

GAS DOME STRUCTURE FOR A SEALED, THERMALLY INSULATED VESSEL

Technical field

The invention concerns the field of sealed, thermally insulating tanks, for storing and/or transporting fluid, such as a cryogenic fluid.

5 Sealed, thermally insulating tanks are used, in particular, for storing liquefied natural gas (LNG), which is stored, at atmospheric pressure, at approximately -162°C.

The invention more particularly concerns a gas dome structure that is intended to define a path for vapor to flow between the inner space of the tank and a vapor header arranged outside the tank.

10 Technological background

Document KR20140088975 discloses a sealed and thermally insulating tank that is housed inside a double hull of a ship and comprises a gas dome structure intended to define a path for vapor to flow between the inner space of the tank and two vapor headers arranged outside the tank.

15 The gas dome structure comprises an outer drum that passes through the outer hull of the double hull and that is welded to the inner hull of the double hull, an inner drum that extends inside the outer drum and is sealingly connected to the primary sealing membrane of the tank and an intermediate insulating gap arranged between the inner drum and the outer drum. The outer drum comprises, at its top end,
20 an assembly flange consisting of a rim folded outward and receiving a removable cover with a seal interposed therebetween. The inner drum and the intermediate insulating gap do not extend up to the top end of the outer drum, and two pipes for collecting gas in the vapor phase pass radially through the outer drum in a top area of the outer drum, above the inner drum and the intermediate insulating gap.

25 Such a gas dome structure is not completely satisfactory. Indeed, in view of its arrangement, such a gas dome structure must be assembled *in situ* on the ship, which complicates assembly operations and makes them more time-consuming.

Moreover, the seal interposed between the removable cover and the assembly flange is in direct contact with the vapor phase contained in the inner drum. However, when the fluid stored in the tank is a cryogenic fluid, such as liquefied gas, the vapor is likely to be at very low temperatures, as low as approximately -160°C.

- 5 Therefore, the seal is likely to be subjected to relatively low temperatures, which is likely to damage it and give rise to leaks in the gas dome. The reliability of such a gas dome is therefore not completely satisfactory.

Summary

- One idea underlying the invention is that of proposing a gas dome structure
10 that is simple to assemble.

According to one embodiment, the invention provides a gas dome structure for a sealed and thermally insulating tank arranged inside a double hull defined by an inner hull and an outer hull; said gas dome structure being intended to pass through the double hull and a ceiling wall of the tank comprising at least one thermally
15 insulating barrier resting against the inner hull and a sealing membrane intended to be in contact with the fluid contained in the tank in such a way as to provide a path for vapor to flow between an inner space of the tank and at least one vapor header arranged outside the tank; the gas dome structure comprising:

- an outer drum capable of passing through two openings provided respectively in the
20 outer hull and in the inner hull;
- an inner drum that extends inside the outer drum, is secured to said outer drum, is open so as to communicate with the inner space of the tank and comprises a peripheral wall intended to be sealingly connected to the sealing membrane;
- an intermediate insulating gap arranged between the inner drum and the outer drum;
- 25 - the outer drum comprising first and second collars that protrude radially outwards from the outer drum and that are respectively suitable for being welded to the outer hull, around the opening provided in the outer hull, and to the inner hull, around the opening provided in the inner hull.

Therefore, as a result of the two abovementioned collars, the gas dome
30 structure can be partially or completely pre-assembled in the workshop and the gas dome structure can easily be assembled on the double hull.

Depending on the embodiment, such a gas dome structure can comprise one or more of the following features.

According to one embodiment, the gas dome structure is a pre-assembled structure.

- 5 According to one embodiment, the second collar intended to be sealingly welded to the inner hull has a diameter smaller than that of the first collar.

According to one embodiment, the outer drum and the inner drum each have a top end; said top ends stopping in a same horizontal plane and being linked together sealingly by an assembly flange; the gas dome structure further comprising a cover
10 that is attached to said assembly flange by attachment members and an annular seal that is compressed between the cover and the assembly flange. Therefore, in such an arrangement, the intermediate insulating gap extends up to the assembly flange, helping further thermally insulate the seal and limiting the risks of a leakage.

According to one embodiment, the assembly flange comprises an outer
15 portion protruding radially out of the outer drum; said attachment members passing through holes provided in said outer portion of the assembly flange.

According to one embodiment, the cover comprises an inner face turned towards the inside of the inner drum; said inner face being provided with a protrusion made of insulating material engaging in the inner drum. This also helps thermally
20 insulate the seal.

According to one embodiment, the gas dome structure further comprises a vapor collection pipe suitable for conveying vapor between the inside of the inner drum and the vapor header arranged outside the tank; said vapor collection pipe passing radially and in a sealed manner through the outer drum, the intermediate
25 insulating gap and the inner drum, and opening on the inside of the inner drum.

According to one embodiment, the gas dome structure comprises an insulating sleeve passing radially and in a sealed manner through the outer drum, the intermediate insulating gap and the inner drum and the vapor collection pipe passes through said insulating sleeve in a sealed manner.

According to one embodiment, the insulating sleeve comprises two concentric cylindrical walls connected together sealingly and separated from each other by an annular gap; said insulating sleeve comprising a sealable connector that opens on the inside of the annular gap and that is suitable for being connected to a vacuum pump in order place the annular gap under vacuum.

According to one embodiment, the vapor collection pipe has a bent portion arranged inside the inner drum and comprises a lower portion oriented parallel to the inner drum towards the inner space of the tank.

According to one embodiment, the gas dome structure further comprises a support device supporting the lower portion of the vapor collection pipe and arranged to distribute the forces applied to said lower portion around the inner periphery of the inner drum.

According to one embodiment, the support device comprises a first annular plate attached to the inner drum and protruding radially towards the inside of the inner drum, a second annular plate attached to the lower portion of the vapor collection pipe and protruding radially towards the outside of said lower portion of the vapor collection pipe and a plurality of support arms distributed at regular intervals around the lower portion of the vapor collection pipe and each comprising a first end attached to the first annular plate and a second end attached to the second annular plate.

According to one embodiment, the lower portion of the vapor collection pipe is equipped with a filter.

According to one embodiment, the vapor collection pipe is connected to a three-way connection arranged outside the outer drum.

According to one embodiment, the inner drum and the outer drum each comprise bellows areas that help allow them to contract or expand under the effect of temperature differentials.

According to one embodiment, the intermediate insulating gap is filled with a gaseous phase placed under vacuum and/or an insulating lining. Advantageously, the insulating lining comprises one or more insulating materials chosen from glass wool,

rock wall, cotton wool, fibrous materials, perlite, expanded perlite, polymer foams and aerogels.

According to one embodiment, the intermediate insulating gap has a bottom end that is sealingly closed by an annular flange.

5 According to one embodiment, the invention also provides a fluid storage device comprising a double hull defined by an inner hull and an outer hull and a sealed and thermally insulating tank arranged in the double hull; the tank comprising:

- a thermally insulating barrier resting against the inner hull;
- a sealing membrane intended to be in contact with the fluid contained in the tank;

10 and

- a gas dome structure as mentioned above that passes through the outer hull, the inner hull, the thermally insulating barrier and the sealing membrane in such a way as to provide a path for vapor to flow between an inner space of the tank and a vapor header arranged outside the tank; the first collar of the gas dome structure being
- 15 welded to the outer hull around an opening provided in the outer hull, the second collar of the gas dome structure being welded to the inner hull around an opening provided in the inner hull, and the inner drum being sealingly connected to the sealing membrane.

 Depending on the embodiment, such a fluid storage device can comprise
20 one or more of the following features.

 According to one embodiment, the opening provided in the inner hull has a diameter smaller than that of the opening provided in the outer hull and the second collar has a diameter smaller than that of the opening provided in the outer hull and larger than that of the opening provided in the inner hull. Such an arrangement allows
25 the gas dome structure to pass easily through the double hull and ensures the gas dome structure is easy to install.

 According to one embodiment, the thermally insulating barrier is a secondary thermally insulating barrier and the sealing membrane is a primary sealing membrane, the tank further comprising a secondary sealing membrane resting against the
30 secondary thermally insulating barrier and a primary thermally insulating barrier

arranged between the secondary sealing membrane and the primary sealing membrane.

According to one embodiment, the outer drum comprises a third collar protruding radially towards the outside of the outer drum and sealingly connected to
5 the secondary sealing membrane.

According to one embodiment, the gas dome structure further comprises an additional drum that extends radially outside the outer drum and that has a top end welded to the first collar and a bottom end welded to the second collar and an insulating lining arranged between the additional drum and the outer drum.

10 According to one embodiment, the intermediate insulating gap arranged between the inner drum and the outer drum is divided into a primary compartment and a secondary compartment, which are sealed with respect to each other.

According to one embodiment, the primary compartment and the secondary compartment are separated by a sealed annular partition attached to the outer drum
15 and to the inner drum.

According to one embodiment, the primary compartment is equipped with one or more ports provided in the outer drum and intended to bring the primary compartment into communication with a primary thermally insulating barrier.

Such a fluid storage device can be part of a land-based storage facility, for
20 example for storing LNG, or be installed in a coastal or deep-water floating structure, in particular a VLEC ship or an LNG carrier ship, a floating storage and regasification unit (FSRU), a remote floating production storage and offloading (FPSO) unit, or in other applications. In the case of a floating structure, the tank can be intended to receive liquefied natural gas acting as fuel for the propulsion of the floating structure.

25 According to one embodiment, the fluid storage device is configured in the form of a ship.

According to one embodiment, the invention also provides a method for loading or unloading such a storage device, which involves conveying a fluid through insulated pipes from or to a floating or land-based storage facility to or from the tank
30 of the storage device.

According to one embodiment, the invention also provides a transfer system for a fluid, the system comprising the abovementioned storage device, insulated pipes arranged so as to link the tank to a floating or land-based storage facility and a pump for drawing a flow of fluid through the insulated pipes from or to the floating or land-based storage facility to or from the tank.

Another idea underlying the invention is that of proposing a gas dome structure that is especially reliable, in particular in that it helps limit vapor leakages.

For this purpose, according to one embodiment, the invention provides a gas dome structure for a sealed and thermally insulating tank arranged inside a double hull defined by an inner hull and an outer hull; said gas dome structure being intended to pass through the double hull and a ceiling wall of the tank comprising at least one thermally insulating barrier resting against the inner hull and a sealing membrane intended to be in contact with the fluid contained in the tank in such a way as to provide a path for vapor to flow between an inner space of the tank and at least one vapor header arranged outside the tank; the gas dome structure comprising:

- an outer drum capable of passing through two openings provided respectively in the outer hull and in the inner hull;
- an inner drum that extends inside the outer drum, is secured to said outer drum and is intended to be sealingly connected to the sealing membrane;
- an intermediate insulating gap arranged between the inner drum and the outer drum; the outer drum and the inner drum each having a top end; a vapor collection pipe passing radially and in a sealed manner through the outer drum, the intermediate insulating gap and the inner drum, and opening on the inside of the inner drum;
- said top ends stopping in a same horizontal plane, and being linked together sealingly by an assembly flange; the intermediate insulating gap extending up to the top ends of the inner and outer drums; the gas dome structure further comprising a cover that is attached to said assembly flange by attachment members and an annular seal that is compressed between the cover and the assembly flange.

Therefore, as a result of such an arrangement, the intermediate insulating gap extends up to the assembly flange, helping further thermally insulate the seal and limiting the risks of a leakage.

Brief description of the figures

The invention will be more clearly understood, and other aims, details, features and advantages of same will become clearer on reading the following description of several specific embodiments of the invention, provided as purely
 5 illustrative and non-limiting examples, with reference to the appended drawings.

- **La figure 1** is a perspective view of a gas dome structure passing through the double hull of a ship and a ceiling wall of a sealed and thermally insulating tank resting against the inner hull of the double hull.

- **La figure 2** is a cross section view of the gas dome structure of figure
 10 1.

- **La figure 3** is a cross section view showing in detail the area in which the pipe for collecting gas in the vapor phase passes through the outer drum, the inner drum and the intermediate insulating gap.

- **La figure 4** is a perspective cross section view showing the gas dome
 15 structure of figure 1 as it passes through the openings provided in the inner hull and in the outer hull.

- **La figure 5** is a perspective cross section view showing in detail the filter equipping the pipe for collecting gas in the vapor phase and the support device supporting said the pipe for collecting gas in the vapor phase on the inner drum of the
 20 gas dome structure.

- **La figure 6** is a schematic cutaway view of a tank of an LNG carrier ship and a terminal for loading/unloading this tank.

- **La figure 7** is a partial cutaway perspective view of a wall of a sealed and thermally insulating tank.

- **La figure 8** is a partial cross section view of a gas dome structure according to a second embodiment.

- **La figure 9** is a partial cross section view of a gas dome structure according to a third embodiment.

Detailed description of embodiments

Referring to figure 1, this figure shows a gas dome structure 1 for a sealed and thermally insulating tank for storing a liquefied gas, such as Liquefied Natural Gas (LNG) or Liquefied Petroleum Gas (LPG). The gas dome structure 1 defines a path for vapor to flow between the inner space 2 of the tank and one or more vapor headers 3, 48 situated outside the tank.

The tank is arranged inside the double hull of a ship comprising an outer hull 4 and an inner hull 5. The inner hull 5 forms the load-bearing structure of the tank. The tank has a generally polyhedron shape.

Referring to figure 7, the multilayer structure of a wall of a sealed and thermally insulating tank according to one embodiment is described. Each wall of the tank comprises, in the thickness direction of the tank, from outside to inside, a secondary thermally insulating barrier 6 resting against the inner hull 5, a secondary sealed membrane 7, a primary thermally insulating barrier 8 and a primary sealed membrane 9 intended to be in contact with the fluid stored in the tank.

The primary thermally insulating barrier 8 and the secondary thermally insulating barrier 6 are each made up of heat-insulating elements and, more particularly, of parallelepiped heat-insulating boxes 10 that are arranged next to one another in a regular pattern. Each heat-insulating box 10 comprises a base panel 11 and a cover panel 12. Side panels 13 and internal webs 14 extend between the base panel 11 and the cover panel 12 in the thickness direction of the tank wall. The base 11 and cover 12 panels and the internal webs 14 delimit spaces in which a heat-insulating lining, for example expanded perlite, is installed. Each heat-insulating box 10 is held against the inner hull 5 by means of anchoring members. The heat-insulating boxes 10 of the primary thermally insulating barrier 8 and of the secondary thermally insulating barrier 6 respectively carry the primary membrane 9 and the secondary membrane 7.

The secondary 7 and primary 9 membranes are each made up of a sequence of parallel strakes 15 made of Invar®, with folded edges, which are arranged in alternation with elongate weld supports 16, also made of Invar®. The strakes 15 comprise, in the width direction, a planar central strip resting against the cover panels 12 of the heat-insulating boxes 10, and folded lateral edges. The folded edges extend

substantially perpendicular to the planar central strip. The folded edges of the strakes 15 are sealingly welded to weld supports 16. Each weld support 16 is held to the underlying thermally insulating barrier 6, 8, for example by being housed in inverted T-shaped grooves provided in the cover panels 12 of the heat-insulating boxes 10.

5 At a corner between two walls, the secondary 7 and primary 9 membranes of the two walls are linked by a connecting ring 17 in the form of a tube with a square cross section. The connecting ring 17 forms a structure that helps take up tensile forces resulting from the thermal contraction of the secondary 7 and primary 9 membranes, the deformation of the hull and movements of the cargo.

10 Referring to figures 2 and 4, a gas dome structure 1 that passes through two openings 18, 19 provided respectively in the outer hull 4 and in the inner hull 5 will now be described. The gas dome structure 1 comprises a cylindrical outer drum 20 that passes through the opening 18 in the outer hull 4 and the opening 19 in the inner hull 5. The outer drum 20 is open at both ends of same. The outer drum 20 is equipped
15 with two collars 21, 22 that are respectively capable of attaching the gas dome structure 1 to the outer hull 4 and the inner hull 5. The collars 21, 22 are welded to the outer drum 20 and protrude radially outwards with respect to the axis of the outer drum 20. As shown in figure 4, the collar 22 which is intended to be attached to the inner hull 5 has an external diameter smaller than that of the opening 18 provided in
20 the outer hull 4 in order to allow it to pass through the opening 18 in the outer hull 4 when the gas dome structure 1 is being installed. However, the external diameter of the collar 22 is larger than that of the opening 19 provided in the inner hull 5. Therefore, the collar 22 can be sealingly welded to the inner hull 5 around the opening 19. The other collar 21 is intended to be sealingly welded to the outer hull 4, around
25 the opening 18 provided in the outer hull 4, and for this reason has an external diameter that is larger than that of the opening 18.

 The gas dome structure 1 further comprises an inner drum 23 attached to the outer drum 20. The inner drum 23 is formed from a cylindrical peripheral wall open at both ends of same. The inner drum 23 is concentric with the outer drum 20 and
30 extends inside same. An intermediate insulating gap 24 is therefore provided between the outer drum 20 and the inner drum 23. The inner drum 23 extends up to the top end of the outer drum 20 and the top ends of the outer 23 and inner 20 drums are

connected together sealingly by a substantially horizontal assembly flange 25. The assembly flange 25 comprises an inner portion that links the ends of the outer 20 and inner 23 drums and an outer portion that protrudes radially outwards from the outer drum 20.

- 5 As shown in particular in figures 2 and 4, the outer drum 20 and the inner drum 23 are each equipped with at least one bellows area 31, 32 that allows them to expand or contract depending on whether or not liquefied gas vapor is contained in the gas dome structure 1.

 In one embodiment, for practical purposes of positioning the collars 21 and
10 22 with respect to the hulls 4 and 5 and/or of compensating for tolerances in the relative positioning of the hulls 4, 5, one and/or the other of the collars 21 and 22, and in particular the collar 21, can be welded to half-moon shaped shims previously welded to the respective hull 4, 5 around the opening 18, 19. The thickness of the shims is dimensioned in such a way as to ensure contact between the collar 21, 22
15 and the respective shims, and between the shims and the hull 4, 5.

 Alternatively, the bellows areas 31, 32 each have an additional length allowing the structure of the dome and, in particular, the inner 23 and outer 20 drums, to be compressed when it is being installed, this compression effect being reduced, or indeed eliminated, during the thermal contraction generated by the cooling of the
20 tank 2. For this purpose, a compression tool can be used in order to press the collar 21 against the hull 4 and compress the bellows areas 31, 32 when welding the collar 21 to the hull 4.

 The gas dome structure 1 is further equipped with a removable cover 26 in order to allow access into the tank via the gas dome structure 1, in particular for tank
25 maintenance and inspection operations. The cover 26 has, on the top face of same, a hooking member 27 allowing it to be manipulated by means of a handling tool. The cover 26 rests against the assembly flange 25 and is attached thereto by means of a plurality of attachment members 28, in particular shown in figures 1 and 4, which each pass through a hole provided at the periphery of the cover and a hole provided in the
30 outer portion of the assembly flange 25. The attachment members 28 consist, for example, of a bolt comprising a threaded rod and a nut cooperating with said threaded rod.

A seal, which is not shown here, is compressed between the cover 26 and the assembly flange 25 and thus helps provide a seal between the outside and the inside of the inner drum 23. The seal is, for example, positioned on a diameter smaller than the diameter at which the attachment members are installed, i.e. between the
5 inner portion of the assembly flange 25 and the cover 26. According to variants not shown here, the seal(s) is/are placed in a recess provided in the cover 26 or in the assembly flange 25. The seal can be flat or toric.

The seal is made from polymer, such as polytetrafluoroethylene (PTFE), butadiene acrylonitrile (NBR) reinforced with glass and/or aramid and/or carbon
10 fibers, for example by the brand Klingersil®. As a result of the arrangement described above and, in particular, the fact that the intermediate insulating gap 24 extends up to the assembly flange 25, the seal is thermally insulated in a satisfactory manner, which helps limit the risks of damage to said seal and the risks of leakage.

Moreover, as shown in figures 2 and 4, the cover 26 comprises, on the inner
15 face of same turned towards the inside of the inner drum 23, a protrusion 33 made of insulating material engaging in the inner drum 23. The protrusion 33 made of insulating material has a diameter slightly smaller than that of the inner drum 23. Such an arrangement also helps thermally insulate the seal. The protrusion 33 made of insulating material is made, in particular, of rigid or flexible insulating foam, for
20 example polyurethane foam or melamine.

At the bottom, the inner drum 23 and the outer drum 20 are also sealingly connected to each other such that the intermediate insulating gap 24 provided between the inner drum 23 and the outer drum 23 is sealed. For this purpose, an annular flange 29 is sealingly welded between the bottom edges of the outer drum 20
25 and of the inner drum 23.

The outer drum 20 and the inner drum 23 pass through the ceiling wall of the tank, i.e. the secondary 6 and primary 8 thermally insulating barriers, and the secondary 7 and primary 9 membranes, and open inside the tank. As shown schematically in figure 2, the inner drum 23 and the outer drum 20 extend up to the
30 primary membrane 9 of the ceiling wall of the tank. The primary membrane 9 is sealingly connected to said annular flange 29 so as to provide continuity in the sealing

of the primary membrane 9. Moreover, the secondary membrane 7 is sealingly welded to the outer drum 20 so as to provide continuity in the sealing of the secondary membrane 7, between the primary 8 and secondary 6 thermally insulating barriers. For this purpose, according to one embodiment, the outer drum 20 is equipped with
 5 a third annular collar 30, shown schematically in figure 2, which protrudes radially outwards from the outer drum 20 and which thus forms a support suitable for allowing the secondary membrane 7 to be welded to the outer drum 20. In an embodiment not shown here, the inner drum 23 and the outer drum 20 extend along the primary membrane 9 of the ceiling wall of the tank and the primary membrane 9 is sealingly
 10 welded to an additional annular collar, not shown here, protruding radially towards the outside of the outer drum 23.

In the embodiment shown, the intermediate insulating gap 24 is filled with an insulating lining 34 that is distributed in a uniform manner on the inner surface of the outer drum 20, between said outer drum 20 and the inner drum 23. The insulating
 15 lining 34 comprises one or more insulating materials chosen from glass wool, rock wall, cotton wool, fibrous materials, perlite, expanded perlite, polymer foams and aerogels. In the embodiment shown, the insulating lining 34 has, in an area corresponding to the bellows areas 32 of the inner drum 23, a recess 46 allowing said bellows areas 32 to be accommodated.

20 In another embodiment, the intermediate insulating gap 24 is placed under vacuum. In such an embodiment, the gas dome structure 1 is equipped with a sealable connector which passes through the inner drum 23 or the outer drum 20, and opens inside the intermediate insulating gap 24, and which is suitable for being connected to a vacuum pump allowing the gas present in the intermediate insulating
 25 gap 24 to be extracted, in order to place it under vacuum. In another embodiment, the two embodiments described above are combined such that the intermediate insulating gap 24 is both filled with an insulating lining 34 and placed under vacuum.

The gas dome structure 1 further comprises at least one vapor collection pipe 35 that passes radially and in a sealed manner through the outer drum 20, the inner
 30 drum 23 and the intermediate insulating gap 24 in order to convey vapor between the inside of the inner drum 23 and the vapor headers 3, 48 situated outside the tank. The vapor collection pipe 35 therefore does not pass through the cover 26, which helps

simplify the operations of removing and fitting the cover 26 when an operator needs to access the inside of the tank.

More particularly, the vapor collection pipe 35 passes in a sealed manner through an insulating sleeve 37, shown in detail in figure 3, that itself passes radially through the outer drum 20, the inner drum 23 and the intermediate insulating gap 24. The insulating sleeve 37 comprises two concentric cylindrical walls linked together sealingly and separated from each other by an annular gap placed under vacuum. For this purpose, the insulating sleeve 37 comprises a sealable connector 38 that opens on the inside of the annular gap and is intended to be connected to a vacuum pump in order place the annular gap under vacuum.

Although in the preferred embodiment shown here, a single vapor collection pipe 35 passes radially and in a sealed manner through the outer 20 and inner 23 drums, the gas dome structure can also comprise several vapor collection pipes 35 passing radially and in a sealed manner through the outer 20 and inner 23 drums.

Figures 2 and 4 show that the vapor collection pipe 35 has a bent portion such that said vapor collection pipe 35 has a lower portion 36 that is oriented parallel to the axes of the inner 23 and outer 20 drums, towards the inner space of the tank. The bent portion and the lower portion 36 are removably attached to the rest of the vapor collection pipe 35, for example by means of bolted assembly flanges. The bent portion and the lower portion 36 can therefore be disassembled in order to allow a person or equipment to pass through this gas dome structure 1.

The gas dome structure 1 is further equipped with a support device 39, in particular shown in figures 2, 4 and 5, which supports the lower portion 36 of the vapor collection pipe 35 and which is arranged to distribute the forces applied to said lower portion 36 around the inner periphery of the inner drum 23. For this purpose, the support device 39 comprises a first annular plate 40 attached to the inner drum 23 and protruding radially towards the inside of the inner drum 23, a second annular plate 41 attached to the lower portion 36 of the vapor collection pipe 35 protruding radially towards the outside of the vapor collection pipe 35 and a plurality of arms 42 distributed at regular intervals around the lower portion 36 of the vapor collection pipe 35, which are each attached between the first annular plate 40 and the second annular plate 41, for example being bolted. Moreover, as shown in figures 2 and 5, the first

annular plate 40 is advantageously supported by support brackets 43 made of sheet metal that are welded against the inner drum 23 and against the lower face of the first annular plate 40.

In an embodiment shown in figure 2, the gas dome structure 1 comprises
5 anchoring tabs 49 that are arranged in the intermediate insulating gap 24 and welded between the inner drum 23 and the outer drum 20, in the support bracket 43 attachment areas. The aim of such anchoring tabs 49 is to take up some of the forces supporting the vapor collection pipe 35 on the outer drum 20, in particular when the thickness of the inner drum 20 means it does not have sufficient mechanical strength.

10 Furthermore, the lower portion 36 of the vapor collection pipe 35 is equipped with a filter 44 producing a head loss and thus helping prevent gas in the liquid phase from rising back up into the vapor header 3 and exiting the tank.

The gas dome structure 1 further comprises at least one pipe 45 for supplying liquefied gas, in particular shown in figures 2 and 4, which passes through the outer
15 drum 20, the intermediate insulating gap 24 and the inner drum 23, above the outer hull 4, and descends along the inner drum 23 in such a way as to open into the inner space of the tank. In the inner space of the tank, the pipe 45 has a plurality of injection nozzles through which liquid gas can be sprayed in order to cool the vapor phase of the gas stored in the tank and thus limit the increase in vapor pressure in the inner
20 space of the tank.

As shown in figure 1, the vapor collection pipe 35 is connected, outside the gas dome structure 1, to a three-way connection 47 leading to two separate vapor headers 3, 48. One of the vapor headers 48 is equipped with a safety valve, which is not shown here. The safety valve is calibrated in such a way as to ensure gas in the
25 vapor phase is discharged from the tank when the vapor pressure in the tank is higher than a threshold pressure of between 0 and 2 bar, for example between 0.2 and 0.4 bar. Given the head losses caused, in particular, by the bent area and the filter 44, the safety valve is calibrated to a pressure slightly lower than the threshold pressure that the vapor pressure in the tank must not exceed. This vapor header 48 can be
30 used to extract vapor from the tank in the case of overpressure and is intended to control the pressure inside the tank in such a way as to avoid overpressures that are likely to damage the tank.

For example, this vapor header 48 conveys the vapor to a vent mast, to a burner, to a propulsion device of the ship or to a liquefaction device in which the gas in vapor phase is reliquefied and then reintroduced into the tank in the liquid phase. The aim of the other vapor header 3 is to allow vapor to flow during operations to load and unload the tank. Specifically, during loading operations, when liquefied gas is transferred from a supply terminal to a tank, gas in the gaseous phase is transferred simultaneously from the tank to the terminal, via the gas dome structure 1 and the vapor header 3, in order to keep the pressure in the gas blanket of the tank substantially constant. Inversely, during unloading operations during which liquefied gas is transferred from the tank to a terminal, gas in the gaseous phase is simultaneously transferred from the terminal to the tank in order to prevent a reduction in pressure in the tank.

The outer drum 20, the inner drum 23, the collars 21, 22, the support device 39 and the vapor collection pipe 35 are made from a metal material, such as stainless steel, or an iron alloy containing nickel or manganese, for example.

Referring to figure 8, this figure shows a gas dome structure 1 according to a second embodiment. This gas dome structure 1 differs from the gas dome structure described previously in that it further comprises an additional insulating barrier 50 between the two collars 21, 22. For this purpose, the gas dome structure 1 comprises an additional drum 51 that extends radially outside the outer drum 20, all the way around same. The additional drum 51 comprises a bottom end that is welded to the collar 22 and a top end that is welded to the collar 21. The additional drum 51 has a diameter smaller than those of the collars 21, 22. More particularly, the diameter of the additional drum 51 is dimensioned such that each of the collars 21, 22 has, at the outer periphery of same, an annular surface intended to be welded to one of the hulls, which has a dimension that is sufficient in order to obtain satisfactory welding.

In the embodiment shown, the additional drum 51 is equipped with a bellows area 52 allowing the additional drum 51 to expand or contract. Moreover, the gap provided between the outer drum 20 and the additional drum 51 is filled with an insulating lining 53 that comprises one or more insulating materials chosen from glass wool, rock wool, cotton wool, fibrous materials, perlite, expanded perlite, polymer foams and aerogels. The additional drum 51 and the insulating lining 53 are pre-

assembled on the gas dome structure 1 in the workshop before it is assembled on the double hull of the ship. Such an arrangement helps increase the thermal insulation capacities of the gas dome structure 1, in particular in the space situated between the two hulls 4, 5. Moreover, the additional drum 51 is sealingly welded to the collars 21, 22 in such a way that said additional drum 51 forms an additional sealed barrier suitable for preventing natural gas from entering the area situated between the two hulls 4, 5.

Referring to figure 9, this figure shows a gas dome structure 1 according to a third embodiment. This embodiment differs from the embodiment in figure 8 described above in that the intermediate insulating gap 24 arranged between the inner drum 23 and the outer drum 20 is divided into two compartments, a primary compartment 24a and a secondary compartment 24b, which are sealed with respect to each other. Such an arrangement provides the gas dome structure with an additional level of sealing. For this purpose, the gas dome structure 1 comprises an annular partition 54, for example made of metal, having an inner periphery that is sealingly welded to the inner drum 23 and an outer periphery that is sealingly welded to a portion of the outer drum 20 situated between the level of the hull 5 and the secondary sealing membrane 7. In the embodiment shown, the annular partition 54 extends at the secondary sealing membrane 7. The secondary compartment 24b is filled with an insulating lining that comprises one or more insulating materials chosen from glass wool, rock wall, cotton wool, fibrous materials, perlite, expanded perlite, polymer foams and aerogels and/or is suitable for being connected to a vacuum pump in order to be placed under vacuum. The primary compartment 24a is also filled with an insulating lining comprising one or more of the abovementioned insulating materials.

Moreover, in the embodiment shown, the outer drum 20 comprises one or more ports 55 allowing the primary compartment 24a to be brought into communication with the primary thermally insulating barrier 8. Therefore, the primary compartment 24a is capable of being flushed with an inert gas at the same time as the primary thermally insulating barrier 8 and of being linked to a detection device that analyses the gas present in the primary thermally insulating barrier in such a way as to detect the presence of possible leaks in the primary and/or secondary membranes.

The technique described above for producing a gas dome structure can be used in different types of membrane tanks, in a land-based facility or in a floating structure such as an LNG carrier ship, or in other applications.

In reference to figure 6, a cutaway view of an LNG carrier ship 70 shows a
 5 sealed and insulated tank 71 that is generally prismatic in shape mounted in the double hull 72 of the ship. The wall of the tank 71 comprises a primary membrane intended to be in contact with the LNG contained in the tank, a secondary membrane arranged between the primary membrane and the double hull 72 of the ship, and two thermally insulating barriers arranged respectively between the primary membrane
 10 and the secondary membrane and between the secondary membrane and the double hull 72.

In a manner known *per se*, loading/unloading pipes 73 arranged on the top deck of the ship can be connected, by means of suitable connectors, to a marine or port terminal in order to transfer a cargo of LNG to or from the tank 71.

15 Figure 6 shows an example of a marine terminal comprising a loading and unloading station 75, a submarine pipe 76 and a land-based facility 77. The loading and unloading station 75 is a fixed offshore facility comprising a movable arm 74 and a tower 78 that supports the movable arm 74. The movable arm 74 carries a bundle of insulated flexible pipes 79 that can be connected to the loading/unloading pipes 73.
 20 The orientable movable arm 74 adapts to all sizes of LNG carrier ship. A connecting pipe not shown here extends into the tower 78. The loading and unloading station 75 allows the LNG carrier ship 70 to be loaded and unloaded from or to the land-based facility 77. This comprises liquefied gas storage tanks 80 and connecting pipes 81 linked by the submarine pipe 76 to the loading and unloading station 75. The
 25 submarine pipe 76 allows liquefied gas to be transferred between the loading and unloading station 75 and the land-based facility 77 over a long distance, for example 5 km, which allows the LNG carrier ship 70 to be kept a long distance from the coast during the loading and unloading operations.

In order to generate the pressure required to transfer the liquefied gas,
 30 pumps installed in the ship 70 and/or pumps equipping the land-based facility 77 and/or pumps equipping the loading and unloading station 75 are implemented.

Although the invention has been described in relation to several specific embodiments, it is obvious that this does not in any way limit it, and that it comprises all the technical equivalents of the described means and the combinations of same, provided they are covered by the context of the invention.

- 5 The use of the verbs “comprise” or “include” and their conjugated forms does not exclude the presence of elements or steps other than those disclosed in a claim.

 The use of reference signs between parentheses in the claims should not be interpreted as a limitation to the claim.

CLAIMS

1. A gas dome structure (1) for a sealed and thermally insulating tank arranged inside a double hull defined by an inner hull (5) and an outer hull (4); said gas dome structure (1) being intended to pass through the double hull and a ceiling
5 wall of the tank comprising at least one thermally insulating barrier (6) resting against the inner hull (5) and a sealing membrane (9) intended to be in contact with the fluid contained in the tank in such a way as to provide a path for vapor to flow between an inner space of the tank and at least one vapor header (3, 48) arranged outside the tank; the gas dome structure (1) comprising:
 - 10 - an outer drum (20) capable of passing through two openings (18, 19) provided respectively in the outer hull (4) and in the inner hull (5);
 - an inner drum (23) that extends inside the outer drum (20), is secured to said outer drum (20), is open so as to communicate with the inner space of the tank and comprises a peripheral wall intended to be sealingly connected to the sealing
15 membrane (9);
 - an intermediate insulating gap (24) arranged between the inner drum (23) and the outer drum (20);
 - the outer drum (20) comprising first and second collars (21, 22) that protrude radially outwards from the outer drum (20) and that are respectively suitable for being welded
20 to the outer hull (4), around the opening (18) provided in the outer hull (4), and to the inner hull (5), around the opening (19) provided in the inner hull (5).
2. The gas dome structure (1) as claimed in claim 1, in which the second collar (22) intended to be sealingly welded to the inner hull (5) has a diameter smaller than that of the first collar (21).
- 25 3. The gas dome structure (1) as claimed in claim 1 or 2, in which the outer drum (20) and the inner drum (23) each have a top end; said top ends stopping in a same horizontal plane and being linked together sealingly by an assembly flange (25); the gas dome structure (1) further comprising a cover (26) that is attached to said assembly flange (25) by attachment members (28) and an annular seal that is
30 compressed between the cover (26) and the assembly flange (25).

4. The gas dome structure (1) as claimed in claim 3, in which the assembly flange (25) comprises an outer portion protruding radially out of the outer drum (20); said attachment members (28) passing through holes provided in said outer portion of the assembly flange (25).

5 5. The gas dome structure (1) as claimed in claim 3 or 4, in which the cover (26) comprises an inner face turned towards the inside of the inner drum (23); said inner face being provided with a protrusion (33) made of insulating material engaging in the inner drum (23).

6. The gas dome structure (1) as claimed in any one of claims 1 to 5,
10 further comprising a vapor collection pipe (35) suitable for conveying vapor between the inside of the inner drum (23) and the vapor header (3, 47); said vapor collection pipe (35) passing radially and in a sealed manner through the outer drum (20), the intermediate insulating gap (24) and the inner drum (23), and opening on the inside of the inner drum (23).

15 7. The gas dome structure (1) as claimed in claim 6, comprising an insulating sleeve (37) passing radially and in a sealed manner through the outer drum (20), the intermediate insulating gap (24) and the inner drum (23) and in which the vapor collection pipe (35) passes through said insulating sleeve in a sealed manner (37).

20 8. The gas dome structure (1) as claimed in claim 7, in which the insulating sleeve (37) comprises two concentric cylindrical walls connected together sealingly and separated from each other by an annular gap; said insulating sleeve (37) comprising a sealable connector (38) that opens on the inside of the annular gap and that is suitable for being connected to a vacuum pump in order place the annular
25 gap under vacuum.

9. The gas dome structure (1) as claimed in any one of claims 6 to 8, in which the vapor collection pipe (35) has a bent portion arranged inside the inner drum (23) and comprises a lower portion (36) oriented parallel to the inner drum (23) towards the inner space of the tank.

30 10. The gas dome structure (1) as claimed in claim 9, further comprising a support device (39) supporting the lower portion (36) of the vapor collection pipe

(35) and arranged to distribute the forces applied to said lower portion (36) around the inner periphery of the inner drum (23).

11. The gas dome structure (1) as claimed in claim 10, in which the support device (39) comprises a first annular plate (40) attached to the inner drum (23) and protruding radially towards the inside of the inner drum (23), a second annular plate (41) attached to the lower portion of the vapor collection pipe (35) and protruding radially towards the outside of said lower portion (36) of the vapor collection pipe (35) and a plurality of support arms (42) distributed at regular intervals around the lower portion (36) of the vapor collection pipe (35) and each comprising a first end attached to the first annular plate (40) and a second end attached to the second annular plate (41).

12. The gas dome structure (1) as claimed in any one of claims 9 to 11, in which the lower portion (36) of the vapor collection pipe (35) is equipped with a filter (44).

13. The gas dome structure as claimed in any one of claims 4 to 9, in which the vapor collection pipe (38) is connected to a three-way connection (47) arranged outside the outer drum (23).

14. The gas dome structure (1) as claimed in any one of claims 1 to 13, in which the inner drum (23) and the outer drum (20) each comprise bellows areas (31, 32).

15. The gas dome structure (1) as claimed in any one of claims 1 to 14, in which the intermediate insulating gap (24) is filled with a gaseous phase placed under vacuum and/or an insulating lining (34).

16. The gas dome structure (1) as claimed in any one of claims 1 to 15, in which the intermediate insulating gap (24) has a bottom end that is sealingly closed by an annular flange (29).

17. The gas dome structure (1) as claimed in any one of claims 1 to 16, further comprising an additional drum (51) that extends radially outside the outer drum (20) and that has a top end welded to the first collar (21) and a bottom end welded to the second collar (22) and an insulating lining (53) arranged between the additional drum (51) and the outer drum (20).

18. The gas dome structure (1) as claimed in any one of claims 1 to 17, in which the intermediate insulating gap (24) arranged between the inner drum (23) and the outer drum (20) is divided into a primary compartment (24a) and a secondary compartment (24b), which are sealed with respect to each other.

5 19. The gas dome structure as claimed in claim 18, in which the primary compartment is equipped with one or more ports provided in the outer drum and intended to bring the primary compartment into communication with a primary thermally insulating barrier.

20. A fluid storage device comprising a double hull defined by an inner
10 hull (4) and an outer hull (5) and a sealed and thermally insulating tank arranged in the double hull; the tank comprising:

- a thermally insulating barrier (6) resting against the inner hull (5);
- a sealing membrane (9) intended to be in contact with the fluid contained in the tank; and
- 15 - the gas dome structure (1) as claimed in any one of claims 1 to 19 that passes through the outer hull (4), the inner hull (5), the thermally insulating barrier (6) and the sealing membrane (9) in such a way as to provide a path for vapor to flow between an inner space of the tank and at least one vapor header (3) arranged outside the tank; the first collar (21) of the gas dome structure (1) being welded to the outer hull
20 (4) around an opening (18) provided in the outer hull (4), the second collar (22) of the gas dome structure (1) being welded to the inner hull (5) around an opening (19) provided in the inner hull (5), and the inner drum (23) being sealingly connected to the sealing membrane (9).

21. The fluid storage device as claimed in claim 20, in which the opening
25 (18) provided in the inner hull (4) has a diameter smaller than that of the opening (19) provided in the outer hull (5) and in which the second collar (22) has a diameter smaller than that of the opening (19) provided in the outer hull (5) and larger than that of the opening (18) provided in the inner hull (4).

22. The fluid storage device as claimed in claim 20 or 21, in which the
30 thermally insulating barrier is a secondary thermally insulating barrier (6) and the sealing membrane is a primary sealing membrane (9), the tank further comprising a

secondary sealing membrane (7) resting against the secondary thermally insulating barrier (6) and a primary thermally insulating barrier (9) arranged between the secondary sealing membrane (7) and the primary sealing membrane (9); the outer drum comprising a third collar (30) protruding radially towards the outside of the outer
5 drum (20) and sealingly connected to the secondary sealing membrane (7).

23. The fluid storage device as claimed in any one of claims 20 to 22 configured in the form of a ship.

24. A method for loading or unloading the fluid storage device as claimed in any one of claims 20 to 23, which involves conveying a fluid through
10 insulated pipes (73, 79, 76, 81) from or to a floating or land-based storage facility (77) to or from the tank of the storage device.

25. A transfer system for a fluid, the system comprising the fluid storage device as claimed in any one of claims 20 to 23, insulated pipelines (73, 79, 76, 81) arranged so as to link the tank (71) to a floating or land-based storage facility (77) and
15 a pump for drawing a fluid through the insulated pipes from or to the floating or land-based storage facility to or from the tank.