

SEALED, THERMALLY INSULATING TANK INCLUDING DEVICES FOR ANCHORING PRIMARY INSULATING PANELS TO SECONDARY INSULATING PANELS

Technical domain

5 The invention relates to the field of sealed, thermally insulated membrane tanks for storing and/or transporting a fluid, such as a cryogenic fluid.

Sealed, thermally insulating membrane tanks are notably used for storing liquefied natural gas (LNG).

Technological background

10 Application WO2014/170588 discloses a sealed, thermally insulating tank for storing liquefied natural gas that is built into the double hull of a ship. Each tank wall has a multi-layer structure and comprises, arranged successively therethrough from the outside towards the inside of the tank, a secondary thermally insulating barrier attached to a load-bearing structure, a secondary sealing membrane bearing against
15 the secondary thermally insulating barrier, a primary thermally insulating barrier bearing against the secondary sealing membrane and a primary sealing membrane designed to be in contact with the liquefied natural gas contained in the tank and bearing against the primary thermally insulating barrier.

In the aforementioned document, the thermally insulating barrier has a
20 plurality of primary insulating panels that are anchored to the secondary insulating panels of the secondary thermally insulating barrier, using anchoring devices. All of the anchoring devices are fitted with a stack of spring washers that ensure an elastic anchoring of the primary insulating panels to the secondary insulating panels. Such an elastic anchoring enables the primary insulating panels to be held against the
25 secondary insulating panels, while enabling small relative movements of the primary insulating panels in relation to the secondary insulating panels. This helps to limit the stresses liable to be exerted on the primary insulating panels and on the secondary insulating panels in the anchoring zones. However, such a sealed tank is not entirely satisfactory. In particular, such anchoring devices require a large number of Belleville
30 washer stacks, which increases the cost of the tank fitted with such anchoring devices and the manufacturing complexity thereof.

Summary

The concept at the heart of the invention involves proposing a sealed, thermally insulating tank in which the insulating panels are anchored more simply and cheaply.

- 5 According to one embodiment, the invention provides a sealed, thermally insulating tank carried on a ship, the ship having a double hull comprising an inner hull that forms a load-bearing structure for the sealed, thermally insulating tank and an outer hull; the double hull having, in the ballast zones, ballast compartments that are designed to receive a liquid, such as sea water, and that are delimited between
- 10 the inner hull and the outer hull; the tank having tank walls that are fastened to the inner hull; each of the tank walls having, arranged successively in a thickness direction of the tank wall, at least one thermally insulating barrier that comprises insulating panels fastened to the inner hull and a sealing membrane bearing against the insulating panel;
- 15 said tank walls including ballast-zone walls that are fastened to the inner hull level with at least one of the ballast compartments in a thickness direction of said ballast-zone wall, and non-ballast-zone walls that are fastened to the inner hull level with none of the ballast compartments in the thickness direction of said non-ballast-zone wall;
- 20 at least one of the insulating panels of the ballast-zone walls being anchored directly or indirectly to the inner hull using first anchoring devices;
at least one of the insulating panels of the non-ballast-zone walls being anchored directly or indirectly to the inner hull using second anchoring devices;
in which each of the first anchoring devices is provided with n_1 elastic members
- 25 arranged to exert an elastic force pressing said ballast-zone-wall insulating panel towards the inner hull while enabling a relative movement, in the thickness direction of the tank wall, of said insulating panel in relation to the load-bearing structure during deformation of the inner hull; n_1 being a whole number equal to or greater than 1; said first anchoring devices having a stiffness K_1 opposing the relative movement of said
- 30 insulating panel in relation to the load-bearing structure in the thickness direction of the tank wall; and
in which each of the second anchoring devices is provided with n_2 elastic members

that are arranged to exert an elastic force pressing said non-ballast-zone-wall insulating panel towards the inner hull while enabling a relative movement of said insulating panel in relation to the load-bearing structure during deformation of the inner hull; n_2 is a whole number equal to or greater than 0; said second anchoring devices having a stiffness K_2 opposing the relative movement of said insulating panel in relation to the load-bearing structure in the thickness direction of the tank wall; the stiffness K_2 being greater than K_1 .

It has indeed been noted that the main forces liable to generate stresses in the anchoring zones of the insulating panels come from the deformation of the inner hull in the ballast zones when the sea water is loaded into the ballast compartments. Indeed, the inner hull is deformed by the movements of the sea water inside the ballast compartments. This causes deformations of the insulating panels, which in turn generate significant forces on the anchoring zones of said insulating panels. Conversely, in the non-ballast-zone walls, the second anchoring devices are mainly subjected only to forces caused by thermal contraction. However, these forces are considerably less than the forces liable to be exerted by deformation of the inner hull in the ballast-zone walls, enabling the stiffness K_2 of the second anchoring devices to be greater.

According to other advantageous embodiments, such a tank may have one or more of the following features:

According to one embodiment, n_2 is less than n_1 . In this case, the elastic members of the first anchoring devices and the elastic members of the second anchoring devices can be identical.

According to another embodiment, n_2 is equal to n_1 . In this case, the elastic members of the first anchoring devices and the elastic members of the second anchoring devices are necessarily different, the stiffness of the elastic members of the first anchoring devices being lower than the stiffness of the second anchoring devices.

According to one embodiment, at least one of the insulating panels of each ballast-zone wall is anchored using first anchoring devices.

According to one embodiment, each of the tank walls comprises successively, from the outside towards the inside of the tank, a secondary thermally insulating barrier that includes secondary insulating panels fastened to the inner hull, a secondary sealing membrane that bears against the secondary insulating panels ,
 5 a primary thermally insulating barrier that comprises a plurality of primary insulating panels bearing against the secondary sealing membrane and a primary sealing membrane that bears against the primary insulating panels and that is designed to come into contact with the liquefied natural gas contained in the tank.

According to one embodiment, the first anchoring devices anchor at least
 10 one of the primary insulating panels of the ballast-zone walls on at least one of the secondary insulating panels of said ballast-zone wall; and the second anchoring devices anchor at least one of the primary insulating panels of the non-ballast-zone walls to at least one of the secondary insulating panels of said non-ballast-zone wall.

15 In this case, the forces liable to generate stresses on the anchoring zones of the primary insulating panels are even greater since the primary insulating panels straddle several secondary insulating panels. Moreover, a more elastic anchoring of at least one of the primary insulating panels on at least one of the secondary insulating panels is advantageous in the ballast zones since a more rigid anchoring of the
 20 primary insulating panels in these zones would require a mechanical reinforcement of these latter, which is difficult and costly to implement.

According to one embodiment, most or all of the primary insulating panels of each ballast-zone wall are anchored to secondary insulating panels of said ballast-zone wall by means of first anchoring devices.

25 According to one embodiment, at least one of the primary insulating panels of each non-ballast-zone wall is anchored to at least one of the secondary insulating panels of said non-ballast-zone wall by means of second anchoring devices.

According to one embodiment, most or all of the primary insulating panels of each non-ballast-zone wall is anchored to the secondary insulating panels of said
 30 non-ballast-zone wall by means of second anchoring devices.

According to one embodiment, the first anchoring devices anchor at least one of the secondary insulating panels of the ballast-zone walls to the inner hull; and the second anchoring devices anchor at least one of the secondary insulating panels of the non-ballast-zone walls to the inner hull.

- 5 According to one embodiment, most or all of the secondary insulating panels of each ballast-zone wall are anchored using first anchoring devices.

According to one embodiment, most or all of the primary insulating panels of each non-ballast-zone wall are anchored by means of second anchoring devices.

- 10 According to one embodiment, the first anchoring devices anchor at least one of the primary insulating panels of the ballast-zone walls to the inner hull; and the second anchoring devices anchor at least one of the primary insulating panels of the non-ballast-zone walls to the inner hull.

- 15 According to one embodiment, each of the first and second anchoring devices has a pin that is anchored directly or indirectly to the inner hull and a retaining member that is mounted on the pin; said retaining member being held on the pin and cooperating with a bearing surface of said insulating panel anchored by said first or second anchoring device such as to hold same towards the inner hull.

According to one embodiment, each pin is anchored to one of the secondary insulating panels.

- 20 According to one embodiment, the pin is anchored to an inner face of said secondary insulating panel, i.e. to a face of the secondary insulating panel facing the secondary sealing membrane.

According to one embodiment, the pin has a thread that cooperates with a nut that holds the retaining member towards the inner hull.

- 25 According to one embodiment, each elastic member is a spring washer, such as a Belleville washer, that is engaged on the pin, between the nut and the retaining member, to provide an elastic force pressing the retaining member against the bearing surface.

- 30 According to one embodiment, the first anchoring devices have a spacer sleeve that is slid onto the respective pin and held towards the inner hull by the nut,

said spacer sleeve having a cylindrical portion that is fitted inside the spring washers to center same and an annular flange that presses said spring washers against the retaining member.

According to one embodiment, each second anchoring device has a spacer
5 sleeve that is slid onto the respective pin and held towards the load-bearing structure by the nut and the spacer sleeve has a flange bearing against the retaining member.

According to one embodiment, the second anchoring devices do not have elastic members and are thus arranged to ensure rigid anchoring.

According to one embodiment, the spacer sleeve of one of the first anchoring
10 devices and the spacer sleeve of one of the second anchoring devices are identical, the flange of said spacer sleeves being off-center in relation to the middle of the spacer sleeve such as to define a cylindrical centering portion that is longer than one half-length of the spacer sleeve, the spacer sleeve of said first anchoring device and the spacer sleeve of said second anchoring device having an inverted orientation such
15 that the cylindrical centering portion of the first anchoring device passes through the n1 spring washers of said first anchoring device and that the cylindrical centering portion of the second anchoring device is arranged between the flange and the nut.

According to one embodiment, the flange is arranged at one end of the spacer sleeve.

20 According to one embodiment, the spacer sleeve of one of the first anchoring devices and the spacer sleeve of one of the second anchoring devices are identical, the flange of said spacer sleeves being off-center in relation to the middle of the spacer sleeve and delimiting two cylindrical portions of different lengths, the longer cylindrical portion of the spacer sleeve of the first anchoring device passing through
25 the spring washers of said first anchoring device, while the shorter cylindrical portion of the spacer sleeve of the second anchoring device passes through a borehole of the retaining member.

According to one embodiment, each primary insulating panel has a rigid outer plate and a layer of insulating polymer foam that is fastened to the rigid outer
30 plate, the layer of insulating polymer foam having a recess that extends into the layer of insulating polymer foam and forms the bearing surface on the rigid outer plate.

According to one embodiment, the rigid outer plate projects beyond the layer of insulating polymer foam about the edge of each primary insulating panel such as to form bearing surfaces on the edge of each primary insulating panel that each cooperate with a retaining member of one of the first and second anchoring devices.

- 5 According to one embodiment, each primary insulating panel straddles at least four secondary insulating panels.

According to one embodiment, the equivalent stiffness of the elastic members of each first anchoring device is less than the equivalent stiffness of the elastic members of each second anchoring device.

- 10 According to one embodiment, said tank walls also have mixed walls that have a portion not level with any of the ballast compartments and a portion level with at least one of the ballast compartments; and at least one of the insulating panels of the mixed walls is anchored directly or indirectly to the inner hull by means of second anchoring devices.

- 15 According to one embodiment, the tank has an overall polyhedral shape and has an upper wall, a lower wall, front and rear transverse walls extending transversely to the longitudinal direction of the ship and side walls, the upper wall, the lower wall and the side walls extending in the longitudinal direction of the ship and linking the front and rear transverse walls; the front transverse wall, the rear transverse wall and
20 the upper wall each being one of the non-ballast-zone walls.

According to one embodiment, the tank has at least four side walls, two of said side walls being vertical side walls and two of said sidewalls being upper oblique side walls, each of which links the upper wall to one of said vertical side walls.

- According to one embodiment, said two upper oblique side walls are each
25 one of the mixed walls. The inner hull level with the upper oblique side walls is less stressed by the ballast than in the ballast walls. Indeed, firstly, the upper oblique side walls are only partially in contact with the ballast compartments. Secondly, the hydrostatic pressure in the ballast compartments level with said upper oblique side walls is lower. Consequently, the upper oblique side walls can be provided with
30 second anchoring devices, like the non-ballast-zone wall.

According to one embodiment, the other tank walls, i.e. the lower wall, the vertical side walls and the lower oblique walls are ballast-zone walls.

Such a tank may be part of an onshore storage facility, for example for storing LNG, or be installed on a coastal or deep-water floating structure, notably a liquefied
 5 natural gas carrier, a floating storage and regasification unit (FSRU), a floating production, storage and offloading (FPSO) unit, inter alia.

According to one embodiment, a ship used to transport a fluid has a double hull and an aforementioned tank arranged in the double hull, the double hull having an inner hull forming the load-bearing structure of the tank.

10 According to one embodiment, the invention also provides a method for loading onto or offloading from such a ship, in which a fluid is channeled through insulated pipes to or from an onshore or floating storage facility to or from the tank on the ship.

According to one embodiment, the invention also provides a transfer system
 15 for a fluid, the system including the aforementioned ship, insulated pipes arranged to connect the tank installed in the hull of the ship to an onshore or floating storage facility and a pump for driving a fluid through the insulated pipes to or from the onshore or floating storage facility to or from the tank on the ship.

Short description of the figures

20 The invention can be better understood, and additional objectives, details, features and advantages thereof are set out more clearly, in the detailed description below of several specific embodiments of the invention given solely as non-limiting examples, with reference to the drawings attached.

- **Figure 1** is a perspective cut-away view of the double hull of a ship and
 25 of a sealed, thermally insulating tank fastened to the inside of said double hull.

- **Figure 2** is a perspective cross-section view of the double hull of a ship showing the ballast compartments designed to be filled with sea water to stabilize the ship.

- **Figure 3** is a perspective cut-away view of a tank wall.

- **Figure 4** is a partial schematic view of a sealed, thermally insulating storage tank showing the ballast zones and the non-ballast zones.

- **Figure 5** is a schematic view of an anchoring device for anchoring the primary insulating panels of the ballast-zone walls according to a first embodiment.

5 - **Figure 6** is a detailed view of the spacer sleeve of the anchoring device in figure 5.

- **Figure 7** is a schematic view of an anchoring device for anchoring the primary insulating panels of the ballast-zone walls according to a second embodiment.

- **Figure 8** is a schematic view of an anchoring device for anchoring the
10 primary insulating panels of the non-ballast-zone walls according to a first embodiment.

- **Figure 9** is a schematic view of an anchoring device for anchoring the primary insulating panels of the non-ballast-zone walls according to a second embodiment.

- **Figure 10** is a cut-away schematic view of a liquefied natural gas carrier
15 ship tank having walls as shown in figure 3 and of a loading/offloading terminal for this tank.

- **Figure 11** is a perspective cut-away view of a wall of a tank according to another embodiment.

- **Figure 12** is a schematic view of an anchoring device for anchoring the
20 primary and secondary insulating panels of the ballast-zone walls according to a third embodiment.

- **Figure 13** is a schematic view of an anchoring device for anchoring the primary and secondary insulating panels of the non-ballast-zone walls according to a third embodiment.

25 **Detailed description of the embodiments**

By convention, the terms “outer” and “inner” are used to determine the relative position of one element in relation to another, with reference to the inside and the outside of the tank.

Figures 1 and 2 show the double hull 1 of a ship. The double hull 1 has an outer hull 2 and an inner hull 3 that forms the load-bearing structure for a sealed, thermally insulating membrane tank 4. The inner hull 3 comprises a plurality of walls defining the general shape of the tank 4, which is usually polyhedral. The inner hull 3 and the outer hull 2 are linked to one another by a plurality of metal sheets 5.

As shown in figure 2, the double hull 1 has ballast zones 6 in the lower portion thereof, in which ballast compartments 7 are formed. The ballast compartments 7 are formed between the inner hull 3 and the outer hull 2 of the double hull 1. The ballast compartments 7 are designed to receive a liquid, such as sea water. These ballast compartments 7 are notably filled with sea water when the tank or tanks of the ship are not very full, in order to ensure the stability of the ship.

Figure 4 shows the overall polyhedral shape of a tank 4 according to one embodiment. The tank 4 has a plurality of walls 8, 9, 10, 11, 12, 13, 14, 15, 16 that are each arranged against a respective wall of the inner hull 3. The tank 4 has an upper wall 8 and a lower wall 9 that are horizontal, and two transverse walls 10 (front and rear) that are horizontal. The front transverse wall is not shown in figure 4. Each of the two transverse walls 10 extends in a plane that is perpendicular to the longitudinal direction of the ship. The tank 4 also has side walls 11, 12, 13, 14, 15, 16. The upper wall 8, lower wall 9 and lateral walls 11, 12, 13, 14, 15, 16 extend in the longitudinal direction of the ship and link the front and rear transverse walls 10 to one another. In the embodiment shown, the transverse walls 10 are octagonal. Moreover, the side walls include two vertical side walls 13, 14, two upper oblique side walls 15, 16, each of which links one of the vertical side walls 13, 14 to the upper wall 8 and two lower oblique side walls 11, 12, each of which links one of the vertical side walls 13, 14 to the lower wall 9.

The tank walls 8, 9, 10, 11, 12, 13, 14 include ballast-zone walls that are held against the inner hull 3 in the ballast zones 6 of the double hull 1, i.e. level with the ballast compartments 7; non-ballast-zone walls that are held against the inner hull 3 outside the ballast zones 6 of the double hull 1, i.e. not level with any of the ballast compartments 7; and mixed walls 15, 16, of which only a portion is fastened to the inner hull level with the ballast compartments 7. In figure 4, the ballast-zone walls are hatched, while the non-ballast-zone walls are blank and the mixed walls have + signs.

In other words, the lower wall 9, the vertical side walls 13, 14 and the lower oblique side walls 11, 12 are ballast-zone walls, while the upper wall 8, and the front and rear transverse walls 10 are non-ballast-zone walls. The upper oblique side walls 15, 16 are mixed walls. The ballast-zone walls are liable to be subjected to greater stresses than the non-ballast-zone walls, on account of deformations of the inner hull 3 in the ballast zones 6 when the sea water is loaded into the ballast compartments 7.

Figure 3 shows the multi-layer structure of each of the walls of a tank according to one embodiment. Each wall has, arranged successively in the thickness direction from the outside towards the inside of the tank, a secondary thermally insulating barrier 17 fastened to the inner hull 3, a secondary sealing membrane 18 bearing against the secondary thermally insulating barrier 17, a primary thermally insulating barrier 19 bearing against the secondary sealing membrane 18 and a primary sealing membrane 20 designed to be in contact with the liquefied natural gas contained in the tank.

The secondary thermally insulating barrier 17 has a plurality of secondary insulating panels 21 anchored to the inner hull 3 using resin cords (not shown) and/or pins (not shown) welded to the inner hull 3. The secondary insulating panels 21 have a substantially rectangular parallelepipedic shape and are juxtaposed in parallel rows separated from one another by interstices 22 providing assembly clearance. The interstices 22 are filled with an insulating blanket, made of glass wool, mineral wool or open-cell soft synthetic foam, for example. Each secondary insulating panel 21 has a layer of insulating polymer foam 24 sandwiched between a rigid inner plate 25 and a rigid outer plate 26. The inner and outer rigid plates 25, 26 are for example plywood plates bonded to said layer of insulating polymer foam 24. The insulating polymer foam may notably be a polyurethane-based foam.

The secondary sealing membrane 18 has a plurality of corrugated metal sheets, each of which is substantially rectangular. The corrugated metal sheets are offset in relation to the secondary insulating panels 21 of the secondary thermally insulating barrier 17 such that each of said corrugated metal sheets extends jointly over four adjacent secondary insulating panels 21. The corrugations project towards the outside of the tank 4, i.e. towards the inner hull 3. The corrugations in the

corrugated metal sheets are seated in the slots formed in the rigid inner plate 25 of the secondary insulating panels 21.

Adjacent corrugated metal sheets are lap-welded together. Furthermore, the corrugated metal sheets are welded to the metal plates 23 that are fastened to the rigid inner plate 25 of the secondary insulating panels 21. The corrugated metal sheets have blanks along the longitudinal edges of same and at the four corners of same to accommodate the pins 27, which are fastened to the rigid inner plates 25 of the secondary insulating panels 21 and are intended to fasten the primary thermally insulating barrier 19 to the secondary thermally insulating barrier 17.

Furthermore, the primary thermally insulating barrier 19 has a plurality of primary insulating panels 28 that are substantially rectangular parallelepipeds. In the embodiment shown, the primary insulating panels 28 are offset in relation to the secondary insulating panels 21 of the secondary thermally insulating barrier 17 such that each primary insulating panel 28 covers four secondary insulating panels 21.

Each primary insulating panel 28 has a layer of insulating polymer foam 29, for example a polyurethane-based insulating polymer foam, sandwiched between two rigid plates, i.e. a rigid outer plate 30 and a rigid inner plate 31. The inner and outer rigid plates 31, 30 are for example made of plywood.

The rigid inner plate 31 of each insulating panel 28 is fitted with metal plates 32 to anchor the corrugated metal sheets of the primary sealing membrane 20. The primary sealing membrane 20 is obtained by assembling a plurality of corrugated metal sheets. Each corrugated metal sheet is substantially rectangular. The corrugations project towards the inside of the tank.

In the embodiment shown, each primary insulating panel 28 has one or more recesses 33 along each of the two longitudinal edges thereof and one recess 34 at each corner thereof. Each recess 33, 34 extends into the rigid inner plate 31 and passes through the entire thickness of the layer of insulating polymer foam 29. At each of the recesses 33, 34, the rigid outer plate 30 projects beyond the layer of insulating polymer foam 29 and the rigid inner plate 31 to form a bearing zone cooperating with an anchoring device. Each recess 33 formed along one edge of one of the primary insulating panels 28 is arranged opposite a recess 33 formed in the

opposing edge of an adjacent primary insulating panel 28. This enables a single anchoring device to cooperate with two bearing surfaces belonging respectively to two adjacent primary insulating panels 28. Furthermore, each recess 34 formed at one of the corners of the primary insulating panels 28 opens out opposite the recesses 34 formed in the adjacent corners of the three adjacent primary insulating panels 28. The four recesses 34 thus together form a cross-shaped seat. This enables a single anchoring device to cooperate with the four bearing surfaces of four adjacent primary insulating panels 28.

In another embodiment (not shown), the recesses are not formed in the edges of the primary insulating panels 28. In this case, each recess is formed by a shaft, for example a cylindrical shaft, that passes through the rigid inner plate 31 and the layer of insulating polymer foam 29. The rigid outer plate 30 that forms the bottom of the recess is then provided with an orifice designed to receive a pin 27 and to form a bearing surface cooperating with an anchoring device.

Figure 5 shows in detail a first anchoring device 35 that anchors the primary insulating panels 28 to the secondary insulating panels 21 in the ballast-zone walls.

Each first anchoring device 35 has a pin 27 that is fastened to the rigid inner plate 25 of one of the secondary insulating panels 21.

In the embodiment shown, an anchoring plate 36 is arranged in a seat formed in the rigid inner plate 25. Furthermore, the rigid inner plate 25 has an edge 37 that covers a portion of the anchoring plate 36 in order to hold the anchoring plate 36 against the layer of insulating polymer foam 24. However, the anchoring plate 36 can be fastened to the inner surface of the secondary insulating panels 21 by any other means, for example gluing.

Moreover, the pin 27 passes through an orifice formed in the secondary sealing membrane 18, for example level with the blanks formed in the edges of two adjacent metal sheets of the secondary sealing membrane 18.

The pin 27 has a threaded end that cooperates with a threaded borehole formed in the anchoring plate 36 such as to rigidly connect said pin 27 to the primary insulating panel 28. The pin 27 has a shoulder 38 that bears in the direction of the inner hull 3 against the secondary sealing membrane 18 about the edge of said orifice.

The secondary sealing membrane 18 is also welded sealingly to the anchoring plate about said pin 27 to ensure a continuous seal.

Each first anchoring device 35 also has a retaining member 39 fastened to the pin 27. For this purpose, the retaining member 39 has a borehole that slides onto
5 the pin 27. The retaining member 39 has feet 40 that are each seated inside one of the recesses 34. Thus, at the corners of the primary insulating panels 28, the retaining member 39 is X-shaped, with each of the four feet 40 seated inside a recess 34 of one of the four adjacent primary insulating panels 28. In the embodiment shown, the retaining member 39 is curved such that the central zone of the retaining member 39
10 with the borehole through which the pin 27 passes is not in the same plane as the feet 40.

Each foot 40 of the retaining member 39 bears against one of the bearing surfaces 41, i.e. a portion of the rigid outer plate 30 projecting beyond the rigid inner plate 31 and the layer of insulating polymer foam 29, such that each bearing surface
15 41 is sandwiched between one of the feet 40 of the retaining member 39 and the secondary sealing membrane 18.

A nut 42 cooperates with a thread of the pin 27 to fasten the retaining member 39 to the pin 27. The nut 42 is associated with a plain washer 43, which is also mounted on the pin 27. Furthermore, the first anchoring device 35 has $n1$ spring
20 washers 44, such as Belleville washers, that are slid onto the pin 27, between the nut 42 and the retaining member 39, which provides an elastic anchoring of the primary insulating panels 28 to the secondary insulating panels 21. $n1$ is a whole number equal to or greater than 1.

Furthermore, the first anchoring device 35 also has an optional spacer sleeve
25 45, shown in detail in figure 6, which notably ensures a relative centering of the spring washers 44. To do this, the spacer sleeve 45 is slid onto the pin 27 between the spring washers 44 and the plain washer 43. The spacer sleeve 45 has two cylindrical portions 46, 47 arranged on both sides of a flange 48. The flange 48 is not centered on the middle of the spacer sleeve 45 such that said flange 48 forms two cylindrical
30 portions 46, 47 of different lengths. Each of the two cylindrical portions 46, 47 has an external diameter that is firstly less than the internal diameter of the spring washers 44 and secondly less than the diameter of the borehole in the retaining member 39

through which the pin 27 passes. The external diameter of the cylindrical portions 46, 47 is nonetheless greater than the internal diameter of the plain washer 43. Furthermore, the external diameter of the flange 48 is greater than the internal diameter of the spring washers 44. Therefore, as shown in figure 5, the cylindrical portion 47 of the spacer sleeve 45 is inserted into the spring washers 44 to center said washers. Furthermore, the nut 42 bears against the cylindrical portion 46 of the spacer sleeve 45 via the plain washer 43 and the spring washers 44 are thus compressed between the flange 48 and the retaining member 39.

Figure 7 shows in detail a first anchoring device 49 that anchors the primary insulating panels 28 to the secondary insulating panels 21 in the ballast-zone walls, according to a second embodiment. In this embodiment, the recess 51 is not formed in the edge of a first insulating panel 28, but is formed by a shaft passing through the rigid inner plate 31 and the layer of insulating polymer foam 29 of the primary insulating panel 28. In this embodiment, the pin 27 of the anchoring device 49 passes through an orifice formed in the rigid outer plate 30. The first anchoring device 49, shown in figure 7, only differs from the anchoring device 35 described with reference to figures 5 and 6 in the form of the retaining member 50. Indeed, in this embodiment, the retaining member 50 is a washer that is slid onto the pin 27 and sandwiched between the spring washers 44 and a bearing zone 41 of the rigid inner plate 30 of the primary insulating panel 28.

Figure 8 shows in detail a second anchoring device 52 that anchors the primary insulating panels 28 to the secondary insulating panels 21 in the non-ballast-zone walls, according to a first embodiment. The second anchoring device 52 only differs from the first anchoring device 35 described with reference to figures 5 and 6 in that there are no spring washers 44 acting against the nut 42 and the retaining member 39. Consequently, the flange 48 of the spacer sleeve 45 bears directly against the retaining member 39.

Thus, the second anchoring device 52 rigidly anchors the primary insulating panels 28 to the secondary insulating panels 21. In the non-ballast-zone walls, the second anchoring devices 52 are mainly subjected to forces caused by thermal contraction. When cooling the tank 4, i.e. when liquefied natural gas is loaded into the tank 4, the primary and secondary insulating panels 28, 21 and the pins 27 are

subjected to thermal contraction. It should be noted that the amplitude of the relative movement of the feet of the retaining member 39 in relation to the bearing surface 41 of the primary insulating panels 28 that could be caused by thermal contraction is extremely small if the second anchoring devices provide elastic anchoring. Indeed, 5 this amplitude depends only on the difference in contraction in the thickness direction of the tank between the portion of the pin 27 extending between the anchoring plate 37 and the retaining member 39 on one hand and the rigid outer plate 40 on the other hand. Since the length of the portion of the pin 27 in question and the thickness of the rigid outer plate 40 are relatively small, the amplitude of the relative movement caused 10 by thermal contraction is in the order of hundredths of millimeters, and can therefore be disregarded. This obviates the need to provide spring washers to offset this contraction difference. A slight deformation of the rigid outer plate 30 by the retaining member 39 when positioning the anchoring device 52 would be sufficient to continue holding the primary insulating panel 28 after cooling.

15 Figure 9 shows in detail a second anchoring device 53 that anchors the primary insulating panels 28 to the secondary insulating panels 21 in the non-ballast-zone walls, according to a second embodiment. The second anchoring device 53 is in this case designed to be arranged in a recess 53, as described with reference to figure 7. The second anchoring device 53 differs from the first anchoring device 49, 20 as shown in figure 7, in that there are no spring washers. Consequently, the flange 48 of the spacer sleeve 45 bears directly against the retaining member 50.

 It can also be seen that a spacer sleeve 45 identical to the spacer sleeve disclosed in figure 6 is used in this embodiment. However, the orientation of said spacer sleeve 45 is inverted in relation to the orientation thereof in figures 5 and 7. 25 Indeed, by providing a spacer sleeve 45 in which the flange 48 is not centered longitudinally, the spacer sleeve 45 is reversible and can be used as required by orienting the longer cylindrical portion 47 towards the secondary thermally insulating barrier 17 where the anchoring device is fitted with spring washers 44 (as shown in figures 5 and 6) or conversely by orienting the shorter cylindrical portion 46 towards 30 the secondary thermally insulating barrier 17 where the anchoring device does not have any spring washers and the flange 48 of the spacer sleeve 45 is directly in contact with the retaining member 39 (as shown in figure 9). Thus, this standard

spacer sleeve 45 can be used regardless of whether the anchoring device has spring washers or not.

Furthermore and advantageously, insulating plugs (not shown) are positioned in the recesses 33, 34, 51 after assembly of the anchoring devices 35, 49, 52, 53 to ensure the continuity of the primary thermally insulating barrier 19 at said recesses 33, 34, 51.

In another embodiment, the second anchoring device 53 may also include spring washers. However, in any case, the stiffness K_1 of the first anchoring devices opposing the relative movement of the respective insulating panel in the thickness direction of the tank wall is strictly less than the corresponding stiffness K_2 of the second anchoring devices.

According to one embodiment, the second anchoring device has n_2 spring washers, where n_2 is a whole number less than n_1 . Thus, the two anchoring devices can use identical spring washers, which facilitates manufacture of the tank.

According to other embodiments, the spring washers of the second anchoring device and the spring washers of the first anchoring device are different. In this case, the numbers n_2 and n_1 can also be equal.

The primary insulating panels 28 of the mixed walls, i.e. the upper oblique side walls 15, 16, can also be anchored using second anchoring devices, according to one of the variants described above.

Figure 12 shows the multi-layer structure of a wall of a tank according to another embodiment.

The secondary thermally insulating barrier 17 is made up of a plurality of juxtaposed secondary insulating panels 21. Each secondary insulating panel 21 is a parallelepipedic box, for example made of plywood, that has a bottom plate 54, a cover plate 55 and partitions 56 that extend in the thickness direction of the wall between the bottom plate 54 and the cover plate 55 and that define the compartments filled with an insulating lining, such as perlite for example. The bottom plates 54

project laterally on two opposing sides of the box to enable cleats 57 to be fastened to each corner of the box on this projecting portion.

The primary thermally insulating barrier 19 is also made up of a plurality of juxtaposed primary insulating panels 28. The structure of the primary insulating panels 28 is substantially similar to the structure of the secondary insulating panels 21. The dimensions of the primary insulating panels 28 are identical to the dimensions of the secondary insulating panels 21, with the exception of the thickness thereof in the thickness direction of the tank, which can be less than the thickness of the secondary insulating panels 21. The bottom plates 58 of the primary insulating panels 28 project laterally on two opposing sides of the box to enable cleats 59 to be fastened to each corner of the box on this projecting portion.

The secondary sealing membrane 18 has a continuous layer of metal strakes with raised edges. The strakes are welded via the raised edges thereof to parallel welding supports that are fastened in the slots formed in the cover plates 55 of the secondary insulating panels 21. The primary sealing membrane 20 has a similar structure and a continuous layer of metal strakes with raised edges. The strakes are welded via the raised edges thereof to parallel welding supports that are fastened in the slots formed in the cover plates of the primary insulating panels 28.

The metal strakes are, for example, made of Invar®, i.e. an alloy of iron and nickel with a coefficient of expansion typically between $1.2 \cdot 10^{-6}$ and $2 \cdot 10^{-6} \text{ K}^{-1}$.

Figure 12 shows a first anchoring device 60 that anchors the primary and secondary insulating panels 28, 21 of the ballast-zone walls. The first anchoring device 60 has a socket 61 that is fastened to the inner hull 3 at the four corners of four adjacent primary insulating panels 21. Each socket 61 houses a nut 62 into which the lower end of a pin 63 is screwed. The first anchoring device 60 also has a retaining member 64 fastened to the pin 63. For this purpose, the retaining member 64 has a borehole that slides onto the pin 63. The retaining member 64 is for example a metal plate. The retaining member 64 bears against the cleats 57 such as to hold the secondary insulating panels 21 against the inner hull 3. A nut 65 cooperates with a thread of the pin 63 to fasten the retaining member 64 to the pin 63. Furthermore, the first anchoring device 60 has a set of $n1$ spring washers 66, where $n1$ is a whole number equal to or greater than 1. The spring washers 66 are for example Belleville

washers. The spring washers 66 are slid onto the pin 63 between the nut 65 and the retaining member 64, which provides an elastic anchoring of the secondary insulating panels 21 to the inner hull 3.

In the embodiment shown, the nut 65 has a cylindrical centering portion 67
 5 that is inserted into the spring washers 66 to center said washers. Furthermore, in the embodiment shown, a lock washer 68 is welded locally to the pin 63 above the nut 65 so as to fasten the nut 65 in position on the pin 63.

Furthermore, the first anchoring device 60 has a plate 69 fastened to the retaining member 64. A spacer element 82, for example made of wood, is arranged
 10 between the retaining member 64 and the plate 69. The thickness of the spacer element 82 is such that the plate 69 is flush with the cover panel 55 of the secondary insulating panels 21. The spacer element 82 has a central seat designed to receive the upper end of the pin 63, the nut 65, the lock washer 68 and the spring washers 66. The spacer element 82 also has boreholes designed to be traversed by screws
 15 83 that enable the plate 69 to be rigidly connected to the retaining member 64.

Furthermore, the plate 69 includes a central threaded borehole that receives the threaded base of a pin 84. The pin 84 passes through a hole formed through a strake of the secondary sealing membrane 18. The pin 84 has a flange 85 that is welded to the periphery thereof, about the hole, to ensure the seal of the secondary
 20 sealing membrane 18. The pin 84 has a threaded upper end onto which is screwed a nut 87 to clamp a retaining member 86 against the cleats 59 of the primary insulating panels 28. The anchoring device 60 also has at least one or more spring washers 88, such as Belleville washers, that are slid onto the pin 84 between the nut 87 and the retaining member 86 and that provide an elastic anchoring of the primary insulating
 25 panels 28 in relation to the plate 69.

Figure 13 shows a second anchoring device 89 that anchors the primary and secondary insulating panels 28, 21 of the non-ballast-zone walls. The second anchoring device 89 differs from the first anchoring device 60, as shown in figure 13, in that there are n2 spring washers 66 between the nut 65 and the retaining member
 30 64.

In this embodiment, the spring washers 66, 88 of the second anchoring device 89 are identical to the spring washers of the first anchoring device 60. Moreover, the number n_2 of spring washers 66 is a whole number that is firstly equal to or greater than 0, and secondly less than n_1 , so that the stiffness K_1 of the first anchoring device 60 is less than the stiffness K_2 of the second anchoring device 60. Thus, the number of spring washers 66, 88 required to build the tank can be reduced.

In other embodiments, as explained previously, the spring washers of the second anchoring device and the spring washers of the first anchoring device are different. In this case, the numbers n_2 and n_1 can also be equal, as long as the stiffness K_1 of the first anchoring device 60 is less than the stiffness K_2 of the second anchoring device 60.

Furthermore, the upper oblique side walls 15, 16 of a tank with such a multi-layer structure can also be anchored using second anchoring devices 89, according to one of the variants described above.

With reference to figure 10, a cut-away view of a liquefied natural gas carrier ship 70 shows a sealed and insulated tank 71 having an overall prismatic shape mounted in the double hull 72 of the ship. The wall of the tank 71 has a primary sealing membrane designed to be in contact with the LNG contained in the tank, a secondary sealing membrane arranged between the primary sealing membrane and the double hull 72 of the ship, and two thermally insulating barriers arranged respectively between the primary sealing membrane and the secondary sealing membrane and between the secondary sealing membrane and the double hull 72.

In a known manner, the loading/offloading pipes 73 arranged on the upper deck of the ship can be connected, using appropriate connectors, to a sea or port terminal to transfer a cargo of LNG to or from the tank 71.

Figure 10 shows an example sea terminal comprising a loading/offloading point 75, an undersea line 76 and an onshore facility 77. The loading/offloading point 75 is a static offshore installation comprising a moveable arm 74 and a column 78 holding the moveable arm 74. The moveable arm 74 carries a bundle of insulated hoses 79 that can connect to the loading/offloading pipes 73. The orientable moveable arm 74 can be adapted to all sizes of liquefied natural gas carrier ships. A connecting

line (not shown) extends inside the column 78. The loading/offloading point 75 makes loading and offloading of the liquefied natural gas carrier ship 70 possible to or from the onshore facility 77. This facility has liquefied gas storage tanks 80 and connection lines 81 connected via the undersea line 76 to the loading/offloading point 75. The
5 undersea line 76 enables liquefied gas to be transferred between the loading/offloading point 75 and the onshore facility 77 over a large distance, for example 5 km, which makes it possible to keep the liquefied natural gas carrier ship 70 a long way away from the coast during loading and offloading operations.

To create the pressure required to transfer the liquefied gas, pumps carried
10 on board the ship 70 and/or pumps installed at the onshore facility 77 and/or pumps installed at the loading/offloading point 75 are used.

Although the invention has been described in relation to several specific embodiments, it is evidently in no way limited thereto and it includes all of the technical equivalents of the means described and the combinations thereof where these fall
15 within the scope of the invention.

Use of the verb "comprise" or "include", including when conjugated, does not exclude the presence of other elements or other steps in addition to those mentioned in a claim.

In the claims, reference signs between parentheses should not be
20 understood to constitute a limitation to the claim.

CLAIMS

1. A sealed, thermally insulating tank (4) carried on a ship, the ship having a double hull (1) comprising an inner hull (3) that forms a load-bearing structure for the sealed, thermally insulating tank (4) and an outer hull (2); the double hull (1)
 - 5 having, in the ballast zones (6), ballast compartments (7) that are designed to receive a liquid, such as sea water, and that are delimited between the inner hull (3) and the outer hull (2); the tank (4) having tank walls (8, 9, 10, 11, 12, 13, 14, 15, 16) that are fastened to the inner hull (3); each of the tank walls having, successively in a thickness direction of the tank wall, at least one thermally insulating barrier (17, 19) that
 - 10 comprises insulating panels (21, 28) fastened to the inner hull and a sealing membrane (18, 20) bearing against the insulating panels (21, 28);
 - said tank walls including ballast-zone walls (9, 11, 12, 13, 14) that are fastened to the inner hull (3) level with at least one of the ballast compartments (7) in a thickness direction of said ballast-zone wall, and non-ballast-zone walls (8, 10) that are fastened
 - 15 to the inner hull (3) level with none of the ballast compartments in the thickness direction of said non-ballast-zone wall;
 - at least one of the insulating panels (28) of the ballast-zone walls (9, 11, 12, 13, 14) being anchored directly or indirectly to the inner hull (3) using first anchoring devices (35, 49);
 - 20 at least one of the insulating panels (28) of the non-ballast-zone wall (8, 10, 15, 16) being anchored directly or indirectly to the inner hull (3) using second anchoring devices (52, 53, 89);
 - in which each of the first anchoring devices (35, 49, 60) is provided with n_1 elastic members (44, 66, 88) arranged to exert an elastic force pressing said ballast-zone
 - 25 wall insulating panel (28) towards the inner hull (3) while enabling a relative movement, in the thickness direction of the tank wall, of said insulating panel (28) in relation to the load-bearing structure during deformation of the inner hull (3); n_1 being a whole number equal to or greater than 1; said first anchoring devices having a stiffness K_1 opposing the relative movement of said insulating panel (28) in relation
 - 30 to the load-bearing structure (3) in the thickness direction of the tank wall; and
 - in which each of the second anchoring devices (52, 53, 89) is provided with n_2 elastic members (44, 66, 88) that are arranged to exert an elastic force pressing said non-

ballast-zone wall insulating panel (28) towards the inner hull (3) while enabling a relative movement of said insulating panel (28) in relation to the load-bearing structure during deformation of the inner hull (3); n_2 is a whole number equal to or greater than 0; said second anchoring devices having a stiffness K_2 opposing the relative
 5 movement of said insulating panel (28) in relation to the load-bearing structure (3) in the thickness direction of the tank wall; the stiffness K_2 being greater than K_1 .

2. The sealed, thermally insulating tank (4) as claimed in claim 1, in which n_2 is less than n_1 .

3. The sealed, thermally insulating tank (4) as claimed in claim 1 or 2,
 10 in which each of the tank walls comprises successively, from the outside towards the inside of the tank, a secondary thermally insulating barrier (17) that includes secondary insulating panels (21) fastened to the inner hull, a secondary sealing membrane (18) that bears against the secondary insulating panels (21), a primary thermally insulating barrier (19) that comprises a plurality of primary insulating panels
 15 (28) bearing against the secondary sealing membrane (18) and a primary sealing membrane (20) that bears against the primary insulating panels (28) and that is designed to come into contact with the liquefied natural gas contained in the tank (4).

4. The sealed, thermally insulating tank (4) as claimed in claim 3, in which the first anchoring devices (35, 49) anchor at least one of the primary insulating
 20 panels of the ballast-zone walls (9, 11, 12, 13, 14) to at least one of the secondary insulating panels (21) of said ballast-zone wall (9, 11, 12, 13, 14); and in which the second anchoring devices anchor at least one of the primary insulating panels (28) of the non-ballast-zone walls (8, 10, 15, 16) to at least one of the secondary insulating panels (21) of said non-ballast-zone wall (8, 10, 15, 16).

25 5. The sealed, thermally insulating tank (4) as claimed in claim 3, in which the first anchoring devices (60) anchor at least one of the secondary insulating panels of the ballast-zone walls (9, 11, 12, 13, 14) to the inner hull (3); and in which the second anchoring devices (89) anchor at least one of the secondary insulating panels of the non-ballast-zone walls (8, 10, 15, 16) to the inner hull (3).

30 6. The sealed, thermally insulating tank (4) as claimed in claim 3 or 5, in which the first anchoring devices (60) anchor at least one of the first insulating

panels of the ballast-zone walls (9, 11, 12, 13, 14) to the inner hull (3); and in which the second anchoring devices (89) anchor at least one of the primary insulating panels of the non-ballast-zone walls (8, 10, 15, 16) to the inner hull (3).

7. The sealed, thermally insulating tank (4) as claimed in any one of
5 claims 1 to 6, in which each of the first and second anchoring devices (35, 49, 52, 53, 60, 89) has a pin (27, 63, 84) that is anchored directly or indirectly to the inner hull (3) and a retaining member (39, 50, 64, 86) that is mounted on the pin (27, 63, 84); said retaining member (39, 50, 65, 86) being held on the pin (27, 63, 84) and cooperating with a bearing surface (41, 57, 59) of said insulating panel (28) anchored by said first
10 or second anchoring device such as to hold same towards the inner hull (3).

8. The sealed, thermally insulating tank (4) as claimed in claim 7, in which the pin (27, 63, 84) has a thread that cooperates with a nut (42, 65, 87) that holds the retaining member (39, 50, 64, 86) towards the inner hull (3).

9. The sealed, thermally insulating tank (4) as claimed in claim 8, in
15 which each elastic member is a spring washer (44, 66, 88) that is engaged on the pin (27, 63, 84), between the nut (42, 65, 87) and the retaining member (39, 50, 64, 86), to provide an elastic force pressing the retaining member against the bearing surface (41, 47, 59).

10. The sealed, thermally insulating tank (4) as claimed in claim 9, in
20 which the first anchoring devices (35, 49) have a spacer sleeve (45) that is slid onto the respective pin (27) and held towards the inner hull (3) by the nut (42), said spacer sleeve (45) having a cylindrical centering portion (47) that is fitted inside the n1 spring washers (44) to center same and an annular flange (48) that presses the n1 spring washers (44) against the retaining member (39, 50).

25 11. The sealed, thermally insulating tank (4) as claimed in any one of claims 7 to 10, in which n2 is equal to 0 and in which each second anchoring device (52, 53) has a spacer sleeve (45) that is slid onto the respective pin (27) and held towards the secondary thermally insulating barrier (17) by the nut (42), and in which the spacer sleeve (45) has a flange (48) bearing against the retaining member (39,
30 50).

12. The sealed, thermally insulating tank (4) as claimed in claims 10 and 11 taken in combination, in which the spacer sleeve (45) of one of the first anchoring devices (35, 49) and the spacer sleeve (45) of one of the second anchoring devices (52, 53) are identical, the flange (48) of said spacer sleeves being off-center in relation to the middle of the spacer sleeve (45) such as to define a cylindrical centering portion that is longer than one half-length of the spacer sleeve, the spacer sleeve of said first anchoring device and the spacer sleeve of said second anchoring device having an inverted orientation such that the cylindrical centering portion (47) of the first anchoring device (35, 49) passes through the n1 spring washers (44) of said first anchoring device (35, 49) and the cylindrical centering portion (47) of the second anchoring device (52, 53) is arranged between the flange (48) and the nut (42).

13. The sealed, thermally insulating tank (4) as claimed in any one of claims 1 to 12, in which said tank walls also have mixed walls (15, 16) that have a portion not level with any of the ballast compartments and a portion level with at least one of the ballast compartments; and in which at least one of the insulating panels of the mixed walls (15, 16) is anchored directly or indirectly to the inner hull by means of second anchoring devices (52, 53, 89).

14. The sealed, thermally insulating tank (4) as claimed in any one of claims 1 to 13, in which the tank (4) has an overall polyhedral shape and has an upper wall (8), a lower wall (9), front and rear transverse walls (10) extending transversely to the longitudinal direction of the ship and side walls (11, 12, 13, 14, 15, 16), the upper wall (8), the lower wall (9) and the side walls (11, 12, 13, 14, 15, 16) extending in the longitudinal direction of the ship and linking the front and rear transverse walls (10), and in which the front transverse wall, the rear transverse wall (10) and the upper wall (8) are each one of the non-ballast-zone walls.

15. The sealed, thermally insulating tank (4) as claimed in claim 14 taken in combination with claim 13, in which the tank (4) has at least four side walls (11, 12, 13, 14, 15, 16), two of said side walls being vertical side walls (13, 14) and two of said sidewalls being upper oblique side walls (15, 16), each of which links the upper wall (8) to one of said vertical side walls (13, 14); each of said two upper oblique side walls (15, 16) being one of the mixed walls.

16. A ship (70) used to transport a fluid, the ship having a double hull (72) and a tank (71) as claimed in any one of claims 1 to 15, placed inside the hull.

17. A transfer system for a fluid, the system including a ship (70) as claimed in claim 16, insulated pipes (73, 79, 76, 81) arranged to connect the tank (71)
5 installed in the hull of the ship to an onshore or floating storage facility (77) and a pump for driving a fluid through the insulated pipes to or from the onshore or floating storage facility to or from the tank on the ship.

18. A method for loading or offloading a ship (70) as claimed in claim 16, in which a fluid is channeled through insulated pipes (73, 79, 76, 81) to or from an
10 onshore or floating storage facility (77) to or from the tank on the ship (71).