

## **GAS DOME STRUCTURE FOR A SEALED, THERMALLY INSULATING TANK**

### **Technical field**

The invention relates to the field of sealed, thermally insulating tanks, for storage and/or transport of fluid, such as a cryogenic fluid. Sealed, thermally  
5 insulating tanks are notably used for storage of liquefied natural gas (LNG), which is stored at about  $-162^{\circ}\text{C}$ , at atmospheric pressure.

The invention relates more particularly to a gas dome structure that is intended to define a channel for circulation of vapour between the interior space of the tank and at least one vapour collector arranged outside the tank.

### **10 Technological background**

Document KR20140088975 discloses a sealed, thermally insulating tank that is housed inside a double hull of a ship and comprises a gas dome structure intended to define a channel for circulation of vapour between the interior space of the tank and two vapour collectors arranged outside the tank.

15 The gas dome structure comprises a hermetic, thermally insulated pipe that passes through the outer hull of the double hull. The sealed pipe comprises, at its upper end, a connecting flange consisting of an edge turned outwards that receives a detachable cover with an interposed seal. However, the seal interposed between the detachable cover and the connecting flange is directly in contact with the vapour  
20 phase present in the inner drum. Now, when the fluid stored in the tank is a cryogenic fluid, such as liquefied gas, the vapour may have low temperatures, down to about  $-160^{\circ}\text{C}$ . Thus, the seal may be subjected to relatively low temperatures and therefore to a wide temperature variation, which over time is likely to damage it and cause leakage from the gas dome structure. The reliability of said gas dome  
25 therefore leaves room for improvement.

### **Summary**

The invention is based on the idea of proposing a gas dome structure comprising a sealed pipe and a detachable cover closing the upper end of the sealed pipe and in which the hermeticity, at the junction between the sealed pipe  
30 and the detachable cover, is provided more reliably and more permanently.

According to one embodiment, the invention supplies a fluid storage device comprising a hull and a sealed thermally insulating tank arranged in the hull; the tank comprising an interior space intended to store fluid and comprising a tank roof having:

- 5 - a thermally insulating barrier resting against the hull ; and
  - a sealing membrane intended to be in contact with the fluid contained in the tank; the fluid storage device having a gas dome structure comprising:
    - a sealed pipe having an upper longitudinal end equipped with a connecting flange and a lower longitudinal end passing through the thermally insulating barrier and the
    - 10 sealing membrane of the tank roof so as to define a channel for circulation between the interior space of the tank and at least one vapour collector arranged outside the tank;
      - a cover that is fixed to said connecting flange by fasteners to close the upper longitudinal end of the sealed pipe;
- 15 - a gasket that is compressed between the cover and the connecting flange;
  - a vapour collecting pipe that passes hermetically through a wall of the sealed pipe so as to enter the sealed pipe in a collecting zone, said vapour collecting pipe thus being able to convey vapour between the collecting zone and the vapour collector arranged outside the tank;
- 20 - the sealed pipe comprising a carrier plate that extends transversely towards the interior of the sealed pipe, and is located longitudinally between the collecting zone and the upper longitudinal end of the sealed pipe; the carrier plate delimiting, on the one hand, a lower portion of the interior of the sealed pipe that is located below the carrier plate and, on the other hand, an upper portion of the interior of the sealed
- 25 pipe that is located above the carrier plate;
  - an insulating plug that blocks the upper portion of the interior of the sealed pipe, said insulating plug comprising an upper surface and a lower surface, which are opposite the cover and the carrier plate, respectively; the carrier plate supporting the insulating plug and interacting with the lower surface of the insulating plug on the
  - 30 entire periphery of said lower surface so as to form a barrier limiting a thermal convection effect between the lower portion and the upper portion of the interior of the sealed pipe.

Thus, owing to the presence of the insulating plug, the minimum temperatures to which the seal might be subjected are not so low, which makes it possible to reduce the thermal variations and thus limit the deterioration of the properties of the seal over time. The service life of the seal will therefore be  
5 prolonged and the risks of leakage between the cover and the upper end of the sealed pipe are therefore reduced.

According to some embodiments, a fluid storage device of this kind may comprise one or more of the following features.

According to one embodiment, the vapour collecting pipe passes through  
10 the wall of the sealed pipe perpendicularly to the longitudinal direction of the sealed pipe.

According to one embodiment, the insulating plug comprises an insulating body and a base that is interposed between the insulating body and the carrier plate.

15 According to one embodiment, the base is equipped with a gripping means projecting in the direction of the upper longitudinal end of the sealed pipe through a hole made in the insulating body.

According to one embodiment, the insulating plug has a circular shape.

According to one embodiment, the base comprises a rigid disk. The rigid  
20 disk is for example made of stainless steel.

According to one embodiment, the gripping means is for example a handle passing through the insulating body.

According to one embodiment, the insulating plug comprises an insulating body comprising an upper plate, a lower plate and a layer of insulating polymer foam  
25 sandwiched between the lower plate and the upper plate.

According to one embodiment, the two upper and lower plates are made of plywood.

According to one embodiment, the layer of insulating polymer foam comprises polyurethane.

30 According to one embodiment, the carrier plate and the insulating plug are fixed together.

According to one embodiment, the carrier plate is equipped with a plurality of pins each having a threaded end projecting in the direction of the upper longitudinal end of the sealed pipe and passing through a respective opening orifice made in the insulating plug, the threaded end of each of said pins interacting with a  
5 nut so as to fasten said insulating plug to the carrier plate.

According to one embodiment, the sealed pipe comprises a shoulder made between a lower part and an upper part of the sealed pipe, said upper part having a diameter greater than the diameter of the lower part and said shoulder forming the carrier plate.

10 According to one embodiment, the carrier plate delimits an upper part and a lower part of the sealed pipe and projects transversely towards the interior of the sealed pipe relative to said upper and lower parts of the sealed pipe.

According to one embodiment, the upper part of the sealed pipe has a diameter less than or equal to the diameter of the lower part of the sealed pipe.

15 According to one embodiment, the sealed pipe comprises an outer drum, an inner drum that passes through the outer drum and an insulating intermediate space provided between the outer drum and the inner drum.

According to one embodiment, the inner drum has an upper longitudinal end that is connected hermetically to the outer drum and that is located in a zone  
20 arranged longitudinally between the carrier plate and the lower longitudinal end of the sealed pipe.

According to one embodiment, the vapour collecting pipe passes hermetically through a wall of the outer drum in a zone located longitudinally between the carrier plate and the upper end of the inner drum.

25 According to one embodiment, the vapour collecting zone is delimited by the carrier plate and the upper end of the inner drum.

According to one embodiment, the gas dome structure comprises a first vapour collecting pipe that comprises a safety valve and leads to a first vapour collector that is connected to a degassing mast, to a burner, to a propulsion device  
30 of the ship and/or to a liquefaction device and a second vapour collecting pipe that leads to the second vapour collector connected to a manifold intended to be connected to a gas storage terminal during loading or offloading of the tank.

According to one embodiment, the connecting flange projects transversely towards the outside of the sealed pipe from the upper longitudinal end of said sealed pipe.

According to one embodiment, the insulating plug has a thickness greater  
5 than 70 mm.

According to one embodiment, each fastener comprises a threaded screw interacting with a nut and passing through a hole made in the cover and a hole made in the connecting flange.

A fluid storage device of this kind may form part of an onshore storage  
10 facility, for example for storing LNG or may be installed in a floating structure, coastal or deep-water, notably an ethane tanker or methane tanker, a floating storage and regasification unit (FSRU), a floating production, storage and offloading (FPSO) unit and others. In the case of a floating structure, the tank may be intended to receive liquefied natural gas to serve as fuel for propulsion of the floating  
15 structure.

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

According to one embodiment, the invention relates to a method for assembling an aforementioned fluid storage device, comprising:

- 20 - forming an assembly comprising the sealed pipe and the vapour collecting pipe in such a way that:
  - the sealed pipe has the upper longitudinal end equipped with the connecting flange, the lower longitudinal end passing through the thermally insulating barrier and the sealing membrane of the tank roof and the carrier  
25 plate that extends transversely towards the interior of the sealed pipe, and is located longitudinally between the collecting zone and the upper longitudinal end of the sealed pipe; and so that
  - the vapour collecting pipe passes hermetically through the wall of the sealed pipe and opens into the interior of the sealed pipe in the collecting  
30 zone;
  - arranging the insulating plug inside the upper portion of the interior of the sealed pipe bearing against the carrier plate;

- fixing the cover to the connecting flange, compressing the gasket between the cover and the connecting flange.

According to some embodiments, a method of assembly of this kind may comprise one or more of the following features.

5           According to a first embodiment, forming the assembly comprising the sealed pipe and the vapour collecting pipe comprises:

- supplying a lower part of the sealed pipe and the carrier plate, the carrier plate being fixed to said lower part and projecting transversely towards the outside of the lower part;

10       - supplying an upper part of the sealed pipe equipped with the connecting flange; the upper part having a diameter greater than that of the lower portion;

- hermetically fixing the upper part on the carrier plate.

          According to one embodiment, the lower part of the sealed pipe and the carrier plate correspond respectively to a sealed pipe and to a connecting flange of  
15       a gas dome structure according to the prior art. Thus, a method of assembly of this kind makes it possible to obtain a gas dome structure according to the invention, simply by adding the upper part onto the original gas dome structure.

          According to another embodiment, forming the assembly comprising the sealed pipe and the vapour collecting pipe comprises:

20       - supplying an upper part of the sealed pipe; said upper part of the sealed pipe being equipped with the connecting flange;

- supplying a lower part of the sealed pipe, said lower part comprising a second flange projecting radially towards the outside;

- supplying the carrier plate;

25       - fixing the carrier plate on the lower part and/or on the upper part of the sealed pipe; and

- fixing the upper part of the sealed pipe to the lower part of the sealed pipe coaxially with the latter.

          According to one embodiment, the lower part of the sealed pipe and the  
30       second flange correspond respectively to a sealed pipe and to a connecting flange

of a gas dome structure according to the prior art. Thus, a method of assembly of this kind makes it possible to modify an existing gas dome structure in order to obtain a gas dome structure according to the invention while having the possibility of keeping the original cover.

5           According to one embodiment, the invention also supplies a method for loading or offloading a fluid storage device of this kind, in which a fluid is conveyed through insulated pipelines from or to a floating or onshore storage facility to or from the ship's tank.

          According to one embodiment, the invention also supplies a transfer  
10   system for a fluid, said system comprising the aforementioned fluid storage device, insulated pipelines arranged so as to connect the tank of the fluid storage device to a floating or onshore storage facility and a pump for driving a fluid through the insulated pipelines from or to the floating or onshore storage facility to or from the tank of the fluid storage device.

#### 15           **Brief description of the figures**

The invention will be better understood, and other aims, details, features and advantages thereof will become clearer in the course of the following description of several particular embodiments of the invention, given only for purposes of illustration, and non-limiting, referring to the appended drawings.

20           - **Fig. 1** is a sectional view illustrating a gas dome structure according to a first embodiment and notably the outer zone of the gas dome that is located outside the double hull of a ship, the inner zone of the gas dome located inside the double hull of the ship being illustrated briefly.

          - **Fig. 2** is an exploded, partially cut-away view of the outer zone of the  
25   gas dome structure of Fig. 1.

          - **Fig. 3** is an exploded view of the insulating plug intended to seal the interior of the sealed pipe of the gas dome structure of Figs. 1 and 2.

          - **Fig. 4** is a sectional view illustrating the outer zone of a gas dome structure according to a second embodiment.

30           - **Fig. 5** is a schematic top view illustrating the geometry of a carrier plate, intended to support a sealing plug, according to one embodiment.

- **Fig. 6** is a schematic sectional illustration of the sealed pipe, of the carrier plate and of the insulating plug of a gas dome structure according to another embodiment.

- **Fig. 7** is a schematic cut-away representation of a tank of an LNG carrier equipped with a gas dome structure and a loading/offloading terminal of this tank.

### Detailed description of embodiments

Fig. 1 shows a partial view of a gas dome structure 1 for a sealed, thermally insulating tank for storing a liquefied gas, such as liquefied natural gas (LNG) or liquefied petroleum gas (LPG), for example. The gas dome structure 1 defines a channel for circulation of vapour between the interior space 2 of the tank and one or more vapour collectors, not shown, which are located outside the tank.

The tank is arranged inside the double hull of a ship. The double hull of the ship comprises an outer hull 4 and an inner hull 5. The inner hull 5 constitutes the carrying structure of the tank and is of polyhedral general shape. As shown in Fig. 1, each wall of the tank comprises, in the direction of the thickness of said wall, from the outside to the interior of the tank, a secondary thermally insulating barrier 6 resting against the inner hull 5, a hermetic secondary membrane 7, a primary thermally insulating barrier 8 and a hermetic primary membrane 9 intended to be in contact with the fluid stored in the tank.

According to one embodiment, the primary thermally insulating barrier 8 and the secondary thermally insulating barrier 6 each consist of heat-insulating elements and more particularly parallelepipedal heat-insulating caissons that are juxtaposed in a regular pattern. Furthermore, the secondary membrane 7 and primary membrane 9 in each case consist of a series of parallel strakes made of Invar® with folded edges, which are arranged alternately with elongated welded supports, also of Invar®. As an example, a sealed, thermally insulating tank having such a structure is described in document FR2877638.

As shown in Fig. 1, the gas dome structure comprises a sealed pipe 10 that passes through two openings made in the outer hull 4 and in the inner hull 5, respectively. The sealed pipe 10 extends in a longitudinal direction oriented orthogonally to the tank roof between an upper longitudinal end 14 and a lower

longitudinal end 15 of said sealed pipe 10. The sealed pipe 10 is welded hermetically to the secondary membrane 7 and the primary membrane 9.

The sealed pipe 10 comprises an outer drum 11, of cylindrical shape, which passes through the opening in the outer hull 4 and the opening in the inner hull 5.

- 5 The outer drum 11 is open at both ends. The gas dome structure further comprises an inner drum 12 fixed to the outer drum 11. The inner drum 12 is formed from a cylindrical peripheral wall open at both ends. The inner drum 12 is concentric with the outer drum 11 and extends within the latter.

- An insulating intermediate space 13 is arranged between the outer drum 11 and the inner drum 12. The insulating intermediate space 13 is filled with insulating packing that is distributed uniformly on the inner span of the outer drum 11, between said outer drum 11 and the inner drum 12. The insulating packing comprises one or more insulating materials selected from glass wool, rock wool, cotton wool, fibrous materials, perlite, expanded perlite, polymer foams and aerogels. Alternatively or  
15 additionally, the insulating intermediate space 13 is maintained under negative pressure.

The inner drum 12 and the outer drum 11 are joined together via an annular plate 16 extending horizontally between the inner drum 12 and the outer drum 11, transversely to the longitudinal direction of the inner drum 12 and the outer drum 11.

- 20 The inner drum 12 does not extend to the upper end of the outer drum 11.

Moreover, Fig. 1 also shows that an insulating packing 42, such as polyurethane foam for example, is distributed around the outer drum 11 in order to insulate the sealed pipe 10, above the upper end of the inner drum 12.

- The gas dome structure 1 comprises at least one vapour collecting pipe 3, 25 17 which passes hermetically through the wall of the sealed pipe 10 and opens into a collecting zone 25, located inside the sealed pipe 10. Thus, each vapour collecting pipe 3, 17 is able to convey vapour between the collecting zone 25 of the interior of the sealed pipe 10 and a vapour collector arranged outside the sealed pipe 10. The collecting zone 25 is located longitudinally between the upper end of the inner drum  
30 12 and the upper longitudinal end 14 of the sealed pipe 10. In the embodiment illustrated in Fig. 1, the gas dome structure 1 comprises two vapour collecting pipes 3, 17 that pass transversely and hermetically through the peripheral wall of the sealed pipe 10. More particularly, the vapour collecting pipes 3, 17 only pass

through the peripheral wall of the outer drum 11 and thus open into the sealed pipe 10, in the collecting zone 25. In the embodiment shown, the ends of the vapour collecting pipes 3, 17 are flush with the wall of the outer drum 11 and therefore do not project inside the sealed pipe 10.

5 One of the vapour collecting pipes 3 leads to a vapour collector, not shown, and is equipped with a safety valve. The safety valve is calibrated so as to ensure evacuation of the gas in vapour phase, from the tank, when the vapour pressure in the tank is above a threshold pressure between 0 and 2 bar, for example between 0.2 and 0.4 bar. Taking into account the pressure losses, the calibration of the  
10 safety valve is slightly lower than the threshold pressure that the vapour pressure in the tank must not exceed. This vapour collecting pipe 3 makes it possible to extract vapour from the tank in case of excessive pressure and aims to control the pressure inside the tank so as to avoid excessive pressure, which may damage it. This vapour collecting pipe 3 conveys the vapour to a vapour collector, which leads for  
15 example to a degassing mast, to a burner, to a propulsion device of the ship or to a liquefaction device in which the gas in vapour phase is condensed and then reintroduced into the tank in liquid phase.

The other vapour collecting pipe 17 leads to a vapour collector that is connected to a manifold intended to be connected to a gas storage terminal during  
20 loading or offloading of the tank. Thus, the vapour collecting pipe 17 allows circulation of vapour during operations of tank loading and offloading. In fact, during loading operations, when liquefied gas is transferred from a supply terminal to a tank, gas in gas phase is transferred simultaneously from the tank to the terminal, through the gas dome structure and the vapour collecting pipe 17, in order to  
25 maintain a roughly constant pressure in the ullage space of the tank. Conversely, during the offloading operations, during which liquefied gas is transferred from the tank to a terminal, gas in gas phase is transferred simultaneously from the terminal to the tank in order to avoid a pressure drop in the tank.

Moreover, as shown in more detail in Fig. 2, the upper longitudinal end 14  
30 of the sealed pipe 10 is equipped with a connecting flange 18. The connecting flange 18 is of annular shape and extends transversely to the longitudinal direction of the sealed pipe 10, i.e. horizontally, to the outside of said sealed pipe 10. The connecting flange 18 is welded to the upper end of the outer drum 11.

The gas dome structure 1 also comprises a cover 19 that is fixed on said connecting flange 18 so as to close the upper longitudinal end 14 of the sealed pipe 10. A gasket 20, shown in Fig. 2, is compressed between the cover 19 and the connecting flange 18. The cover 19 is fixed detachably on the upper longitudinal end 5 14. When the cover 19 is removed, it is thus possible to gain access to the interior space 2 of the tank via the sealed pipe 10, for example in order to carry out operations of maintenance and inspection of the tanks. The cover 19 is fixed to the connecting flange 18 by means of a plurality of fasteners, not shown, each passing through a hole 21 made in the periphery of the cover 19 and an opposite hole 22 10 made in the external periphery of the connecting flange 18. The fasteners each consist for example of a bolt comprising a threaded rod and a nut interacting with said threaded rod. On its upper face the cover 19 has a securing means 21 allowing it to be manipulated by means of a maintenance tool.

The gasket 20 is compressed between the cover 19 and the connecting 15 flange 18 and can thus provide a seal between the outside and the interior of the sealed pipe 10. The gasket 20 may be positioned on a diameter smaller than the installation diameter of the fasteners, i.e. between the inner portion of the connecting flange 18 and the cover 19.

In the embodiment shown, the gasket 20 comprises one or more eyes that 20 are made in tabs 23 projecting towards the outside of the gasket 20. The eyes are each arranged opposite a hole 21 made in the cover 19 and a hole 22 made in the connecting flange 18. Thus, each of the eyes has one of the fasteners passing through it, so as to hold the gasket 20 in position. Alternatively, according to embodiments that are not shown, the gasket 20 is placed in a recess made in the 25 cover 19 or in the connecting flange 18 in order to hold said gasket 20 in position.

The gasket 20 is made of polymer, such as polytetrafluoroethylene (PTFE), butadiene acrylonitrile (NBR) reinforced with glass and/or aramid and/or carbon fibres. The gasket may be a flat seal or an O-ring seal.

Moreover, the sealed pipe 10 and more particularly the outer drum 11 of 30 the sealed pipe 10 has a shoulder 24. The shoulder 24 is arranged in a zone located longitudinally between the collecting zone 25 and the upper longitudinal end 14 of the sealed pipe 10. The shoulder is obtained by a change in diameter of the outer drum 11 between an upper part 26 and a lower part 27 of the outer drum 11. The

upper part 26 of the outer drum 11 has a diameter greater than that of the lower part 27 of the outer drum 11, which makes it possible to provide, inside the sealed pipe 10, a carrier plate 29, of annular shape, extending transversely between the upper part 26 of the outer drum 11 and the lower part 27 of the outer drum 11. The carrier plate 29 is reinforced mechanically by the presence of gusset plates positioned on the outside of the sealed pipe 10 and joining the lower surface of the carrier plate to the outside surface of the outer drum 11. The carrier plate 29 makes it possible to support an insulating plug 30. The purpose of the insulating plug 30 is to seal the upper portion of the interior of the sealed pipe 10. The insulating plug 30 has a lower surface 31 opposite the carrier plate 29. The insulating plug 30 and the carrier plate 29 interact with one another, constantly, on the entire periphery of the insulating plug 30. Thus, such an arrangement makes it possible to limit forced convection between, on the one hand, the lower space of the sealed pipe 10 that is arranged underneath the carrier plate 29, and, on the other hand, the upper space of the sealed pipe 10 that is arranged above the carrier plate 29.

In the embodiment shown in Fig. 2, the insulating plug 30 comprises an insulating body 32 and a base 33. The base 33 comprises a rigid disk, for example made of stainless steel, with the insulating body 32 resting against it. The base also comprises one or more gripping handles 34 that project upwards, towards the upper longitudinal end of the sealed pipe 10. The handles 34 each pass through a respective hole 35 made in the insulating body 32. Thus, these handles 34 facilitate gripping and manipulation of the insulating plug 30.

The insulating body 32 is shown in cut-away in Fig. 3. The insulating body 32 comprises a layer of insulating polymer foam 36 sandwiched between an upper plate 37 and a lower plate 38. The upper plate 37 and lower plate 38 are, for example, plywood plates glued on said layer of insulating polymer foam 36. These plywood plates are advantageous in that they make it possible to stiffen the insulating body while contributing to its thermal insulation character. The layer of insulating polymer foam 36 may notably comprise a polyurethane-based foam, optionally reinforced with glass fibres. As an example, the insulating body has a thickness greater than 70 mm, for example of the order of 150 mm.

In the embodiment shown, the insulating plug 30 is fixed to the carrier plate 29. This makes it possible to guarantee that the insulating plug 30 remains in position against the carrier plate 29 and helps to limit, or even eliminate, forced

thermal convection between the carrier plate 29 and the insulating plug 30. For this purpose, the carrier plate 29 is equipped with a plurality of pins 39, shown in Figs. 1 and 2, which are distributed uniformly around the longitudinal direction of the sealed pipe 10. The pins 39 project upwards towards the upper longitudinal end 14 of the sealed pipe 10. Each of the pins 39 passes through through-holes 40, 41 made in the base 33 and in the insulating body 32 of the insulating plug 30. Furthermore, each of the pins 39 comprises a threaded end that interacts with a nut so as to fasten the insulating plug 30 to the carrier plate 29.

Note that the holes 40, 41 are also advantageous in that they allow an equilibration of pressures between the upper part of the interior space of the sealed pipe 10, located above the carrier plate 29, and the lower part of the interior space of the sealed pipe 10, located beneath the carrier plate 29.

It was found that the presence of an insulating plug 30 bearing against the carrier plate 29, as described above, allows the minimum temperature to which the gasket 20 may be subjected to be increased considerably. Thus, as an example, for a gas dome structure 1 equipping a tank in which liquefied natural gas is stored at a temperature of the order of  $-162^{\circ}\text{C}$ , the arrangement described above is able to guarantee that the temperature of the gasket 20 does not fall below  $-50^{\circ}\text{C}$ , whereas the temperature of the gasket 20 of a gas dome structure 1 according to the prior art is likely to fall below  $-80^{\circ}\text{C}$ .

In an embodiment that is not shown, the base 33 is a rigid structure consisting of machine-welded metal bars.

In an embodiment that is not shown, the base 33 and the insulating body 32 are not integral. In this case, the insulating body 32 comprises, on its upper face turned towards the cover 19, gripping means such as handles, to allow it to be removed. The insulating body 32 does not then comprise holes 35 allowing passage of handles, or through-holes 41 as in the embodiment described with reference to Figs. 1 to 3. In such an embodiment, the base 33 may be fixed to the carrier plate 29. For this purpose, the base 33 then has holes allowing passage of pins, which are welded to the carrier plate 29. According to another embodiment, the base 33 is not fixed to the carrier plate 29.

Fig. 4 illustrates a gas dome structure 101 according to a second embodiment. Elements that are identical or similar to elements in Figs. 1 to 3, i.e.

performing the same function, bear the same reference number increased by 100. This gas dome structure 101 differs from that described above in that it is notably obtainable by adapting a gas dome structure according to the prior art, i.e. as described in document KR20140088975, for example. To adapt a gas dome structure 1 according to the prior art, an extra part comprising, on the one hand, a cylindrical upper part 126 extending the initial sealed pipe 10 upwards and, on the other hand, a connecting flange 118 that projects towards the outside of the cylindrical portion 125, will be welded onto the part, referenced 129 in Fig. 3, which is originally a flange intended to receive a cover. The upper part 26 has a diameter greater than that of the original lower part 127. Therefore the structure of the gas dome 101 thus modified has an arrangement equivalent to the gas dome structure 1 described above with reference to Figs. 1 to 3. In particular, the part 129 forms the carrier plate against which the insulating plug 130 is fixed. The operation for adapting a gas dome structure according to the prior art is therefore easy to implement.

The insulating plug 130 may have a structure similar to the insulating plug 30 described above. According to one embodiment, pins 139 are additionally welded onto the carrier plate 129 and thus allow the insulating plug 130 to be fixed on the carrier plate 129 in a similar way to that described above. Moreover, the connecting flange 118, the gasket and the cover 119 are also similar to those described above in relation to the preceding embodiment.

Fig. 5 is a top view illustrating schematically the form of a carrier plate 229 according to one embodiment. It can be seen that the radially inner edge of the carrier plate 229 does not necessarily have a circular shape, as illustrated for example in Fig. 2, and may have other shapes, such as a square shape.

It should also be noted that although, in all the embodiments shown, the carrier plate 29, 129, 229 extends in a horizontal plane, it may also have some other configuration in other embodiments. In particular, in an embodiment that is not illustrated, the carrier plate has a tapered shape in which the cone axis coincides with the longitudinal axis of the sealed pipe 10, 110. In such a case, the lower surface of the insulating plug advantageously has a complementary tapered shape.

Fig. 6 illustrates schematically the structure of a gas dome 301 according to another embodiment. Elements that are identical or similar to elements in Figs. 1 to

3, i.e. performing the same function, bear the same reference number increased by 300. This embodiment differs from the embodiments described above in that the carrier plate 329 is not formed owing to a shoulder of the outer drum 311. In fact, in this embodiment, the carrier plate 329 is a part that is welded onto the inner drum  
5 311, on the upper part 326 and/or on the lower part 327 of said inner drum 311, and that projects inside the sealed pipe 310 relative to said upper part 326 and said lower part 327.

With such an arrangement, the diameter of the upper part 326 of the sealed pipe 310 may be less than, as shown in Fig. 6, or equal to the diameter of the lower  
10 part 327, according to another embodiment.

A gas dome structure 301 of this kind is also obtainable by adapting a gas dome structure according to the prior art. In this case, the lower part 327 of the sealed pipe 310 corresponds to the sealed pipe of a gas dome structure according to the prior art. Thus, in order to obtain a gas dome structure according to the  
15 invention, the upper part 326 equipped with the connecting flange 318 will be added onto the original gas dome structure. According to one embodiment, not illustrated, the upper part 326 has a diameter equal to that of the lower part and the upper part is welded onto the part, referenced 343, that served originally, i.e. before the structural modification, as a flange intended to receive the cover. This makes it  
20 possible to use a cover 319 having the same diameter as the original cover and therefore allows the original cover 319 to be reused when adapting a gas dome structure according to the prior art.

The technique described above for making a gas dome structure may be used in various types of membrane tanks, in an onshore facility or in a floating  
25 structure such as an LNG carrier or some other.

Referring to Fig. 7, a cut-away view of an LNG tanker 70 shows a sealed and insulated tank 71 of prismatic general shape installed in the double hull 72 of the ship. The wall of the tank 71 comprises a primary hermetic barrier intended to be in contact with the LNG contained in the tank, a secondary hermetic barrier  
30 arranged between the primary hermetic barrier and the double hull 72 of the ship, and two insulating barriers arranged respectively between the primary hermetic barrier and the secondary hermetic barrier and between the secondary hermetic barrier and the double hull 72.

In a manner known per se, loading/offloading pipelines 73 arranged on the upper deck of the ship may be connected, by means of suitable connectors, to an offshore terminal or a port terminal for transferring a cargo of LNG from or to the tank 71.

5            Fig. 7 shows an example of an offshore terminal comprising a loading and offloading facility 75, an underwater pipeline 76 and an onshore facility 77. The loading and offloading facility 75 is an offshore fixed facility comprising a moving arm 74 and a rig 78 that supports the moving arm 74. The moving arm 74 carries a bundle of insulated flexible pipes 79 that can be connected to the loading/offloading  
10 pipelines 73. The adjustable moving arm 74 adapts to all sizes of LNG tankers. A connecting pipe, not shown, extends inside the rig 78. The loading and offloading facility 75 allows loading and offloading of the LNG tanker 70 from or to the onshore facility 77. The latter comprises storage tanks for liquefied gas 80 and connecting pipes 81 connected by the underwater pipeline 76 to the loading or offloading facility  
15 75. The underwater pipeline 76 allows transfer of the liquefied gas between the loading or offloading facility 75 and the onshore facility 77 over a great distance, for example 5 km, which makes it possible to keep the LNG tanker 70 at a great distance from the shore during the operations of loading and offloading.

Pumps on board the ship 70 and/or pumps equipping the onshore facility  
20 77 and/or pumps equipping the loading and offloading facility 75 are employed to create the pressure necessary for transferring the liquefied gas.

Although the invention has been described in connection with several particular embodiments, it is quite obvious that it is not in any way limited to these, and that it comprises all the technical equivalents of the means described as well as  
25 their combinations if the latter are within the scope of the invention.

Use of the verbs "have", "comprise" or "include" and their conjugated forms does not exclude the presence of other elements or of other steps than those stated in a claim.

In the claims, any reference symbol in parentheses is not to be interpreted  
30 as a limitation of the claim.

## CLAIMS

1. Fluid storage device comprising a hull and a sealed thermally insulating tank arranged in the hull (4, 5); the tank comprising an interior space (2) intended to store fluid and comprising a tank roof having:
- 5 - a thermally insulating barrier (6) resting against the hull (4, 5); and
  - a sealing membrane (9) intended to be in contact with the fluid contained in the tank; the fluid storage device having a gas dome structure (1, 101, 301) comprising:
    - a sealed pipe (10, 110, 310) having an upper longitudinal end (14, 114, 314) equipped with a connecting flange (18, 118, 318) and a lower longitudinal end (15)
    - 10 passing through the thermally insulating barrier (6) and the sealing membrane (9) of the tank roof so as to define a channel for circulation between the interior space (2) of the tank and at least one vapour collector arranged outside the tank;
    - a cover (19, 119, 319) that is fixed to said connecting flange (18, 118, 318) by fasteners to close the upper longitudinal end (14, 114, 314) of the sealed pipe (10,
    - 15 110, 310);
    - a gasket (20) that is compressed between the cover (19, 119, 319) and the connecting flange (18, 118, 318);
    - a vapour collecting pipe (3, 17, 117) that passes hermetically through a wall of the sealed pipe (10, 110, 310) so as to enter the sealed pipe (10, 110, 310) in a
    - 20 collecting zone (25, 125, 325), said vapour collecting pipe (3, 17, 117) thus being able to convey vapour between the collecting zone (25, 125, 325) and the vapour collector arranged outside the tank;
    - the sealed pipe (10, 110, 310) comprising a carrier plate (29, 129, 329) that extends transversely towards the interior of the sealed pipe (10, 110, 310), and is
    - 25 located longitudinally between the collecting zone (25, 125, 325) and the upper longitudinal end (14, 114, 314) of the sealed pipe (10, 110, 310); the carrier plate (29, 129, 329) delimiting, on the one hand, a lower portion of the interior of the sealed pipe (10, 110, 310) that is located below the carrier plate (29, 129, 329) and, on the other hand, an upper portion of the interior of the sealed pipe (10, 110, 310)
    - 30 that is located above the carrier plate (29, 129, 329);

- an insulating plug (30, 130, 330) that seals the upper portion of the interior of the sealed pipe (10, 110, 310), said insulating plug (30, 130, 330) comprising an upper surface and a lower surface (31), which are opposite the cover (19, 119, 319) and the carrier plate (29, 129, 329), respectively;
- 5 the carrier plate (29, 129, 329) supporting the insulating plug (30, 130, 330) and interacting with the lower surface of the insulating plug (30, 130, 330) on the entire periphery of said lower surface (31) so as to form a barrier limiting a thermal convection effect between the lower portion and the upper portion of the interior of the sealed pipe (10, 110, 310).
- 10           2.       Fluid storage device according to Claim 1, in which the insulating plug (30, 130, 330) comprises an insulating body (32) and a base (33) that is interposed between the insulating body (32) and the carrier plate (29, 129, 329).
3.       Fluid storage device according to Claim 2, in which the base (33) is equipped with a gripping means (34) projecting in the direction of the upper
- 15 longitudinal end (14, 114, 314) of the sealed pipe (10, 110, 310) through a hole (35) made in the insulating body (32).
4.       Fluid storage device according to Claims 1 to 3, in which the insulating plug (30, 130, 330) comprises an insulating body (32) comprising an upper plate (37), a lower plate (38) and a layer of insulating polymer foam
- 20 sandwiched between the lower plate (38) and the upper plate (37).
5.       Fluid storage device according to any one of Claims 1 to 4, in which the carrier plate (29, 129, 329) and the insulating plug (30, 130, 330) are fixed together.
6.       Fluid storage device according to Claim 5, in which the carrier
- 25 plate (29, 129) is equipped with a plurality of pins (39, 139) each having a threaded end projecting in the direction of the upper longitudinal end (14, 114) of the sealed pipe (10, 110) and passing through a respective through-hole (40, 41) made in the insulating plug (30, 130), the threaded end of each of said pins interacting with a nut so as to fasten said insulating plug (30, 130) to the carrier plate (29, 129).
- 30           7.       Fluid storage device according to any one of Claims 1 to 6, in which the sealed pipe (10, 110) comprises a shoulder (24) formed between a lower part (27, 127) and an upper part (26, 126) of the sealed pipe (10, 110), said upper

part (26, 126) having a diameter greater than the diameter of the lower part (27, 127) and said shoulder (24) forming the carrier plate (29, 129).

8. Fluid storage device according to any one of Claims 1 to 6, in which the carrier plate (329) delimits an upper part (326) and a lower part (327) of the sealed pipe (310) and projects transversely towards the interior of the sealed pipe (310) relative to said upper part (326) and lower part (327) of the sealed pipe (310), the upper part (326) of the sealed pipe (310) having a diameter less than or equal to the diameter of the lower part (327) of the sealed pipe (310).

9. Fluid storage device according to any one of Claims 1 to 8, in which the sealed pipe (10, 110, 310) comprises an outer drum (11, 110, 310), an inner drum (12) which passes through the outer drum (11, 110, 310) and an insulating intermediate space (13) provided between the outer drum (11, 110, 310) and the inner drum (12).

10. Fluid storage device according to Claim 9, in which the inner drum (12) has an upper end that is connected hermetically to the outer drum (11, 110, 310) and that is located in a zone arranged longitudinally between the carrier plate (29, 129, 329) and the lower longitudinal end (15) of the sealed pipe (10, 110, 310).

11. Fluid storage device according to Claim 9 or 10, in which the vapour collecting pipe (3, 17) passes hermetically through a wall of the outer drum (11, 110, 310) in a zone located longitudinally between the carrier plate (29, 129, 329) and the upper end of the inner drum (12).

12. Fluid storage device according to any one of Claims 1 to 11, in which the connecting flange (18, 118, 318) projects transversely towards the outside of the sealed pipe (10, 110, 310) from the upper longitudinal end (14, 114, 314) of said sealed pipe (10, 110, 310).

13. Fluid storage device according to any one of Claims 1 to 12, in which each fastener comprises a threaded screw interacting with a nut and passing through a hole (21) made in the cover (19) and a hole (22) made in the connecting flange (18).

14. Fluid storage device according to any one of Claims 1 to 13, configured in the form of a ship.

15. Method for assembling a fluid storage device according to any one of Claims 1 to 14, comprising:

- forming an assembly comprising the sealed pipe (10, 110, 310) and the vapour collecting pipe (3, 17, 117) in such a way that:

- 5           - the sealed pipe (10, 110, 310) has the upper longitudinal end (14, 114, 314) equipped with the connecting flange (18, 118, 318), the lower longitudinal end (15) passing through the thermally insulating barrier (6) and the sealing membrane (9) of the tank roof and the carrier plate (29, 129, 329) that extends transversely towards the interior of the sealed pipe
- 10           (10, 110, 310), and is located longitudinally between the collecting zone (25, 125, 325) and the upper longitudinal end (14, 114, 314) of the sealed pipe (10, 110, 310); and so that
- the vapour collecting pipe (3, 17, 117) passes hermetically through the wall of the sealed pipe (10, 110, 310) and opens into the interior of the
- 15           sealed pipe (10, 110, 310) in the collecting zone (25, 125, 325);
- arranging the insulating plug (30, 130, 330) inside the upper portion of the interior of the sealed pipe (10, 110, 310) bearing against the carrier plate (29, 129, 329);
- fixing the cover (19, 119, 319) to the connecting flange (18, 118, 318), compressing the gasket (20) between the cover and the connecting flange.

20           16. Method of assembly according to Claim 15, in which forming the assembly comprising the sealed pipe (110) and the vapour collecting pipe (3, 17) comprises:

- supplying a lower part (127) of the sealed pipe (110) and the carrier plate (129), the carrier plate (129) being fixed to said lower part (127) and projecting
- 25           transversely towards the outside of the lower part (127);
- supplying an upper part (126) of the sealed pipe (110) equipped with the connecting flange (118); the upper part (126) having a diameter greater than that of the lower portion (127);
- fixing the upper part (126) hermetically on the carrier plate (129).

30           17. Method of assembly according to Claim 15, in which forming the assembly comprising the sealed pipe (10, 110, 310) and the vapour collecting pipe (3, 17) comprises:

- supplying an upper part (326) of the sealed pipe (310), said upper part (326) of the sealed pipe (310) being equipped with the connecting flange (318);

- supplying a lower part (327) of the sealed pipe (310), said lower part (327) comprising a second flange (343) projecting radially towards the outside;

5 - supplying the carrier plate (329);

- fixing the carrier plate (329) on the lower part (327) and/or on the upper part (326) of the sealed pipe (310); and

- fixing the upper part (326) of the sealed pipe (310) to the lower part (327) of the sealed pipe, coaxially with the latter.

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18. Method for loading or offloading a fluid storage device according to any one of claims 1 to 14, in which a fluid is conveyed through insulated pipelines (73, 79, 76, 81) from or to a floating or onshore storage facility (77) to or from the tank of the fluid storage device.

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19. Transfer system for a fluid, the system comprising a fluid storage device according to any one of Claims 1 to 14, insulated pipelines (73, 79, 76, 81) arranged so as to connect the tank (71) to a floating or onshore storage facility (77) and a pump for driving a fluid through the insulated pipelines from or to the floating or onshore storage facility to or from the tank.

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