encounter for the high pressure due to deep water depth. Examples of the other subsea liquid filled objects are subsea motors, subsea switchgears, subsea frequency converters, rectifiers and hydraulic store tanks.

[0003] The subsea installations are used for example in modern oil and gas production in which the collection, separation, boosting and transport of production fluids takes place on the seabed. These processes require large amounts of power that has to be transferred from a remote location at suitable voltages and currents for minimum power loss, to the subsea installations.

[0004] During operation of the subsea installation, temperature and volume of the insulation and/or cooling fluid varies, whereby pressure compensation of the fluid is needed. This involves use of a pressure compensator, which is in fluid communication with the tank of the installation. The pressure compensator receives excess fluid when its temperature and volume increase, and returns the fluid back to the vessel when it cools down. The pressure compensator may also have a variable volume when it performs an expansive and a contracting movement for compensating the volume variation of the insulating fluid. An example of this type of pressure compensator is a bellow compensator.

[0005] Large pressure compensator movements due to large insulation fluid volume variations in a high hydrostatic pressure decrease mechanical cycling lifetime of the pressure compensator. Therefore only a small part of the full compensation capacity of the pressure compensator is used when the water depth is high (1...3 km) having 100...300 bar pressure in order to improve the cycling lifetime of the pressure compensator. This, in turn, will generate a need of using a high

number of pressure compensators leading to an expensive price of the large subsea installations and other related subsea components.

BRIEF DESCRIPTION OF THE INVENTION

5 **[0006]** An object of the present invention is to provide a pressure compensator of a subsea installation to solve the above problems. The objects of the invention are achieved by a pressure compensator of a subsea installation which is characterized by what is stated in the independent claims. The preferred embodiments of the invention are disclosed in the dependent claims.

10 **[0007]** The invention is based on the idea of providing a pressure compensator of a subsea installation. The subsea installation comprises a tank comprising an insulation fluid or other fluid. The pressure compensator is in fluid communication with the tank. The pressure compensator is configured to compensate volume variations of the insulation fluid or the other fluid by performing an expansive and a contracting movement. The subsea installation comprises means for heating
15 the insulation fluid or the other fluid for reducing the volume variations of the insulation fluid or the other fluid.

[0008] An advantage of pressure compensator of a subsea installation of the invention that it provides a longer pressure compensator lifetime and better reliability.

20 BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached drawings, in which

25 Figure 1 shows a pressure compensator of a subsea installation;
 Figure 2 shows a bellow compensator;
 Figure 3 shows a cylinder compensator;
 Figure 4 shows a pressure compensator of a subsea installation;
 Figure 5 shows a pressure compensator of a subsea installation;
 Figure 6 shows a heat pump.

30 DETAILED DESCRIPTION OF THE INVENTION

[0010] Figure 1 shows a pressure compensator 1 of a subsea installation 2. The subsea installation 2 comprises a tank 3 comprising an insulation fluid 4 or other fluid. The pressure compensator 1 is in fluid communication with the

tank 3, and the pressure compensator 1 is configured to compensate volume variations of the insulation fluid 4 or the other fluid by performing an expansive and a contracting movement. The subsea installation 1 comprises means for heating 5 the insulation fluid 4 or the other fluid for reducing the volume variations of the insulation fluid 4 or the other fluid.

[0011] The fluid communication between the pressure compensator and the tank 3 may be provided by a connection pipe 10 as shown in Fig.1. The pressure compensator receives excess insulation fluid 4 from the tank 3 when fluid's temperature and volume increases, and returns the insulation fluid 4 back 10 to the tank 3 when the fluid's 4 temperature and volume decreases.

[0012] The heating of the insulation fluid 4 or the other fluid inside the tank 3 of the subsea installation 2 reduces the temperature variation of the fluid 4. The other fluid may be a cooling fluid, for instance. The reduction of temperature variation of the insulating fluid 4 or other fluid results in reduction of volume variation of the insulating fluid 4 or other fluid in the tank 3. The reduction of the volume variation reduces the number of the mechanical movements of the pressure compensator 1. Further, also the extent of the mechanical movements is reduced. This means that large amplitude cycling of the pressure compensator 1 decreases. This decreases mechanical stress and strain on the pressure compensator 1 parts 20 in the presence of hydrostatic pressure of the sea water 6. Further, the risk of fatigue failures in the moving parts of the pressure compensator 1 due to a repetitive stress diminishes.

[0013] The reduction of the volume variations of the insulation fluid 4 or the other fluid in the tank 3 enables a better utilization of the compensation capacity of the subsea pressure compensators 1. As the number of large amplitude cycling of the pressure compensator 1 decreases larger pressure compensator axial movements in high hydrostatic pressure can be allowed leading the need of fewer pressure compensators 1, longer pressure compensator cyclic lifetime and more competitive price of the subsea installation 2.

[0014] The dimensioning of a pressure compensator 1 system of a subsea installation 2 is preferably made to allow a full volume variation of the insulation fluid 4 or the other fluid. This prevents damages in the subsea installation 2 if there is a temporal failure in the heating and/or cooling of the insulation fluid 4 or the other fluid in the tank 3. The full variation means the difference of the volumes 35 between the volume of the insulation fluid 4 or the other fluid at the temperature reached with the full heat load produced by the heat generating electric apparatus

7 and at the temperature of the surrounding water 6.

[0015] The pressure compensator 1 of a subsea installation 2 can be used in a subsea environment, e.g. exist on the sea bed. The pressure compensator 1 of a subsea installation 2 is also suitable for deep waters, where the water depth is high, 1000...3000 m, and the prevailing pressure is 100...300 bar. The water temperature in an ocean is typically 5-6°C in the depth of 1000 m and 0-3°C in the depth of 3000 m.

[0016] Examples of pressure compensators 1 performing an expansive and a contracting movement are a bellow compensator 8 and a cylinder compensator 9.

[0017] A bellow compensator 8 has one or more foldable and/or flexible side walls 14 for allowing volume variations of the bellow compensator 8. For instance, a top wall 13 or a bottom wall 11 may be arranged to move vertically y to compensate for the volume variations of the insulating 4 or cooling fluid.

[0018] Fig.2 shows a bellow compensator 8. The compensator is in fluid communication with the tank 3. The fluid communication between the bellow compensator and the tank 3 is provided by a connection pipe 10. The connection pipe 10 may enter the bellow compensator 8 through the bottom wall 11 of the compensator 8. The bottom of the bellow 12 may be arranged fixedly with respect to the tank 3. The compensator 8 is thus allowed to expand and contract such that its top wall 13 may move in the vertical direction y, and its foldable side walls 14 may straighten and fold depending on the fluid volume within the compensator 8.

[0019] The expansive and contracting movement of the bellow 12 for compensating the volume variation of the insulating fluid 4 may also be provided by the bottom wall 11. Then the bellow compensator 8 has a top wall 13 which is rigidly arranged with respect to the tank 3.

[0020] In Figure 2, the bellow compensator 8 is mounted to the side wall of the tank 3 but the bellow compensator 8 may be arranged to the roof of the tank, for instance.

[0021] The expansive and contracting movement of the bellow 12 part of the pressure compensator 1 provides repetitive stress causing fatigue to the material of the bellow 12 part. As the cycling is reduced by controlling the volume variation the fatigue risk is diminished.

[0022] Figure 3 shows a cylinder compensator 9. A cylinder compensator 9 has a movable piston 15 which is arranged to compensate for the volume variations of the insulating fluid 4 and which separates the insulating fluid 4 from

exterior seawater 6. For instance, a cylinder compensator 9 is a vertically arranged cylinder housing a piston 15, which can move vertically due to the volume variations of the insulating 4 or another fluid, e.g. cooling fluid. Below the piston 15 is arranged a fluid space 16 for the insulating fluid 4 and above the piston 15 is a seawater space 17. The piston 15 is sealed such that mixing of the insulating fluid 4 and seawater 6 is prevented.

[0023] In the shown Figure 1 there is shown one pressure compensator 1 but the number of the pressure compensators is naturally not limited to one but can be any number greater than one.

10 **[0024]** In an embodiment, the subsea installation comprises a heat generating electric apparatus 7. In Fig.1 the heat generating electric apparatus 7 is a subsea transformer and the insulation fluid 4 is transformer oil. The transformer oil is mineral oil or silicon oil, for instance. Examples of other heat generating apparatuses 7 are motors, switchgears, frequency converters, rectifiers and hydraulic
15 store tanks.

[0025] In another embodiment, parts of the heat generating electric apparatus 7 or the total apparatus can be located within the tank 3. As shown in Fig.4, the active parts of the transformer, i.e. the transformer windings and a transformer core, can be located within the tank 3. Fig.4 shows also the transformer input connections 18 and the load 19 to the transformer. Same reference signs in the Figures
20 refer to corresponding parts in Figures.

[0026] Further, the heat generating electric apparatus 7 may comprise an electric power switch and /or a variable speed drive which can be located within the tank 3, for example.

25 **[0027]** In yet another embodiment, the means for heating 5 may be configured to provide heating to the insulation fluid 4 or the other fluid when the heat generating electric apparatus 7 is in a non-operating state. The heating of the insulation fluid 4 or the other fluid prevents the cooling of the insulation fluid 4 or the other fluid close to the temperature of the surrounding water 6 when the heat generating electric apparatus 7 is not providing heating to the insulation fluid 4 or the
30 other fluid in the tank 3. As the temperature decrease remains smaller the contracting movement of the pressure compensator 1 due to the volume reduction of the insulation fluid 4 or the other fluid remains also smaller.

[0028] Another advantage of keeping the insulation fluid 4 or the other
35 fluid temperature higher than the surrounding water 6 is that it keeps also the parts of heat generating electric apparatus 7 located within the tank 3 at a higher

temperature. For instance, the lifetime of a transformer is increased by keeping the hot spot area of the transformer winding drier.

[0029] In a further another embodiment, the means for heating 5 may be configured to gradually close down the heating to the insulation fluid 4 or the other fluid during the start-up of the heat generating electric apparatus 7.

[0030] In a still another embodiment, the subsea installation 2 may comprise means for cooling 20 the insulation fluid 4 or the other fluid for reducing the volume variations of the insulation fluid 4 or the other fluid. Fig.5 shows a pressure compensator of a subsea installation comprising means for heating 5 and means for cooling 20.

[0031] In an embodiment, the means for cooling 20 is configured to provide cooling when the heat generating electric apparatus 7 is in an operating state. As the temperature increase remains smaller the expanding movement of the pressure compensator 1 due to the volume increase of the insulation fluid 4 or the other fluid remains also smaller.

[0032] Cooling can be provided through natural or forced convection, for instance.

[0033] The means for cooling may be a heat pump 21 as shown in Fig.6. The part of the heat pump 22a which is in heat transferring contact with the surrounding water 6 operates as a condenser and the part of the heat pump 22b which is in heat transferring contact with the insulating fluid 4 or the other fluid operates as an evaporator. Thus the heat pump transfers heat from the insulating fluid 4 or the other fluid in the tank 3 to the surrounding water 6.

[0034] The part of the heat pump 22a which is in heat transferring contact with the surrounding water 6 may be an external unit heat exchanger outside of the tank 3. The part of the heat pump 22a which is in heat transferring contact with the surrounding water 6 may also be integrated to an outer wall 23 of the tank 3. An example of the integration is shown in Fig.6 where an outer wall of the tank 23 is forming a part of the condenser housing. Surrounding water 6 freely flows across an outer wall 23 of the tank 3 and cools the working fluid circulating in the heat pump 21 as the heat is dissipated through the outer wall of the tank 23 to the surrounding water 6. The part of the heat pump 22a forming the condenser is separated from the insulation fluid 4 with a cover 24 which prevents the heat transfer from the condenser to the insulation fluid 4. Another example of the integration is where the outer surface of the condenser housing may be attached, e.g. connected with thermal grease, to the outer wall 23 of the tank 3.

[0035] An advantage of controlling the insulation fluid 4 or the other fluid temperature increase by providing cooling is that it keeps also the parts of heat generating electric apparatus 7 located within the tank 3 at a lower temperature. For instance, the lifetime of a transformer is increased by keeping the temperature rise of the transformer winding within limits. Another advantage of providing cooling to a transformer is that it increases the loading capability of the transformer which is limited mainly by winding temperature. A further advantage of providing cooling to a transformer is the possibility of obtaining a higher power density in a low volume subsea transformer.

[0036] In another embodiment, the subsea installation comprises a temperature sensor 25 for measuring the temperature of the insulation fluid 4 or the other fluid, and a temperature controller 26 comprising a temperature range. The temperature sensor 25 and the temperature controller 26 are shown in Fig.5 only. The temperature sensor 25 and the temperature controller 26 may be installed in any pressure compensator of a subsea installation presented in the Figures.

[0037] In yet another embodiment, the temperature range of the temperature controller 26 is a pre-set range or the temperature range is adjustable by remote control through data transmission.

[0038] In a further another embodiment, when the heat generating electric apparatus 7 is in an operating state the means for heating 5 is configured to provide heating if the measured temperature goes below a set temperature range and the means for cooling 20 are configured to provide cooling if the measured temperature exceeds the set temperature range.

[0039] The heat load to the insulating fluid 4 or the other fluid produced by the heat generating electric apparatus 7 depends on the loading 19 of the apparatus. Thus the need of heating or cooling the insulating fluid 4 or the other fluid in the tank varies when the heat generating electric apparatus 7 is in an operating state.

[0040] An advantage of controlling the insulation fluid 4 or the other fluid temperature to remain in a set temperature range is that the volume variations of the insulation fluid 4 or the other fluid remain in a volume range defined by the temperature variation range.

[0041] In a still another embodiment, the means for heating 5 and the means for cooling 20 is a reversible heat pump working in direction either to provide heating or to provide cooling.

[0042] The heat pump 21 shown in Fig.6 may also present a reversible heat pump. In the heating mode the part of the heat pump 22a which is in heat transferring contact with the surrounding water 6 operates as an evaporator and the part of the heat pump 22b which is in heat transferring contact with the insulating fluid 4 or the other fluid operates as a condenser. Thus the heat pump 21 transfers heat from the surrounding water 6 to the insulating fluid 4 or the other fluid in the tank.

[0043] In the cooling mode the part of the heat pump 22a which is in heat transferring contact with the surrounding water 6 operates as a condenser and the part of the heat pump 22b which is in heat transferring contact with the insulating fluid 4 or the other fluid operates as an evaporator. Thus the heat pump 21 transfers heat from the insulating fluid 4 or the other fluid in the tank 3 to the surrounding water 6.

[0044] In an embodiment, the means for heating 5 comprises a resistive heater, an inductive heater or a heating cable with an internal temperature control or a heat pump 21.

[0045] When the heat pump is used only for heating the insulating fluid 4 or another fluid the part of the heat pump 22a which is in heat transferring contact with the surrounding water 6 operates as an evaporator and the part of the heat pump 22b which is in heat transferring contact with the insulating fluid 4 or the other fluid operates as a condenser. Thus the heat pump transfers heat from the surrounding water 6 to the insulating fluid or the other fluid in the tank 3.

[0046] The required power to the heating or cooling the insulating 4 or the other fluid can be taken with several means, e.g. by separate heating transformer or reactor.

[0047] The invented pressure compensator of a subsea installation provides a longer pressure compensator lifetime and better reliability, which are key factors for a deep water subsea transformer operation. The invented pressure compensator of a subsea installation is advantageous in subsea installations having a high heat generation causing large volume variations to the insulating fluid.

[0048] The invented pressure compensator of a subsea installation can be applied to different types of subsea installations comprising insulation or other fluid in a tank. Examples of such subsea assemblies are subsea motors, subsea switchgears, subsea frequency converters, rectifiers and hydraulic store tanks.

[0049] It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The

invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

[0050] Part list: 1 a pressure compensator; 2 a subsea installation; 3 a tank; 4 an insulation fluid; 5 means for heating; 6 water; 7 a heat generating apparatus; 8 a bellow compensator; 9 a cylinder compensator; 10 a connection pipe; 11 a bottom wall; 12 a bellow; 13 a top wall; 14 side walls; 15 a piston; 16 a fluid space; 17 a sea water space; 18 input connections; 19 a load; 20 means for cooling; 21 a heat pump; 22a-b a part of the heat pump; 23 an outer wall of a tank; 24 a cover; 25 a temperature sensor; 26 a temperature controller; y vertical direction.

CLAIMS

1. A pressure compensator (1) of a subsea installation (2), wherein the subsea installation (2) comprises a tank (3) comprising an insulation fluid (4) or other fluid, the pressure compensator (1) is in fluid communication with the tank (3), the pressure compensator (1) is configured to compensate volume variations of the insulation fluid (4) or the other fluid by performing an expansive and a contracting movement, **characterized** in that the subsea installation (2) comprises means for heating (5) the insulation fluid (4) or the other fluid for reducing the volume variations of the insulation fluid (4) or the other fluid.

2. A pressure compensator according to claim 1, **characterized** in that the subsea installation (2) comprises a heat generating electric apparatus (7).

3. A pressure compensator according to claim 2, **characterized** in that the means for heating (5) is configured to provide heating to the insulation fluid (4) or the other fluid when the heat generating electric apparatus (7) is in a non-operating state.

4. A pressure compensator according to claim 3, **characterized** in that the means for heating (5) is configured to gradually close down the heating to the insulation fluid (4) or the other fluid during the start-up of the heat generating electric apparatus (7).

5. A pressure compensator according to claim 1, **characterized** in that the subsea installation (2) comprises means for cooling (20) the insulation fluid (4) or the other fluid for reducing the volume variations of the insulation fluid (4) or the other fluid.

6. A pressure compensator according to claims 2 and 5, **characterized** in that the means for cooling (20) is configured to provide cooling when the heat generating electric apparatus (7) is in an operating state.

7. A pressure compensator according to any of claims 1-6, **characterized** in that the subsea installation (2) comprises a temperature sensor (25) for measuring the temperature of the insulation fluid (4) or the other fluid, and a temperature controller (26) comprising a temperature range.

8. A pressure compensator according to claim 7, **characterized** in that the temperature range of the temperature controller (26) is a pre-set range or the temperature range is adjustable by remote control through data transmission.

9. A pressure compensator according to claims 2, 5 and 7, **characterized** in that when the heat generating electric apparatus (7) is in an operating state the means for heating (5) is configured to provide heating if the measured temperature goes below the temperature range and the means for cooling (20) are configured to provide cooling if the measured temperature exceeds the temperature range.

10. A pressure compensator according to claim 9, **characterized** in that the means for heating (5) and the means for cooling (20) comprises a reversible heat pump (21) working in direction either to provide heating or to provide cooling.

11. A pressure compensator according to any of claims 5-6, **characterized** in that the means for cooling (20) comprises a heat pump.

12. A pressure compensator according to any of claims 1-8, **characterized** in that the means for heating (5) comprises a resistive heater or an inductive heater or a heat pump (21).

13. A pressure compensator according to any of claims 1-7, **characterized** in that the means for heating (5) comprises a heating cable with an internal temperature control.

14. A pressure compensator according to any of claims 1-13, **characterized** in that the heat generating electric apparatus (7) comprises a subsea transformer.

15. A pressure compensator according to claim 14, **characterized** in that the insulation fluid (4) is transformer oil.

16. A pressure compensator according to claim 14, **characterized** in that transformer windings and a transformer core are located within the tank (3).

17. A pressure compensator according to any of claims 1-16, **characterized** in that an electric power switch and /or a variable speed drive are located within the tank (3).

18. Use of a pressure compensator of a subsea installation according to any of claims 1-17 in a subsea environment.

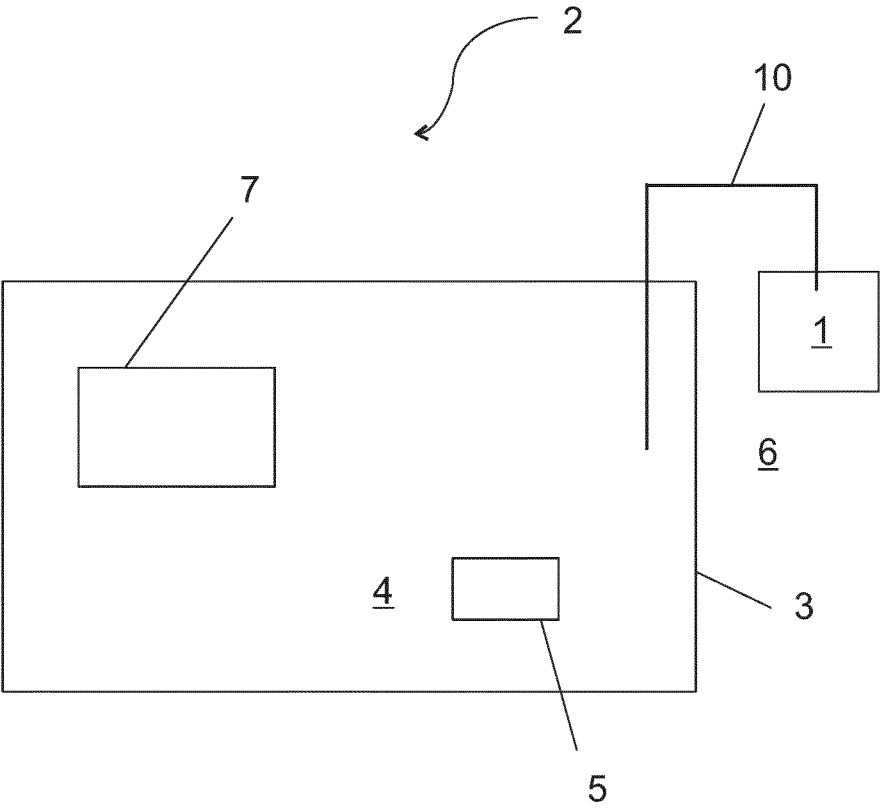


Figure 1

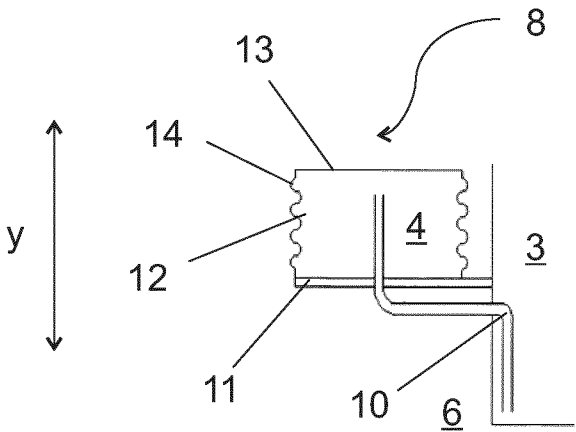


Figure 2

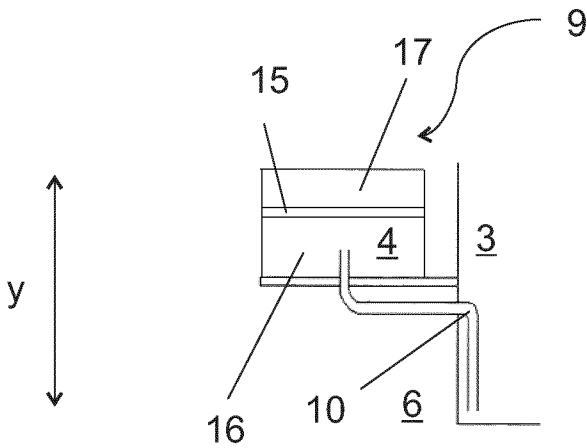


Figure 3

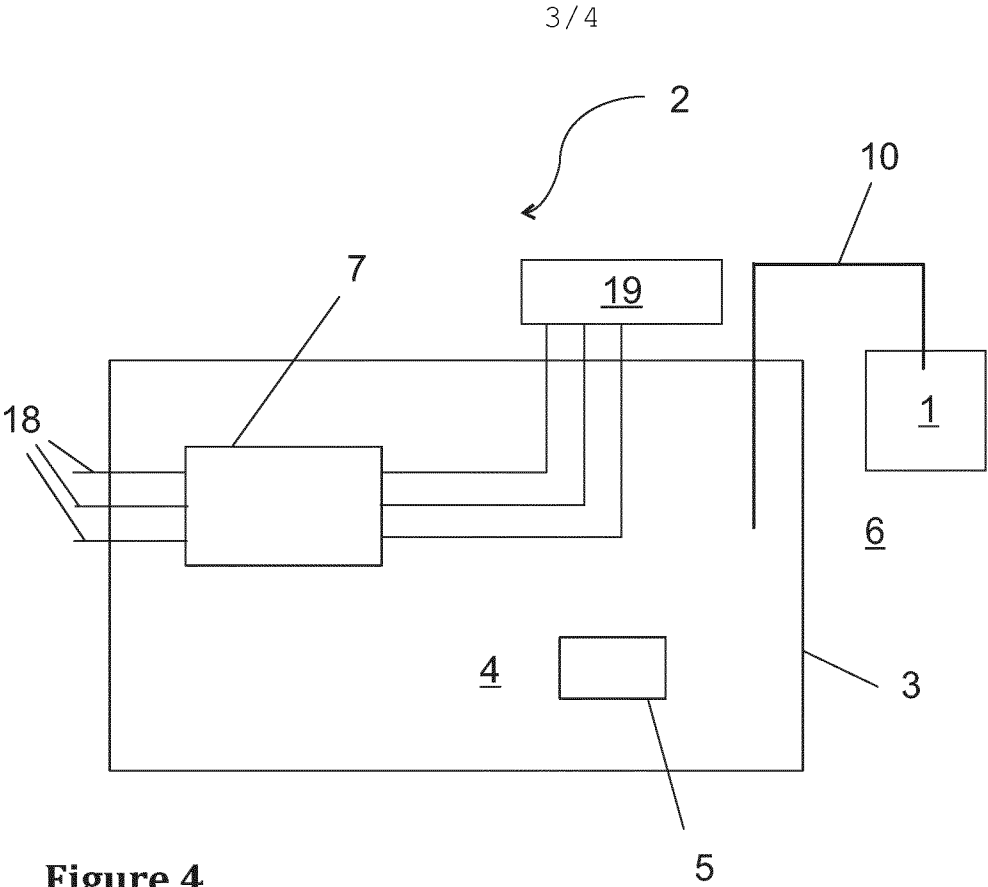


Figure 4

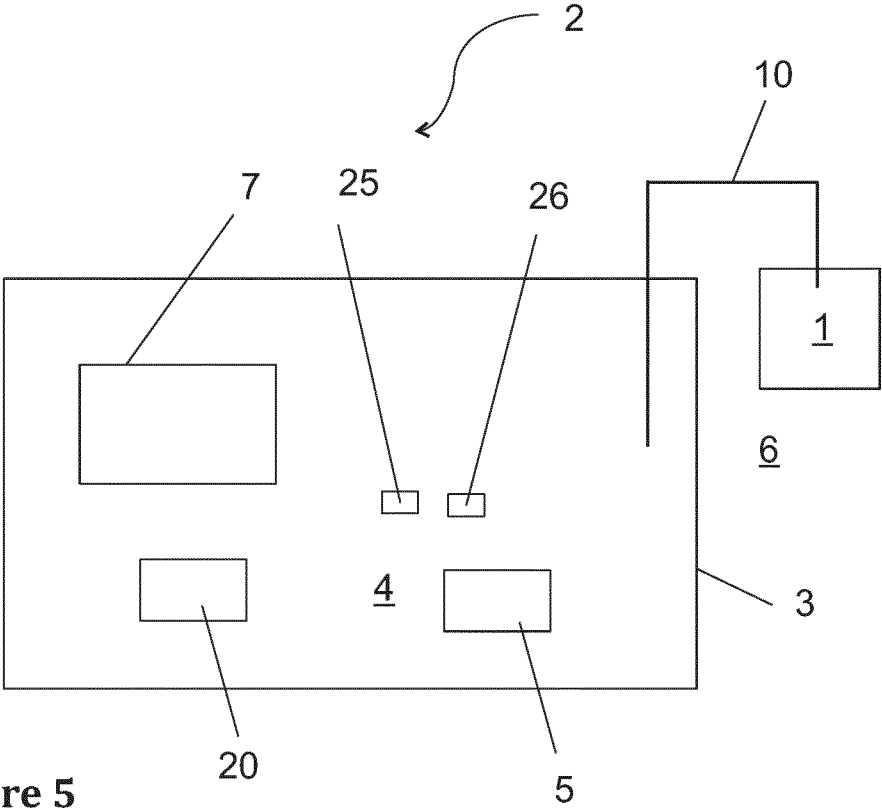


Figure 5

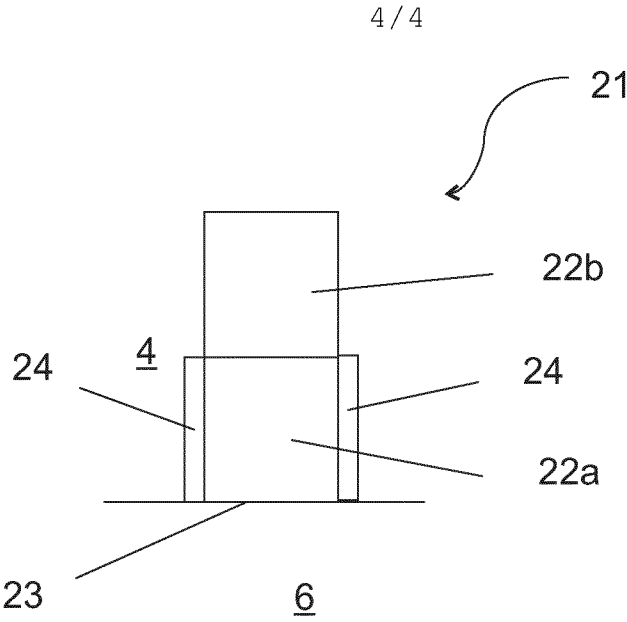


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/084319

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01F27/00 H01F27/02 H01F38/00
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)
H01F

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 2 511 919 A1 (ABB TECHNOLOGY AG [CH]) 17 October 2012 (2012-10-17) paragraphs [0023], [0024]; figures 1-3 -----	1-18
A	WO 02/41336 A1 (ABB OFFSHORE SYSTEMS AS [NO]; HAFSKJOLD GUNNAR [NO]; SOELVIK NILS ARNE) 23 May 2002 (2002-05-23) abstract page 4, lines 19-25; figure 1 ----- -/-	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

18 April 2018

Date of mailing of the international search report

14/05/2018

Name and mailing address of the ISA/

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Winkelman, André

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/084319

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2007/055588 A1 (NORSK HYDRO PRODUKSJON A S [NO]; HARAM KARL OLAV [NO]; SKROEVSETH OLA) 18 May 2007 (2007-05-18) abstract page 3, line 4 - page 4, line 6; figure 1 -----	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/084319

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