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is controlled by a control device adapted to control the fluid communication between the first volume and the second volume in response to a pressure difference between the pressure in the first volume and the pressure in the second volume.



Description

TECHNICAL FIELD

[0001] The present invention relates to a subsea separation and processing system for produced fluids comprising a first volume and a second volume, which first volume and second volume are in fluid communication.

BACKGROUND

[0002] Offshore oil and natural gas production from subterranean reservoirs are generally accompanied by generation of produced fluids including produced water, which are the mixture of water and impurities comprising hydrocarbons, aromatics, polycyclics, water soluble organics, oil and grease, other organic compounds, dissolved solids, and other materials separated from the produced oil or natural gas. This produced fluid derives from the natural presence of water in oil and natural gas reservoirs, the use of water and steam for injection subsurface into the well to enhance oil recovery, and other uses of water in fossil fuel production. Fossil fuel production includes production of subsurface deposits of oil, natural gas and mixtures thereof. The large volume of produced fluids generated during fossil fuel production poses a substantial storage, treatment and disposal problem. Indeed the volume of produced fluid per unit of production tends to increase with the maturity of an oil field thereby posing an ongoing and growing disposal problem.

[0003] The produced fluid including produced water comprises various impurities, some or all of which may be present in any given sample of produced fluid. Characteristics of impurities that may be found in produced fluid, either in solution, colloid or separate phase, typically include high total dissolved solids, suspended solids, mineral content, hydrocarbons, including aromatics and cyclic hydrocarbons, oil, gas, sulfur compounds such as H₂S, mercaptans and other organo-sulfur compounds, alkalinity, barium, boron, and other metals, such as mercury which is environmentally highly undesired.

[0004] Characteristics of produced fluid vary greatly from site to site and can also vary during the lifetime of a well.

[0005] The suspended solids, such as minerals like sand, may have an abrasive effect which is undesired as it may significantly reduce the lifetime of pumps and other process equipment.

[0006] The volume of produced fluid may be a small fraction of, but is commonly comparable to, or even substantially in excess of, the volume of produced oil. Thus, capacity for high volume treatment and disposal of produced fluid is often essential in oil and gas production.

[0007] At present an option is that the offshore platforms contain equipment for separating and cleaning produced fluid to allow for the fluid to be released to the environment, but this equipment requires platform space which is a limiting factor. The platform will normally com-

prise equipment to handle hydrocarbon fractions separated from the produced fluid, however, the platforms are not always equipped with systems for handling the solid fraction.

[0008] In some situations the solids may comprise compounds that may not be released into the environment without further treatment. Equipment for such treatment is normally not installed on the platform and the solids have to be transported to shore or another facility to be treated.

[0009] As an alternative to conventional topside processing on a platform, the well stream may be fully or partially processed at subsea, and consequently requires treating produced fluid subsea prior to release back to the environment or injection into the well. Subsea treatment of produced water eliminates the seemingly unnecessary transport of produced fluid from seabed to surface. However, the facilities for storage and processing of the produced fluid is required to be located subsea at the seabed. The subsea storage and processing equipment should be able to treat the process fluid for injection into the well or alternatively for release into the environment, i.e. the sea.

[0010] Various systems and methods for the subsea processing and storage of a well stream and produced fluids are described e.g. in the documents WO 16/202977, WO 00/39031, WO 16/178985 and WO 12/087149.

[0011] However, in operation the pressure in the produced fluid may vary and this varying pressure may be critical to the equipment which may suffer damage.

[0012] Hitherto, one solution in respect of varying pressure in subsea equipment has been to apply exaggerated dimensions to the equipment. However, such a solution is costly. The increased cost has somewhat limited the use of subsea storage and processing systems. Another solution is to release produced water into the ambient environment, however, this is not an acceptable solution from the view of environmental protection.

DISCLOSURE OF THE INVENTION

[0013] The object of the present invention is to provide a subsea storage and processing system for process fluid in which the risk of damage on the equipment due to certain changes in pressure is reduced in a simple and cost effective manner.

[0014] Another object is to provide a subsea storage and processing system for process fluid in which the produced fluid can be handled in an environmentally acceptable way.

[0015] The present invention provides several other advantages, which will be clear from the description.

[0016] The present invention provides an alternative solution to the known systems.

[0017] The present invention relates to a subsea storage and processing system for produced fluids comprising a first volume having a volume of at least 250 m³ and

a second volume which is smaller than the first volume of the system. The first volume and the second volume are in fluid communication, the fluid communication being controlled by a control device adapted to control the fluid communication between the first volume and the second volume in response to a pressure difference between the pressure in the first volume and the pressure in the second volume.

[0018] Produced fluid in the context of this application is the aqueous containing phase that is co-produced from a producing well along with the oil and/or gas phases during normal production operations. The produced fluid comprises water as the main component mixed with additives and excipients. The produced fluid may be circulated and re-used several times, optionally with a purification process between each use.

[0019] According to the invention, the first volume and the second volume are two separate volumes each defined by a container containing the first volume and the second volume respectively. The containers containing the first volume and the second volume can be made from substantially rigid or substantially unflexible material or the containers can be made from flexible material. One of the containers can be made from unflexible material and the other container can be made from flexible material. The containers may both be flexible and able to provide varying volumes. Thus, the first volume and the second volume may vary in size, however, the first volume will be larger than the second volume. The second volume is intended to serve as a buffer volume and need not to have a large volume. A typical volume of the first volume may be in the range of about 250 m³ to about 6000 m³. The corresponding volume of the second volume may e.g. be in the range of about 12 m³ to about 600 m³.

[0020] The term "substantially" should herein be taken to mean that ordinary product variances and tolerances are comprised.

[0021] The first volume is the primary storage for the produced fluid, and during normal production the first volume provides a sufficient storage capacity. During the time the produced fluid is stored in the first volume, the produced fluid will separate into a water phase (produced water), an oil phase and a gas phase. Optionally solid particles, such as sand particles, will collect in the bottom part of the first volume. Depending on the operational conditions of the actual well from which the produced fluid originates the residence time of the produced fluid in the first volume may vary between e.g. 5 minutes to e.g. 24 hours. Thus, the flow of the produced fluid through the first volume may vary significantly. The first volume will be equipped with suitable outlets for oil, gas and water (produced water), preferable in the form of pipelines. The first volume also has a connection to the second volume.

[0022] However, variations in the operational conditions of the well may result in that increased amounts of produced fluid enter the first volume which may increase the pressure in the first volume, which may eventually

result in damage to the equipment. Thus, according to the present invention it has surprisingly been realized that a critical increased pressure in the first volume may be reduced to an acceptable level by conducting a part of the produced fluid from the first volume to a second volume. According to the present invention the second volume is in fluid communication with the first volume, e.g. by a pipeline and the fluid communication is controlled by a control device, e.g. a venturi and/or valve. Thus, the second volume may serve as a buffer for the first volume. The second volume mainly contains a water phase (produced water) from the first volume, and thus does not necessarily require means for separation of a gas and an oil phase. Thus, the second volume may be a rather simple construction.

[0023] In case of a more rare incident where the pressure decreases in the first volume due to decreased amount of produced fluid feed to the first volume, the pressure in the first volume may be increased to an acceptable level by conducting produced fluid stored in the second volume to the first volume.

[0024] The fluid communication between the first volume and the second volume is controlled by a control device and in an embodiment the control device is adapted to allow fluid communication between said first volume and said second volume if the pressure in the first volume deviates from one or more predetermined threshold values.

[0025] The predetermined threshold values may vary depending on the actual configuration of the system. In an embodiment the predetermined threshold value is the operating pressure measured in bar in the first volume +/- 3.5 bar, such as +/- 2.0 bar, such as +/- 0.5 bar, or +/- 0.1 bar. In an embodiment the predetermined threshold value is the operating pressure measured in bar in the first volume +/- 0.05 bar. The skilled person will be able to determine the proper threshold values for an actual configuration of the system.

[0026] The predetermined threshold value may determine the required dimensions of the equipment, and for the purpose of obtaining a cost-effective dimensioning of the equipment, in an embodiment the predetermined threshold value is the operating pressure measured in bar in the first volume +/- 0.1 bar.

[0027] The operating pressure in the first volume normally depends on the pressure in the ambient environment and normally the operational pressure in the first volume is adjusted to correspond to the ambient pressure and applying an overpressure in the range e.g. 0.1 to 5.0 bar, such as an overpressure in the range 0.1 to 3.0 bar, such as ambient pressure plus 0.5 bar. Thus, the operational pressure in the first volume normally is ambient pressure plus e.g. 0.2 bar, such as e.g. 0.5 bar. The overpressure will also serve to ensure that a flexible container containing the first volume will function properly.

[0028] To provide a sufficient storage volume for produced fluid in the subsea storage the first volume should be at least 250 m³, and preferably the first volume is in

the range 250 m³ to 10,000 m³, such in the range 1,000 m³ to 8,000 m³, such in the range 2,500 m³ to 6,000 m³, such in the range 3,000 m³ to 5,000 m³.

[0029] The volume of the second volume is smaller than the first volume as the first volume is the primary storage for produced fluid and the second volume serves as a buffer volume. Thus, in an embodiment the volume of the second volume is less than 1/10 of the volume of the first volume. The volume of the second volume may be less than 1/20 of the volume of the first volume. The volume of the second volume may be in the range of 10 m³ to 1000 m³, such as in the range of 25 m³ to 500 m³.

[0030] In an embodiment the control device controls which fluid communication between the first volume and the second volume is selected from a venturi, valve, throttling ejector or eductor. In an embodiment the control device is an electrically operated valve. An electrically operated valve responds quickly to an electrical signal and provides rapid opening and closing of the valve.

[0031] The control device is preferably connected with a control unit, such as a computer device, which may control opening and closing of the control device, thereby controlling the fluid communication between the first volume and the second volume. The control unit may be connected with pressure sensors in the first volume and optionally other parts of the system, such as e.g. pumps and additional valves, allowing the control unit to monitor and control the pressure in the system.

[0032] In principle the first volume may be contained in any suitable container, such as a container made from fibre-reinforced polymer, glass fibre, concrete or steel, however, in an embodiment the first volume is contained in a flexible bag or bladder. Thus, it is possible to have a first volume which is flexible at least to a certain degree.

[0033] In an embodiment the flexible bag containing the first volume is encapsulated in a protective structure. The protective structure serves to protect the flexible bag and the protective structure may be constructed from e.g. fibre-reinforced polymer or glass fibre. The protective structure may be formed as a substantially cylindrically shaped encapsulation e.g. with a dome-shaped top and with rounded edges and the flexible bag containing the first volume is preferably shaped to fit within the shape of the protective structure.

[0034] As in the case with the first volume, the second volume may also be contained in any suitable container, e.g. a container made from concrete or steel. However, it is desired that the second volume is flexible and in an embodiment the second volume is contained in a flexible bag or bladder.

[0035] For the purpose of protecting the flexible bag containing the second volume, in an embodiment the flexible bag containing the second volume is encapsulated in a protective structure. The protective structure may have a substantially cylindrical shape, a substantially spherical shape or a substantially box-like shape. The protective structure may be manufactured from glass fiber, fiber-reinforced polymer, fiber-reinforced plastic,

concrete or metallic material, such as steel.

[0036] In the subsea storage and processing system described above the flexible bags are encapsulated in protective structures. However, in some environments it may be desirable to have a compact structure and in an embodiment the flexible bag containing the first volume and the flexible bag containing the second volume are encapsulated in the same protective structure. This protective structure may have a substantially cylindrical shape, a substantially spherical shape or a substantially box-like shape, and be manufactured from glass fiber, fiber-reinforced polymer, concrete or steel.

[0037] In an embodiment the flexible bag containing the first volume and the flexible bag containing the second volume are encapsulated in two separate protective structures which may allow more freedom for the design of the system.

[0038] The flexible bag containing the first volume and the flexible bag containing the second volume may be made from the same or different material. The material for the bags can be selected from polymer material such as e.g. polyethylene, polyvinyl difluoride or polyamide. The polymer material may be reinforced with fibers such as aramide fibers. The bags may also have a layered structure comprising two or more layers.

[0039] Thus, the bag material may consist of a fabric/weaving as the main structure providing the required mechanical properties and strength of the bag. The bag may be further coated with an elastomeric coating on the outside/inside to protect the weaving, give it the necessary resistance to chemical degradation and make it liquid proof. The coating on each side will depend on the use and purpose and the weaving and coating can be selected from numerous material alternatives. The coated fabric is delivered in sheets on rolls, and because of the size, the rolls are joined together in order to form a bag or bladder. Possible joining methods are vulcanization. The joining quality and strength is designed to be at the same level as the base material to form a consistent bag or bladder construction. Vulcanized rubber type of materials (elastomer - cross linked polymer) can be used to withstand aging caused by oil contaminated water, pressure and temperature.

[0040] The protective structure can be fabricated out of steel, concrete, fiber-reinforced plastic or glass-reinforced plastic. The inner panel of the structure can e.g. be made from metal plates formed into a cylinder/dome assembly. The inner structure may be strengthened with horizontal (ring) and vertical T-beam stiffeners around the circumference to avoid buckling. If foundation design shows a requirement for anchoring with e.g. piles, the protective structure may be equipped with pile sleeves.

[0041] The inner surface of the protective structure is preferably smooth to reduce wear and potential damaging effects to the flexible bag. Corners and edges on the inner surface are designed to have as large radii as possible, for a transition between floor and cylinder wall without any sharp edges.

[0042] When the protective structure is manufactured from materials such as glass fiber, fiber-reinforced polymer or fiber-reinforced plastic, the protective structure may have a certain flexibility due to the flexibility of the chosen materials. This flexibility may also serve to reduce the risk of damage on the equipment.

[0043] In an embodiment the one or more protective structures comprise a lid covering an opening in the top of the protective structure. The lid may provide access to the internal parts of the protective structure, e.g. for service and maintenance. To facilitate service and maintenance the lid may comprise the pipelines for collecting oil and gas and produced water from the bag. Optionally the lid also comprises other equipment, such as pressure sensors and devices for removing solids.

[0044] The flexible bag containing the first volume can be attached to the protective structure in any suitable manner. However, in an embodiment the flexible bag containing the first volume is attached to the lid. In this way it is possible to pull the bag out of the protective structure when the lid is removed. This may facilitate service and maintenance of the entire system. The bag can be attached to the lid by use of bolts, clamps or other squeezing means. It is also possible to vulcanize the bag to the lid.

[0045] The flexible bag containing the second volume may also be attached to the protective structure in any suitable manner. In an embodiment the flexible bag containing the second volume is attached to the lid in a manner corresponding to the way of attachment of the flexible bag containing the first volume.

[0046] The produced fluid may comprise rather large amounts of solids such as sand, which may have an abrasive effect on pumps, valves and other equipment in the system, and, thus, it is desirable to remove the solids, and in an embodiment the system comprises a sand accumulator for removal of solids. The sand accumulator can be placed in the inlet to first volume, thus, the amount of solids entering the first volume can be reduced.

[0047] To obtain a more compact subsea storage and processing system the invention also provides embodiments in which sand accumulators are included in the first volume and/or in the second volume.

DETAILED DESCRIPTION OF THE INVENTION

[0048] The invention will now be described in further details with reference to embodiments shown in the drawings in which:

Figure 1 shows a subsea storage and processing system for produced fluids;

Figure 2 shows a subsea storage and processing system for produced fluids according to the invention;

Figure 3 shows a subsea storage and processing

system for produced fluids according to the invention;

Figure 4 shows a more compact subsea storage and processing system for produced fluids according to the invention; and

Figure 5 shows a subsea storage and processing system for produced fluids including a sand accumulator according to the invention.

[0049] The figures are not accurate in every detail but only sketches intended to show the principles of the invention. Details which are not a part of the invention may have been omitted. In the figures the same reference numbers are used for the same parts.

[0050] Figure 1 shows a known subsea storage and processing system for produced fluids 100. The system comprises a flexible bag 102 comprising a volume 103. The flexible bag 102 is encapsulated in a protective structure 104 having a substantially cylindrical shape with a dome-like top. The protective structure 104 has a lid 105 closing an opening in the dome-like top.

[0051] Inside the flexible bag 102 in the volume 103 produced fluid is stored and separates into a water phase 106, an oil phase 107 and a gas phase 108. Not shown solid particles in the fluid may be separated from the fluid by gravity and sink towards the bottom 109 of the protective structure 104. In this particular embodiment the bottom 109 has an inclined bottom part 109a which may serve to guide solid particles towards the center part of the flexible bag for easy collection.

[0052] The produced fluid is fed to the volume 103 via inlet or pipeline 110, which is controlled by the valve 111.

[0053] The separated phases in the flexible bag 102 are collected via different outlets or pipelines. The produced water 106 is collected via the outlet 112 controlled by valve 113 and connected with the pump 114. The pump 114 may increase the pressure in the produced water, which may then be injected into a well via pipeline 115.

[0054] The gas phase 108 can leave the system via pipeline 116 controlled by valve 117. From the pipeline 116, the gas can be released to ambient.

[0055] The oil phase 107 is collected via the outlet 119 controlled by the valves 118 and 120. At least a fraction of the gas phase 108 may be collected with the oil phase 107. This is done by use of the outlet 121 controlled by the valve 122. The outlet 121 is unified with the outlet 119 at the T-piece 123 at which the oil phase 107 and the gas phase are mixed. The product flow from outlet 119 can be fed to an oil (and gas) storage.

[0056] Solids, such as sand, are collected at the bottom 109 and can be removed by a suction device or by replacement of the flexible bag 102. The solids normally require a further treatment to remove harmful substances before release into the ambient environment. Thus, the flexible bag 102 may function as a sand accumulator.

[0057] As it can be seen from figure 1, flexible bag 102 of the known subsea storage and processing system for produced fluids does not fully fill the protective structure but has some room for expanding in case the feed of produced fluid suddenly increases. However, the flexible bag 102 only provides a very limited buffer volume which can reach its limits rather fast.

[0058] In such cases the subsea storage and processing system for produced fluids 100 only have the following options in case the feed of produced fluid suddenly increases beyond the limits of the flexible bag.

1. To block the feed of produced fluid by closing the valve 111. However, this is not desirable as it may lead to increased pressure and eventually damage on process equipment.

2. To release the produced fluid via one or more of the outlets 112, 116 and 119. This is not a desirable solution as it may cause environmental problems.

[0059] Moreover, in the event the valve 113 or the pump 114 is blocked the system will not be able to release produced fluid and pressure in the system will raise.

[0060] Figure 2 shows a subsea storage and processing system for produced fluids 1A according to the invention. The system 1A includes several elements which correspond to elements in the system 100 shown in figure 1. The system 1A comprises a flexible bag 2 comprising a first volume 3. The flexible bag 2 is encapsulated in a protective structure 4. The protective structure 4 has a substantially cylindrical shape with a dome-like top. The protective structure 4 has a lid 5 closing an opening in the dome-like top. The flexible bag 2 is attached to the lid 5 and all inlets 10 and outlets 12, 16, 19 and 21 pass through the lid 5.

[0061] Inside the flexible bag 2 in the first volume 3 produced fluid is stored and separates into a water phase 6, an oil phase 7 and a gas phase 8.

[0062] The produced fluid is fed to the first volume 3 via inlet or pipeline 10, which is controlled by the valve 11.

[0063] The bottom 9 in the protective structure is designed with an inclined bottom part 9a which may serve to guide solid particles towards the center part of the flexible bag 2 for easier collection.

[0064] The separated phases in the flexible bag 2 are collected via different outlets or pipelines. The produced water 6 is collected via the outlet 12 controlled by the valve 13 and connected with the pump 14. The pump 14 may increase the pressure in the produced water which may be injected into a well via pipeline 15.

[0065] The gas phase 8 can leave the system via outlet 16 controlled by valve. From the pipeline 16, the gas can be released to ambient environment.

[0066] The oil phase 7 is collected via the outlet 19 controlled by the valves 18 and 20. At least a fraction of the gas phase 8 may be collected with the oil phase 7. This is done by use of the outlet 21 controlled by the valve

22. The outlet 21 is unified with the outlet 19 at the T-piece 23 at which the oil phase 7 and the gas phase 8 are mixed. The product flow from outlet 19 may be fed to an oil (and gas) storage. The possibility of mixing the oil and gas phase is only an optional solution and may be omitted. Thus, in other embodiments the gas phase is collected solely via the outlet 16.

[0067] The system 1A also includes a pipeline 26 connected with outlet 12 for produced water at the venturi 25a. The pipeline 26 is connected to a flexible bag 32 comprising a second volume 33. Thus, fluid communication is established between the first volume 3 and the second volume 33 via the outlet 12 and pipeline 26. The fluid communication between the first volume 3 and the second volume 33 is controlled by the venturi 25a and/or the valve 27.

[0068] The flexible bag 32 comprising the second volume 33 is encapsulated in a protective structure 34. In the embodiment shown in figure 2 the flexible bag 32 is not fully expanded in the protective structure 34 but is able to expand in the directions indicated by arrows. Thus, the flexible bag 32 provides a flexible second volume 33, which is able to receive or deliver produced water when the pressure in the first volume exceeds a predetermined threshold value. When such an incident appears the valve 27 will open and allow process water to flow between the first volume 3 and the second volume 33 until an acceptable pressure is obtained in the first volume 3. Alternatively, if the valve 27 is not present, the venturi 25a can serve to control the flow of produced fluid between the first volume 3 and the second volume 33.

[0069] Figure 3 also shows a subsea storage and processing system for produced fluids 1B according to the invention. The system 1B corresponds to the system 1A shown in figure 2 except for the venturi 25a which has been replaced by a T-piece. Thus, the valve 27 controls the fluid communication between the volume 3 and the volume 33 via the pipelines 12 and 26.

[0070] Figure 4 shows a subsea storage and processing system for produced fluids 1C according to the invention. The system 1C also includes several elements corresponding to the elements in the system 100 shown in figure 1. The system comprises a flexible bag 2 comprising a first volume 3. The flexible bag 2 is encapsulated in a protective structure 4. The protective structure 4 has a substantially cylindrical shape with a dome-like top. The protective structure 4 has a lid 5 closing an opening in the dome-like top. The flexible bag 2 is attached to the lid 5 and all inlets 10 and outlets 12, 16, 19 and 21 pass through the lid 5.

[0071] Inside the flexible bag 2 in the first volume 3 produced fluid is stored and separates into a water phase 6, an oil phase 7 and a gas phase 8.

[0072] The produced fluid is fed to the first volume 3 via inlet or pipeline 10, which is controlled by the valve 11.

[0073] The separated phases in the flexible bag 2 are collected via different outlets or pipelines. The produced water 6 is collected via the outlet 12 controlled by valve

the 13 and connected with the pump 14. The pump 14 may increase the pressure in the produced water which may be injected into a well via the valve device 28 and the pipeline 29.

[0074] The gas phase 8 can leave the system via outlet 16 controlled by valve 17. From the pipeline 16, the gas can be released to ambient environment.

[0075] The oil phase 7 is collected via the outlet 19 controlled by the valves 18 and 20. At least a fraction of the gas phase 8 may be collected with the oil phase 7. This is done by use of the outlet 21 controlled by the valve 22. The outlet 21 is unified with the outlet 19 at the T-piece 23 at which the oil phase 7 and the gas phase 8 are mixed. The product flow from outlet 19 may be fed to an oil (and gas) storage.

[0076] The system 1C also includes a pipeline 26 connected with outlet 12 for produced water at the T-piece 25. The pipeline 26 is connected to a flexible bag 42 comprising a second volume 43. Thus, fluid communication is established between the first volume 3 and the second volume 43 via the outlet 12 and pipeline 26. The fluid communication between the first volume 3 and the second volume 43 is controlled by the valve 27. In an alternative not shown embodiment the valve may be replaced by a venturi.

[0077] The second volume 43 is also connected with valve device 28 by means of a pipeline 36.

[0078] The flexible bag 42 comprising the second volume 43 is encapsulated in the protective structure 4. Thus, the flexible bag 42 and the second volume are encapsulated in the same protective structure 4, whereby a more compact design is achieved. However, the second volume 43 functions in a manner corresponding to the function of the second volume 33 shown in figure 2, which is encapsulated in the protective structure 34 separated from the protective structure 4.

[0079] The valve device 28 is adapted to allow produced water to flow from outlet 12 to pipeline 29. The valve device 28 may also allow flow of produced water from outlet 12 to the second volume 43 or flow of produced water from the second volume 43 to the pipeline 29 via the connecting pipeline 36. Thus, the second volume 43 can be at least partly emptied or filled via the valve device 28.

[0080] Figure 5 shows yet an embodiment of a subsea storage and processing system for produced fluids 1D according to the invention. The system 1A comprises a flexible bag 2 comprising a first volume 3. The flexible bag 2 is encapsulated in the protective structure 4. The protective structure 4 has a substantially cylindrical shape with a dome-like top. The protective structure 4 has a lid 5 closing an opening in the dome-like top. The flexible bag 2 is attached to the lid 5 and all inlets 10 and outlets 12, 16, 19 and 21 pass through the lid 5.

[0081] Inside the flexible bag 2 in the first volume 3 produced fluid is stored and separates into a water phase 6, an oil phase 7 and a gas phase 8.

[0082] The produced fluid is fed to the first volume 3

via inlet or pipeline 10, which is controlled by the valve 11.

[0083] The separated phases in the flexible bag 2 are collected via different outlets or pipelines. The produced water 6 is collected via the outlet 12 controlled by the valve 13 and connected with the pump 14. The pump 14 may increase the pressure in the produced water which may be injected into a well via pipeline 15. Alternatively the produced water can be released into the ambient sea via the pipeline 15.

[0084] The gas phase 8 can leave the system via outlet 16 controlled by valve. From the pipeline 16, the gas can be released to ambient environment.

[0085] The oil phase 7 is collected via the outlet 19 controlled by the valves 18 and 20. At least a fraction of the gas phase 8 may be collected with the oil phase 7. This is done by use of the outlet 21 controlled by the valve 22. The outlet 21 is unified with the outlet 19 at the T-piece 23 at which the oil phase 7 and the gas phase 8 are mixed. The product flow from outlet 19 may be fed to an oil (and gas) storage.

[0086] The system 1D also includes a pipeline 26 connected with outlet 12 for produced water at the venturi 25a. The pipeline 26 is connected to the combined storage and sand accumulator 50.

[0087] The combined storage and sand accumulator 50 comprises a flexible bag 52 comprising a second volume 53. Thus, fluid communication is established between the first volume 3 and the second volume 53 via the outlet 12 and the pipeline 26. The fluid communication between the first volume 3 and the second volume 33 is controlled by the venturi 25a and/or the valve 27. The flexible bag 52 is able to expand and retract in the protective structure 54, whereby the second volume may serve as a buffer for produced fluid lead to the first volume 3.

[0088] The combined storage and sand accumulator 50 also serves as a sand accumulator. Thus, produced fluid comprising sand and optionally other solids can be lead to the flexible bag 52 and during a residence period the sand will sink towards the bottom from where it can be collected. The device 50 may also function as a sand accumulator, line 56 is the inlet for the sand accumulator and line 55 is the outlet. The fluids collected via the outlet 55 may optional be led to first volume 3 for further separation.

[0089] The present invention as described above and exemplified in the figures 2 to 5 provides a simple solution for a subsea storage and processing system handling produced fluids from a well in cases where the amount of produced fluid and the pressure suddenly change, i.e. a rapid decrease or a rapid increase in the amount of produced fluid and the pressure. The buffer volume provided by the second volume will ensure that the amount of produced fluid and the pressure in the first volume rapidly can be offset to an acceptable level. Thereby, possible damage on the process equipment can be avoided.

[0090] All the valves in the systems described in the

examples above are electrically operated and the pressure in the system is monitored by pressure sensors which are not shown in the figures. The valves and the pressure sensors are connected with a not shown control unit, which opens or closes the valves in response to signals from the pressure sensors. Pressure sensors, electrically controlled valves and control units for monitoring and controlling the operation of subsea storage and processing system for produced fluids are well-known and therefore not described in details in this application.

[0091] Although the valves in the examples above are electrically operated, hydraulically operated valves or manually operated valves may be applied as well in the systems according to the invention. Also acoustic sensors may be applied, e.g. for measuring the volume in the buffer volume (the second volume). Other types of sensors or instruments for e.g. measuring the temperature, differential pressure, phase transitions and other desired parameters may be applied in the systems

Claims

1. A subsea storage and processing system for produced fluids comprising a first volume having a volume of at least 250 m³ and a second volume which is smaller than the first volume of the system, said first volume and said second volume being in fluid communication, said fluid communication being controlled by a control device adapted to control the fluid communication between said first volume and said second volume in response to a pressure difference between the pressure in the first volume and the pressure in the second volume.
2. A subsea storage and processing system according to claim 1, wherein the control device is adapted to allow fluid communication between said first volume and said second volume if the pressure in the first volume deviates from one or more predetermined threshold values.
3. A subsea storage and processing system according to claim 2, wherein the predetermined threshold value is the operating pressure measured in bar in the first volume +/- 0.1 bar.
4. A subsea storage and processing system according to anyone of the claims 1-3, wherein the first volume is in the range 250 m³ to 10,000 m³, such in the range 1,000 m³ to 8,000 m³, such in the range 2,500 m³ to 6,000 m³, such in the range 3,000 m³ to 5,000 m³.
5. A subsea storage and processing system according to anyone of the preceding claims, wherein the volume of the second volume is less than 1/10 of the volume of the first volume.
6. A subsea storage and processing system according to anyone of the preceding claims, wherein the control device is selected from a valve, venture, throttling, eductor and/or ejector.
7. A subsea storage and processing system according to anyone of the preceding claims, wherein the first volume is contained in a flexible bag.
8. A subsea storage and processing system according to claim 7, wherein the flexible bag containing the first volume is encapsulated in a protective structure.
9. A subsea storage and processing system according to anyone of the preceding claims, wherein the second volume is contained in a flexible bag.
10. A subsea storage and processing system according to claim 9, wherein the flexible bag containing the second volume is encapsulated in a protective structure.
11. A subsea storage and processing system according to anyone of the claims 7 to 10, wherein the flexible bag containing the first volume and the flexible bag containing the second volume are encapsulated in the same protective structure.
12. A subsea storage and processing system according to anyone of the claims 7 to 10, wherein the flexible bag containing the first volume and the flexible bag containing the second volume are encapsulated in separate protective structures.
13. A subsea storage and processing system according to anyone of the claims 8 to 12, wherein the one or more protective structures comprise a lid covering an opening in the top of the protective structure, preferably the flexible bag containing the first volume and the flexible bag containing the second volume are attached to said lid.
14. A subsea storage and processing system according to anyone of the preceding claims, wherein the system comprises a sand accumulator.
15. A subsea storage and processing system according to claim 14, wherein the sand accumulator is included in the first volume and/or the second volume.

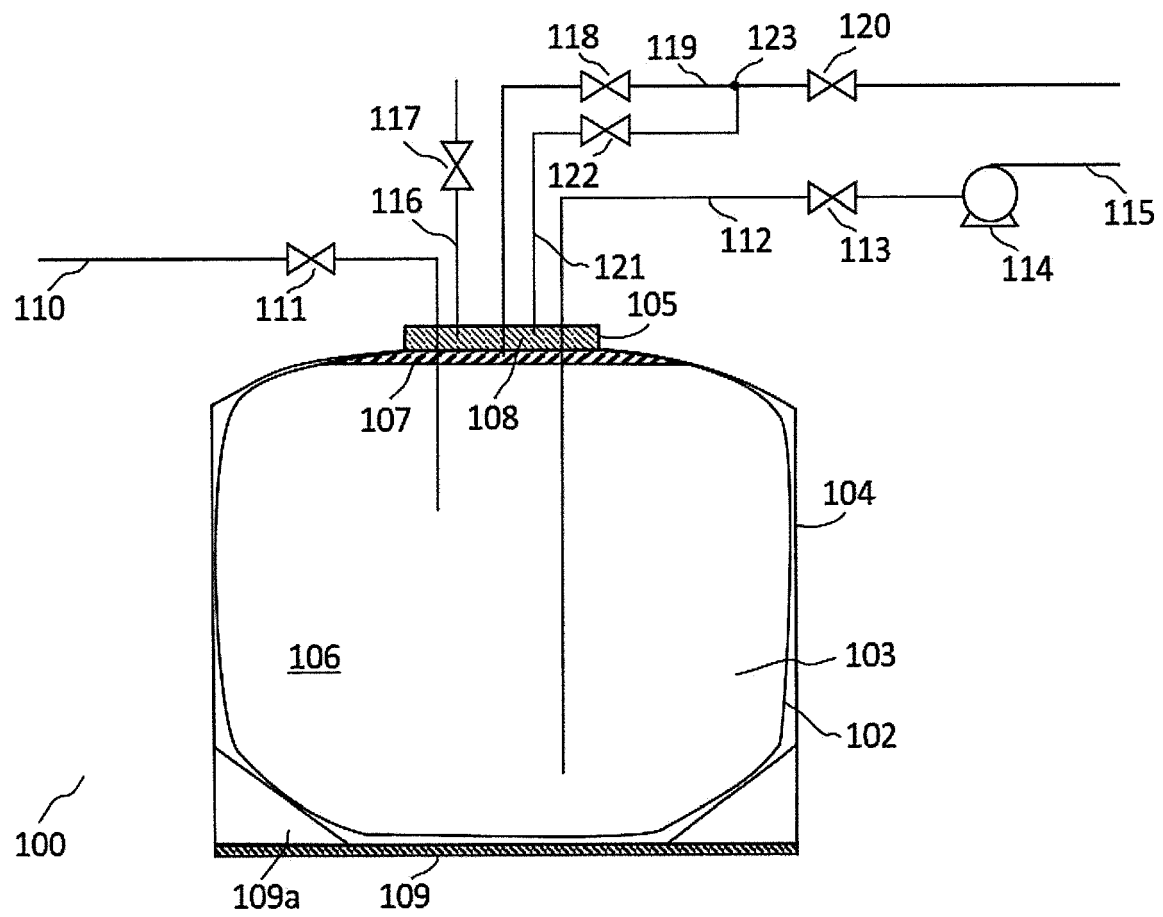


Fig. 1

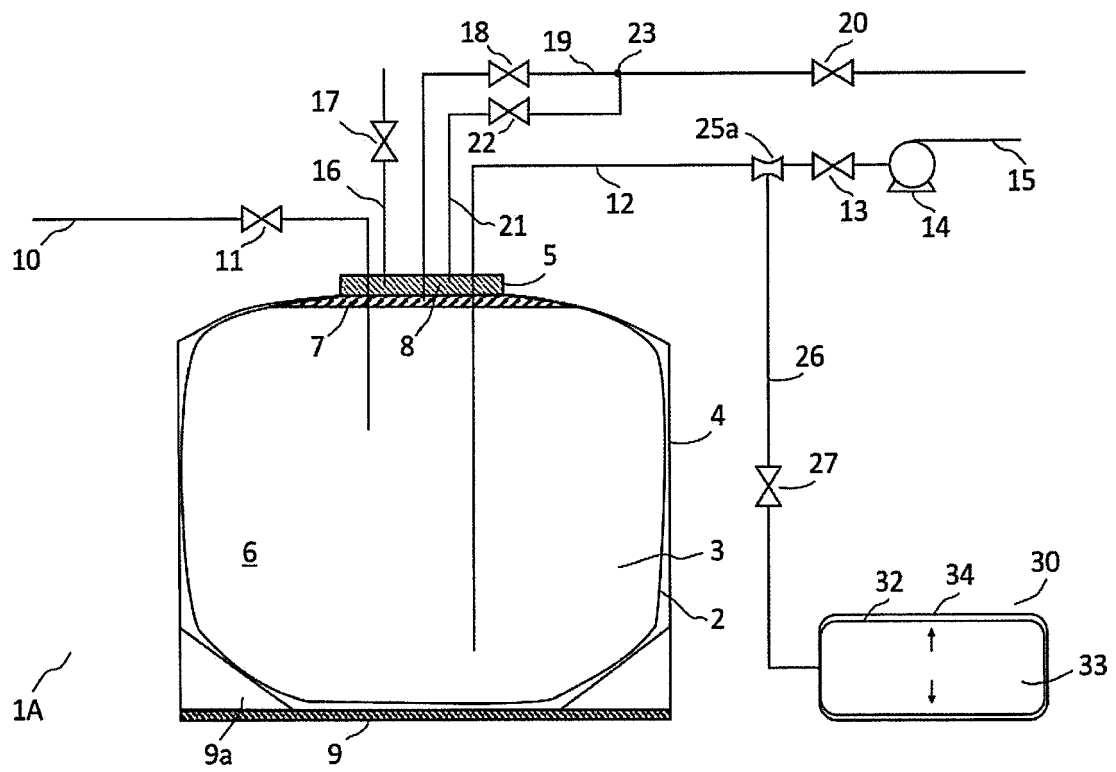


Fig. 2

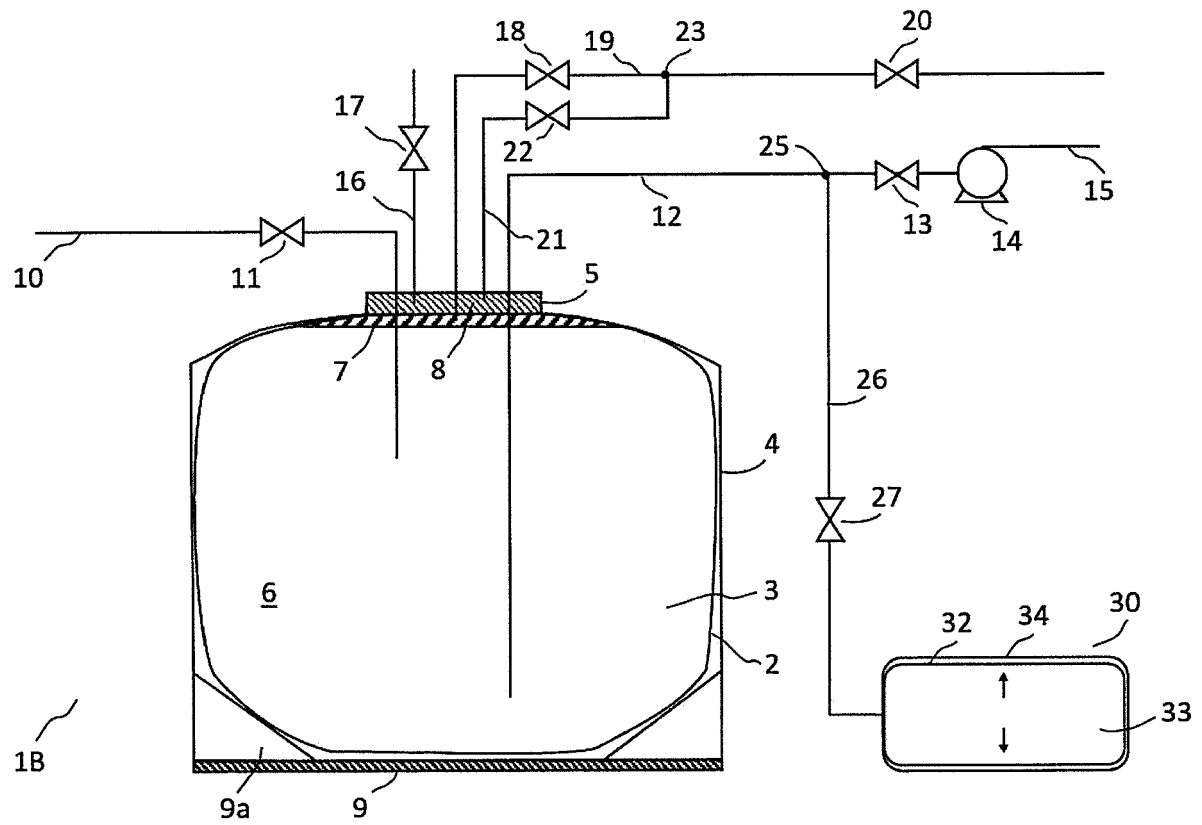


Fig. 3

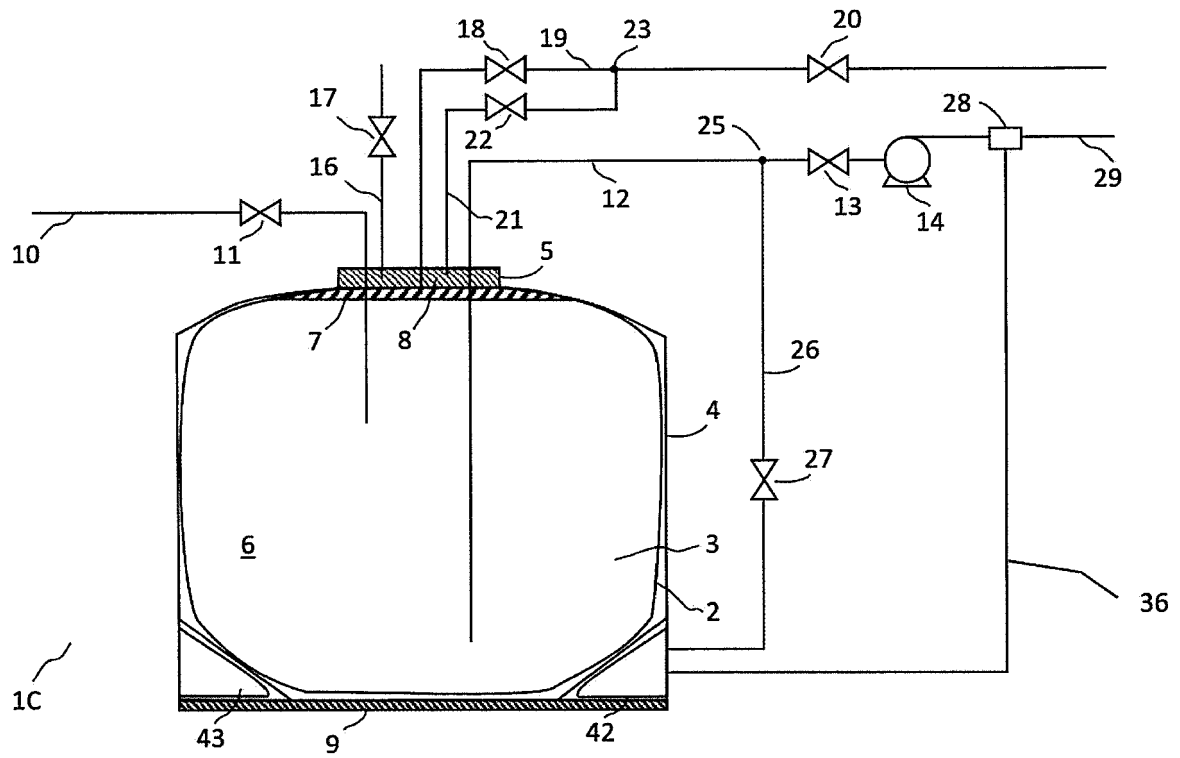


Fig. 4

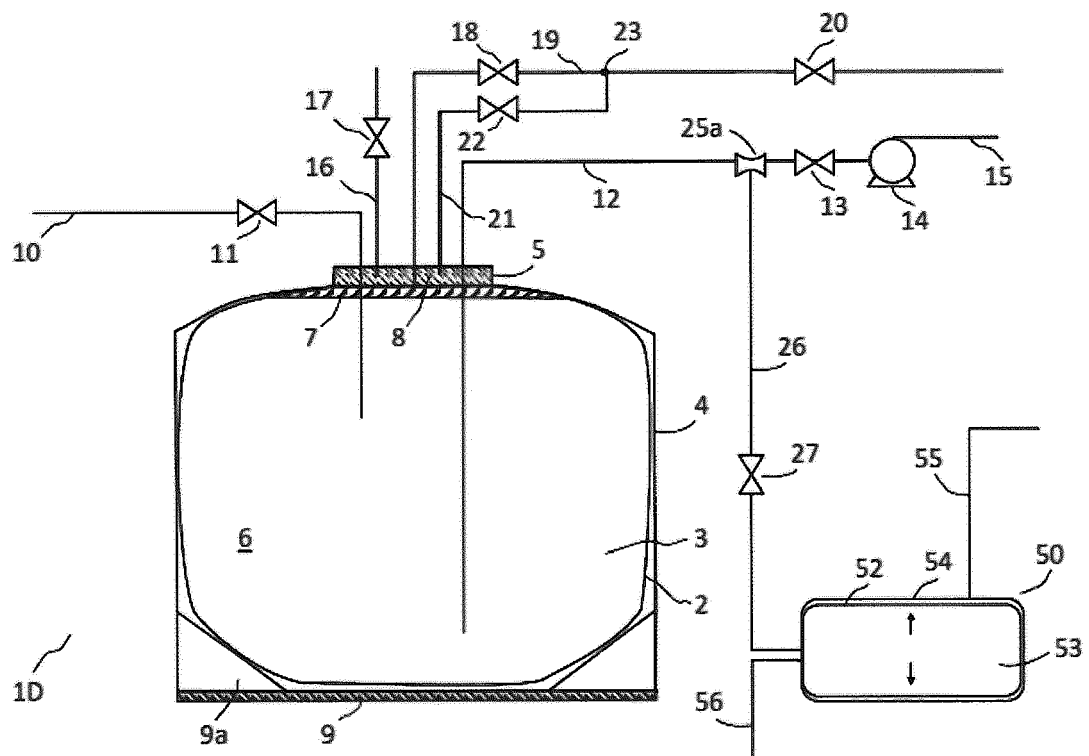


Fig. 5



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