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Krohn

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(54) **SUBSEA STORAGE TANK FOR BULK STORAGE OF FLUIDS SUBSEA**

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B65D 88/78 (2006.01)

(52) **U.S. Cl.**
CPC ***B65D 88/78*** (2013.01)

(58) **Field of Classification Search**
CPC B65D 88/78
See application file for complete search history.

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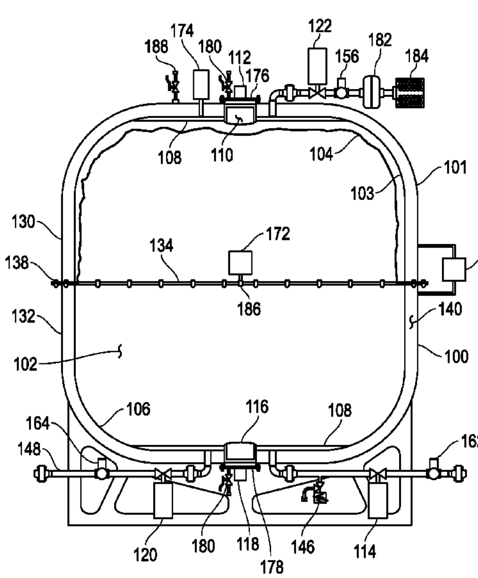
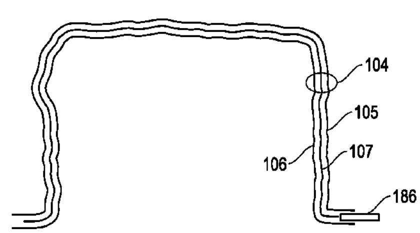
(57) **ABSTRACT**

A subsea storage tank for the storage of bulk fluids is adapted for being set on the sea floor, and is adapted for supplying to local subsea oil and gas production facilities a wide variety of production support fluids. The subsea storage tank includes an inner and outer shell, the shells being adapted so that a barrier fluid can be inserted into and between the shells. An interior barrier separates the interior stored fluid from sea water that is free to enter into the tank, on the opposite side of the barrier, to compensate to the varying volume of stored fluid. An identical tandem barrier is formed nearly identical to the first barrier, and is formed and positioned so that the two barriers act together, and so that the space between them can contain fluid as well, and acts like a bladder.

4 Claims, 3 Drawing Sheets





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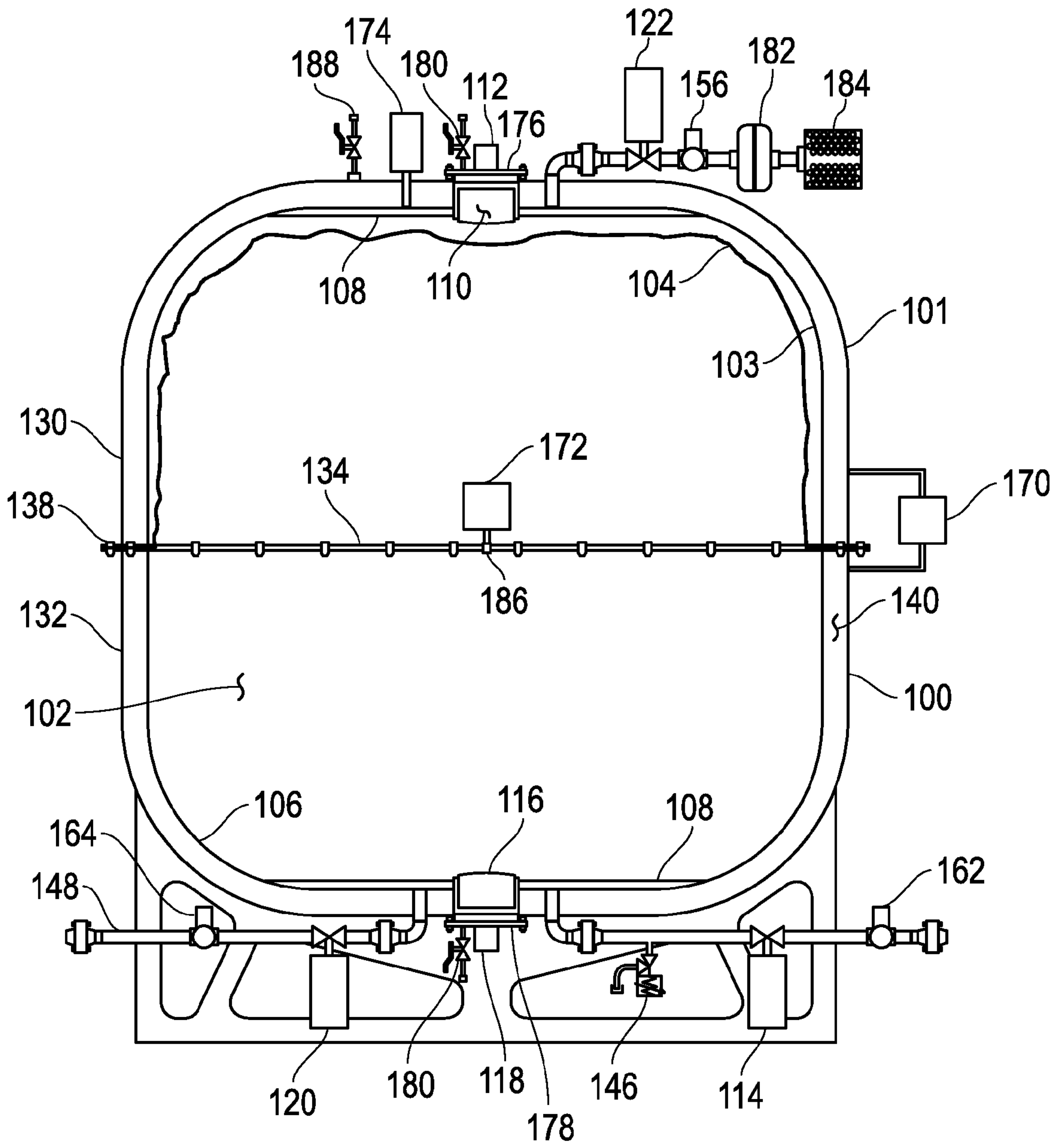
174
188
180
112
176
122
156
182
184
108
110
104
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103
130
172
134
170
138
186
140
132
100
102
106
116
108
164
148
162
120
180
118
146
114
178

FIG. 1A

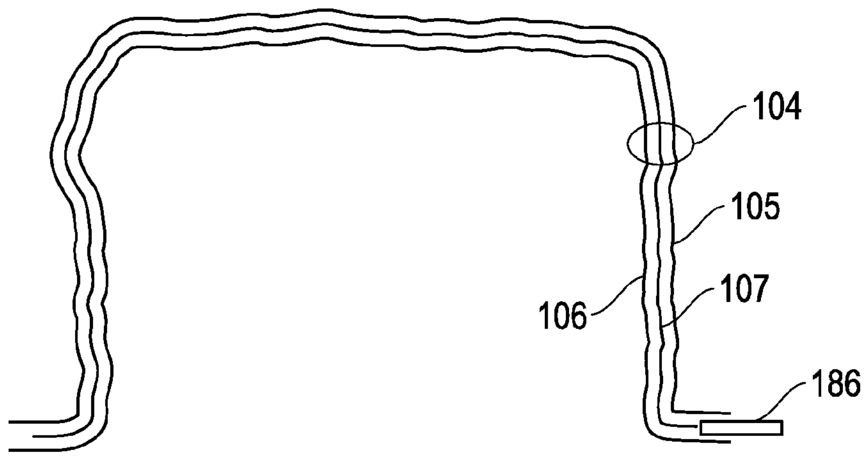

FIG. 1B

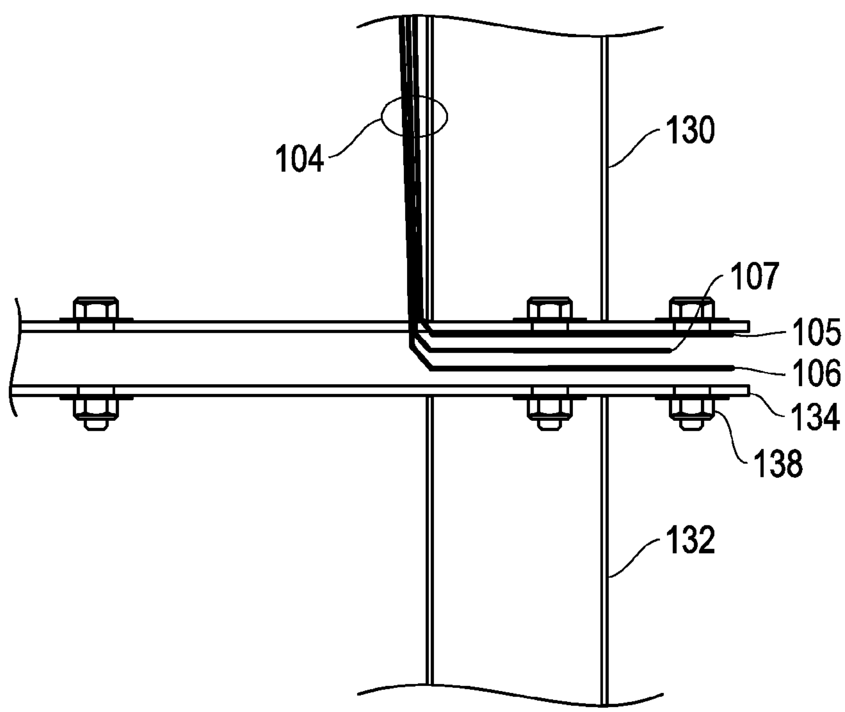

FIG. 1C

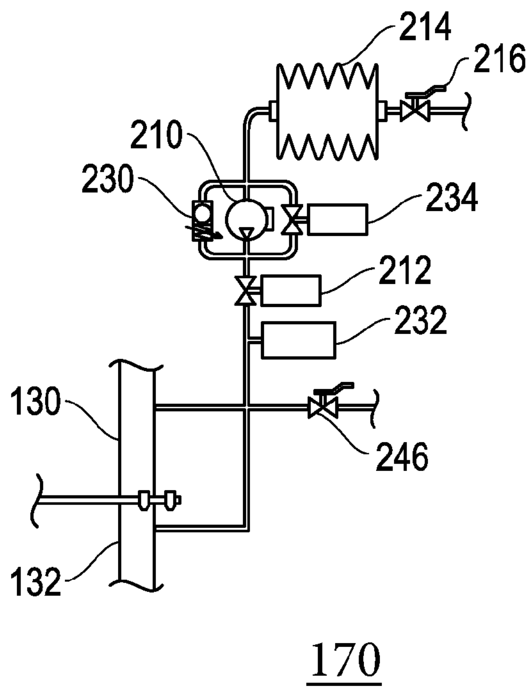
214
216
210
230
234
212
232
130
246
132
170

FIG. 2

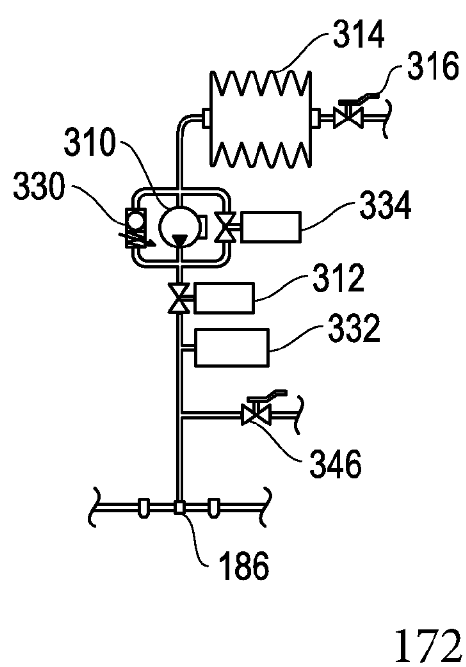
314
316
310
330
334
312
332
346
186
172

FIG. 3

SUBSEA STORAGE TANK FOR BULK STORAGE OF FLUIDS SUBSEA

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims the benefit of provisional patent application Ser. No. 62/102,743, filed Jan. 13, 2015.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable.

THE NAMES OF THE PARTIES TO A JOINT RESEARCH AGREEMENT

Not Applicable.

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not Applicable.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The invention relates to a tank for the storage of fluids and chemicals subsea.

(2) Description of Related Art

Tanks that are placed subsea must have certain features to ensure their survivability in the environment. They must contain the working fluids, be compensated to the outside environment and related hydrostatic pressure, and remain intact and in service for the length of their intended mission.

U.S. Pat. No. 7,424,917, which is incorporated herein by this reference, discloses a subsea pressure compensation system which includes a chamber with a piston therein acted on an exposed side by sea water, to provide operational hydraulic fluid for operating a subsea device, with a piston rod having an end in a separate chamber acted on by a fluid to compensate for a pressure differential between the pressure of the water on one piston side and the pressure of the operational hydraulic fluid on the other piston side. However, this reference does not teach, nor suggest, using any of the compensator system or system of pumps to act upon the compensator itself as a self-contained method to test or measure the integrity of the compensator itself, or of any of the barriers that separate the internal fluid from the surrounding outside fluid.

U.S. patent application No. 20080210434A1, which is incorporated herein by this reference, discloses a subsea and modular tanker-based hydrocarbon production system comprising a plurality of interlinked individual tank units which is wholly submersible. However, this reference does not teach, nor suggest, utilizing a pump to generate either a fluid pressure or vacuum to measure the integrity of the walls of the tank.

U.S. patent application No. 20130167962A1, which is incorporated herein by this reference, describes a pressure compensator for a subsea device that embodies the ability of the subsea tank to remain pressure compensated. However, this reference does not teach, nor suggest, using the fluid that is contained between the walls of the compensator to be used in a test protocol to assure the integrity of the wall, or barrier, of the compensator or vessel.

U.S. patent application No. 20150246770A1, which is incorporated herein by this reference, discloses a subsea storage tank, including a body having a storage space therein and formed of light weight concrete inner and outer sides of which are watertight coated or plated. However, this reference does not teach or suggest provisions that allow for the pressurization or vacuum of fluid between the tank inner and outer sides, nor could the fluid in this location be used to test the integrity of either wall of the storage tank or the integrity of the seals of the separation unit.

In light of the foregoing, a need remains for a modular subsea tanker hydrocarbon system, having a dual wall tank, and a barrier bladder, and utilizing a pump to generate either a fluid pressure or vacuum to measure the integrity of both the walls of the tank, and the barrier bladder, to sea water or working fluid.

BRIEF SUMMARY OF THE INVENTION

A subsea storage tank for the storage of bulk fluids, adapted for being set on the sea floor and adapted for supplying to local subsea oil and gas production facilities a wide variety of production support fluids. The subsea storage tank includes an inner and outer shell. The shells are adapted so that fluid can be inserted between the shells. The tank is split into two nearly identical halves, each half having a flange to bolt and assemble the halves into a complete tank. Into and between the flanged halves of the tank, a barrier that also is sealed like a bladder is placed to isolate and prevent comingling of a storage fluid in one half of the tank from the other half. An interior volume is dedicated to the storage of bulk fluids. An interior barrier separates the interior stored fluid from sea water that is free to enter into the opposite side of the barrier to compensate to the varying volume of stored fluid. An identical tandem barrier is formed nearly identical to the first barrier, and is formed and positioned so that the two barriers act together, and so that the space between them can contain fluid as well, and acts like a bladder. A light film of mineral oil or other fluid is between these two barriers so that they are free to slide against each other. The tank includes a pressure or vacuum pump and associated automatic valves so that the shell, and the barrier bladder, can be pressurized or vacuum drawn down to test the integrity of either the shell or the barrier bladder. This testing can be performed at any time, either locally or remotely, either on the surface above the water, or in service subsea, and whether or not the tank contains any amount of bulk fluid. The tank is adapted for lowering subsea either full or empty of bulk fluid, and is adapted for fitting to a temporary or permanent subsea structure, by hoses, pipes, or hydraulic couplings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The novel features, characteristic of the invention, are set forth in the appended claims. However, the invention itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood by reference to the following detailed description, when read in conjunction with the accompanying drawings in which the left-most significant digit in the reference numerals denotes the first figure in which the respective reference numerals appear.

FIG. **1**A is a cross-section view of a tank with schematic representations of the tank's dual shells, dual barrier bladder, fluid connections, sump pans, test pumps, valves, and associated instruments.

FIG. **1B** is a cross section of the dual barrier bladder showing the first barrier wall, second barrier wall, the porous mesh between the walls, and the fluid access port.

FIG. **1C** is a schematic diagram showing a separation flange of the tank, the dual barrier bladder, and a porous mesh that is between the two barriers of the bladder.

FIG. **2** is a schematic diagram showing equipment used to test the dual shells of the tank.

FIG. **3** is a schematic diagram showing equipment used to test the dual barrier bladder inside the tank.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1A**, a storage tank **100** is full of bulk fluid **102** such that a dual barrier bladder **104** is pushed against an inner tank shell **103** and two sump pans **108**. This full position actuates a first large diameter piston **110**, applying force to a tank full limit switch **112**, which generates a signal to stop filling the tank **100**. When stop filling is indicated, a fill valve **114** closes. A second large diameter piston **116** and a tank empty limit switch **118** are located at the bottom of the tank **100** such that when the tank **100** is emptied, the dual barrier bladder **104** applies a force against the second large diameter piston **116**, which in kind, applies a force against the limit switch **118**, sending a control signal to shut a discharge valve **120**. During either fill or discharge operation, a sea water compensation valve **122** is open to allow the free flow of sea water into the interior of the tank **100** and to the opposite side of the dual barrier bladder **104**. FIG. **1A** shows a cross section of the tank **100** independent of the overall potential size of the tank **100**. This configuration can be applied to tanks of relatively small volumes of several hundred gallons to tanks sized well over thousands of gallons. The defining quality of the geometry of the tank **100** is that the tank **100** is comprised of split halves, a first shell half **130**, which is flanged and bolted to a second shell half **132**, which creates a flange **134** to seal the edges of the dual barrier bladder **104**, which is fastened together with bolts **138**. Each shell half **130** and **132** is constructed as a dual wall shell, so that in each shell half **130** and **132** a fluid can be placed in a space **140** between the inner tank shell **103** and an outer tank shell **101**, and can be sealed and controlled.

The first shell half **130** and the second shell half **132** are tested by a tank shell test package **170**, through a tubing conduit connection drawing on the fluid in the space **140**. The shell test package **170** is shown in FIG. **2**. This testing can be accomplished when the tank **100** is on the surface, or below sea water, and at any time. The dual barrier bladder **104** is tested by a dual barrier bladder test package **172**, shown in FIG. **3**. This testing can be accomplished when the tank **100** is on the surface or below sea water, and at any time, and can be accomplished concurrently with testing either shell half **130** or **132**.

Filling operations of the tank require that the fill valve **114** be opened, so that bulk fluid can then be pumped into the tank **100**. The discharge valve **120** may be open or closed, and the tank **100** can be discharging or not discharging during the fill operation. The tank **100** can be filled before deployment subsea, and can be filled while deployed subsea during operation or when idle.

Measurement of the tank **100** levels for volumes of either the bulk fluid, or of compensating sea water, is performed by tracking and comparing the amount of either fluid as it enters or exits the tank **100**. A flow meter **156** for the sea water compensation measures the amount of sea water that enters and exits the tank **100**. A fill flow meter **162** measures the amount of bulk fluid that enters the tank **100**. A discharge flow meter **164** measures the amount of bulk fluid that is discharged from the tank **100**. A control method is established that compares the amount of fluid that passes each of these meters **156**, **162**, and **164**. This amount is always compared so that it is understood to very exact amounts how much bulk fluid, or sea water, is in the tank **100**. If for any reason the tank **100** is completely emptied or completely filled, the tank empty limit switch **118** or the tank full limit switch **112** will signal the control system to stop discharge, stop fill, or close the discharge valve **120**, the fill valve **114**, or the sea water compensation valve **122**.

The fill valve **114**, the discharge valve **120**, and the safety valve **146** are necessary to ensure that the storage tank **100** cannot be compromised should a malfunction of a control system (not shown) occur. The safety valve **146** for the discharge fill piping **148** will open should the storage tank **100** become over-pressured. The compensation valve **122** is also a safety valve in that it is normally open, and the control system is required to shut it in any necessary operation. A pressure transducer **174** measures internal tank pressure, and differential pressure between the inside and outside of the storage tank **100**. When the pressure transducer **174** signals that an overpressure or under pressure condition is detected of a certain value, the fill valve **114** and the discharge valve **120** can be automatically closed.

On the top and bottom of the storage tank **100** are two access ports **176** and **178**. The access port **176** has a piston **110**, and the access port **178** has a piston **116**. The pistons **110** and **116** will translate when the dual barrier bladder **104** presses from the inside against the pistons **110** and **116**. The pressure by the dual barrier bladder **104** pushes the pistons **110** and **116** against limit switches **112** and **118**, thus signaling the position of the dual barrier bladder **104**. The limit switch **112** signals that the storage tank **100** is full of bulk fluid. When the limit switch **118** signals, then the storage tank **104** is empty of bulk fluid. Included in the access port **176** is a vent and drain valve **180**. The vent and drain valve **180** is used for releasing trapped air in the assembled storage tank **104**. The vent and drain valve **180** is also used for releasing trapped air in the first shell half **130** and in the second shell half **132**, or for draining fluid from either the first shell half **130** or from the second shell half **132**. When differential pressure is detected by the pressure transducer **174** of a certain value, the fill valve **114** and the discharge valve **120** can be automatically closed.

A fine sea water filter **182** and a coarse marine life excluder **184** are used together to keep debris and marine life from entering the tank. A vent valve **188** is located at the top of the tank **100** and the first shell half **130** to allow air to be vented when filling the space **140**.

FIG. **1B** shows a first barrier bladder wall **105**, a second barrier bladder wall **106**, and a porous mesh membrane **107**, which is located between the first barrier bladder wall **105** and the second barrier bladder wall **106**, which together form the dual barrier bladder **104**. Bonded between the walls **105**, **106** is a tube access port **186** that allows fluid to enter from the dual barrier bladder test package **172** into a bladder inner space between the walls **105**, **106** of the dual barrier bladder **104**.

FIG. **1C** shows a view of the flange **134** of the storage tank **100**, the dual barrier bladder **104**, and the porous mesh membrane **107**. The flange **134** is shown with a gap to illustrate the dual barrier bladder **104**, the first barrier bladder wall **105**, the second barrier bladder wall **106**, and the porous mesh membrane **107**, which is sealed by the flange **134**. The bolts **138** are shown elongated only to illustrate the dual barrier bladder **104** and the porous mesh membrane **107**. The porous mesh membrane **107** allows the free flow of lubricating oil or other fluid to flow and communicate throughout the entire inner space surfaces.

FIG. **2** shows the tank shell test package **170**, which includes a pump **210**, valves **212** and **216**, a pressure transducer **232**, a regulator valve **230**, and a fluid storage compensator **214**. The pump **210** can be configured to either pressurize or pull a vacuum on the first shell half **130** and the second shell half **132**. The pump operation is controlled by an operator either at the storage tank **100** or remotely. When the pump **210** is operated, the valve **212** opens and allows fluid to flow from or into the fluid storage compensator **214**. The fluid storage compensator **214** is sealed from the outside environment. The fluid storage compensator **214** can be filled or vented with the valve **216**.

When the pump **210** is used for a test, it is operated for a specific amount of time until a designated pressure or vacuum is reached. This test pressure or vacuum is regulated by a regulator valve **230**, that can be either locally adjusted or remotely adjusted, and remotely controlled. The test pressure or vacuum is measured by a pressure transducer **232**. Once desired pressure or vacuum is achieved, the valve **212** is closed, trapping the pressure or vacuum to be recorded and viewed for a defined amount of time. Upon completion of the test, both the valve **212**, and a valve **234**, are opened to allow fluid to flow from the fluid storage compensator **214** to equalize the fluid pressure. A valve **246** is used to fill the first shell half **130** and the second shell half **132** with fluid.

FIG. **3** shows the dual barrier bladder test package **172**, which includes a dual barrier bladder testing pump **310**, valves **312**, **316**, **330**, and **334**, a pressure differential transducer **332**, a regulator valve **330**, and a fluid storage compensator **314**. The pump **310** can be configured to either fill or pull a vacuum on the dual barrier bladder **104**, via the access port **186** bonded into the perimeter seal of the dual barrier bladder **104**. The access port **186** allows fluid to be placed between the walls of the dual barrier bladder **104**, and then removed from between the walls of the dual barrier bladder **104**. The pump **310** operation is controlled by an operator either at the storage tank **100** or remotely. When the pump **310** is operated, the valve **312** opens and allows fluid to flow from or into the fluid storage compensator **314**. The fluid storage compensator **314** is sealed from the outside environment. The fluid storage compensator can be filled or vented with the valve **316**. A valve **346** allows fluid to be added, drained, or vented from the dual barrier bladder **104**. The valve **346** is used to test and flush the pump **310**.

When the pump **310** is used for a test, it is operated for a specific amount of time until a designated vacuum is reached. This test vacuum is regulated by the valve **330**, that can be either locally adjusted or remotely adjusted, and remotely controlled. The test vacuum is measured by a pressure differential transducer **332**. Once desired vacuum is achieved, the valve **312** is closed, trapping the vacuum to be recorded and viewed for a derived amount of time. Upon completion of the test, both the valve **312**, and the valve **334**, are opened to allow fluid to flow from the fluid storage compensator **314** to equalize the fluid pressure. The dual bladder barrier **104** is configured in nearly two identical formed layers to the interior half of the storage tank **100** that are chemically resistant, impermeable coated fabric barriers.

What is claimed is:

1. A subsea storage tank for the storage of bulk fluids, the tank comprising:

an upper shell half and a lower shell half, the two halves being nearly identical halves, each half having a flange to bolt and assemble the halves into a complete tank;

into and between the flanged halves of the tank, a first barrier bladder isolates and prevent comingling of a storage fluid in one half of the tank from the other half of the tank;

an identical tandem barrier bladder is positioned so that the two barrier bladders to act together, and so that the space between them can contain fluid as well, and an inner shell and an outer shell, the shells adapted for receiving a barrier fluid between the shells.

2. The subsea storage tank according to claim **1**, further comprising a pump and associated automatic valves so that the shells, and the barrier bladders, can be pressurized or vacuum drawn down to test the integrity of either the shells or the barrier bladders.

3. The subsea storage tank according to claim **2**, further comprising adaptations and connections for lowering the tank subsea either full or empty of bulk fluid, and for fitting to a temporary or permanent subsea structure, by hoses, pipes, or hydraulic couplings.

4. The subsea storage tank according to claim **3**, further comprising access ports with pistons, wherein the pistons move in response to pressure from the barrier bladders to close the access ports, thus stopping the entry of fluid into the tank.

* * * * *