Description

Title of the invention: Tank wall comprising a through-conduit

Technical domain

[0001] The invention relates to the manufacture of sealed and thermally insulating tanks. In particular, the present invention relates to tanks designed to contain hot or cold liquids, and more specifically tanks for storing and/or transporting liquefied gases in a load-bearing structure, by sea.

Technological background

[0002] Sealed and thermally insulating tanks can be used in different industries to store hot or cold products. For example, in the energy sector, such a product may be liquefied natural gas (LNG). Liquefied natural gas (LNG) is a liquid that can be stored at atmospheric pressure at approximately -163°C in onshore storage tanks or in tanks carried on board floating structures. Such floating structures in particular include barges, liquefied natural gas carriers for transporting the product, and offshore facilities, known by the acronyms FPSO and FSRU, for storage, liquefaction, or regasification of the product.

[0003] These sealed and thermally insulating tanks are made of one or several sealed membranes associated with insulating layers. A sealed and thermally insulating tank comprising a tank wall fastened to a load-bearing structure, in which the tank wall has a multi-layer structure comprising successively a primary sealed membrane intended to be in contact with the product contained in the tank, a primary thermally insulating barrier, a secondary sealed membrane, and a secondary thermally insulating barrier is known, in particular from document FR 2781557 A.

[0004] The sealed membranes have sufficient elasticity to withstand stresses resulting from, for example, hydrostatic pressure, dynamic pressure in the event of cargo movement, and/or temperature variations. However, such sealed membranes and the underlying thermal insulation material are relatively fragile and cannot necessarily bear the weight of a pylon, such as the LNG tank loading/unloading pylon. For this purpose a support foot can be provided, as in document FR 2961580 A.

[0005] Moreover, the thermodynamic conditions of the sealed and thermally insulating tanks during the storage of such a liquid lead to a certain amount of vapor evaporating, which results in variations in the internal pressure of the tanks. In order to control the pressure

of these tanks, the evaporation gases are collected and conveyed to an evaporation manifold to be reliquefied or burned in the propulsion engine of a ship, for example. For this purpose, a manifold conduit can be provided, as in document FR 2984454 A.

[0006] Therefore, there are different functions that may require a through-conduit to pass through the multi-layer structure of the tank wall.

Summary

[0007] In the aforementioned tanks, deformations of all the elements occur due to the temperature changes affecting the tank wall when the tank is filled with a very cold liquid such as LNG and, conversely, when the tank is emptied, resulting in a return to ambient temperature. In addition to these thermal contraction and expansion effects, which are repeated over the service life of the sealed and thermally insulating tank, the tanks in ships are also subject to stresses due to the deformation of the hull of the ship at sea. This results in the fatiguing of the elements, which has to be monitored over time to prevent failure.

[0008] One idea behind the invention is to increase the fatigue strength of the tank wall in the zone about which the through-conduit passes through the multi-layer structure.

[0009] According to one embodiment, the invention provides a sealed and thermally insulating tank arranged in a load-bearing structure to contain a fluid, the sealed and thermally insulating tank comprising

a tank wall anchored against the load-bearing structure, the tank wall having a multi-layer structure comprising successively, in a thickness direction from the outside to the inside of said sealed and thermally insulating tank, a secondary thermally insulating barrier, a secondary sealed membrane carried by the secondary thermally insulating barrier, a primary thermally insulating barrier carried by the secondary sealed membrane, and a primary sealed membrane carried by the primary thermally insulating barrier and which is intended to be in contact with the fluid contained in said sealed and thermally insulating tank, the multi-layer structure comprising a primary space arranged between the primary sealed membrane and the secondary sealed membrane, the primary space containing the primary thermally insulating barrier, and

a through-conduit arranged through the tank wall, the primary sealed membrane being sealingly connected to the through-conduit,

said tank wall comprising about the through-conduit

secondary thermally insulating blocks anchored against the load-bearing structure, the secondary thermally insulating blocks forming the secondary thermally insulating barrier about the through-conduit, each of said secondary thermally insulating blocks having at

least one lateral side extending in the thickness direction of the tank wall, said secondary thermally insulating blocks being arranged in relation to one another so as to form a shaft between the opposing lateral sides of two adjacent secondary thermally insulating blocks,

a sealing layer covering the secondary thermally insulating blocks, the sealing layer forming the secondary sealed membrane,

a sealing plate arranged parallel to the tank wall, the sealing plate having an inner surface facing the inside of said sealed and thermally insulating tank, the inner surface being located at the same level as the sealing layer, the sealing plate being arranged about the through-conduit, the secondary sealed membrane being extended to the sealing plate,

an outer conduit extending parallel to the through-conduit about the through-conduit towards the outside of said sealed and thermally insulating tank from the sealing plate, the outer conduit being in communication with the primary space to allow an inerting gas to flow between the primary space and the outer conduit,

primary thermally insulating blocks arranged on the secondary sealed membrane, the primary thermally insulating blocks forming the primary thermally insulating barrier about the through-conduit, a first and a second of said primary thermally insulating blocks having a lateral side extending in the thickness direction of the tank wall, the lateral side having a cut-out portion intended to receive a portion of the through-conduit and at least one interface portion adjacent to the cut-out portion, the interface portion of said first primary thermally insulating block being arranged opposite the interface portion of said second primary thermally insulating block,

said secondary thermally insulating blocks and said first and second primary thermally insulating blocks being arranged in relation to one another such that the interface portion of said first primary thermally insulating block and the interface portion of said second primary thermally insulating block have no overlap, in the thickness direction, with the shaft between two adjacent secondary thermally insulating blocks.

[0010] These features help to increase the fatigue resistance of the secondary sealed membrane, while maintaining a flexible sealing membrane layer arranged across the secondary thermally insulating blocks. Indeed, the absence of any overlap, in the thickness direction, between the interface portions of two adjacent primary thermally insulating blocks and the shafts of the adjacent secondary thermally insulating blocks obviates the risk of increased stress on the secondary sealed membrane due to thermal contractions or compressive forces.

[0011] According to the embodiments, such a sealed and thermally insulating tank may have one or more of the following features.

[0012] According to one embodiment, the sealing layer is a first sealing layer covering the secondary thermally insulating blocks, in which said tank wall comprises a second sealing layer sealingly fastened across the first sealing layer and the inner surface of the sealing plate about the through-conduit, the second sealing layer extending the secondary sealed membrane to the sealing plate.

[0013] According to one embodiment, the second sealing layer comprises at least two sealing strips, each sealing strip being arranged across two adjacent secondary thermally insulating blocks.

[0014] According to one embodiment, the second sealing layer has two sealing strips that are aligned with one another, on both sides of the through-conduit so as to cover the shaft.

[0015] According to one embodiment, the two sealing strips of the second sealing layer are positioned perpendicular to said at least one interface portion of the first primary thermally insulating block and said at least one interface portion of the second primary thermally insulating block.

[0016] According to one embodiment, the tank wall comprises two prefabricated panels arranged on either side of the through-conduit, each of the prefabricated panels comprising a lower thermally insulating block forming a secondary thermally insulating block, the first sealing layer covering the secondary thermally insulating block, and an upper thermally insulating block arranged on a central zone of the first sealing layer and of the lower thermally insulating block without covering a peripheral zone of said first sealing layer, the upper thermally insulating block being part of the primary thermally insulating barrier, said primary thermally insulating blocks being arranged between the upper thermally insulating blocks of the two prefabricated panels on said peripheral zone of the first sealing layer of the two prefabricated panels and on said shaft.

[0017] According to one embodiment, the primary sealed membrane has sealing plates sealingly connected to each other at edges of the sealing plates, and the upper thermally insulating blocks of the two prefabricated panels have anchoring strips at said edges of the sealing plates to anchor the sealing plates to said prefabricated panels, the primary thermally insulating blocks having thermal protection strips at said edges of the sealing plates so that the sealing plates are not anchored to said primary thermally insulating blocks.

[0018] According to one embodiment, the primary sealed membrane comprises at least one series of corrugations comprising corrugations extending along directrices parallel to each other, said corrugations projecting towards the inside of said sealed and thermally insulating tank, and in which a window interrupts at least one directrix of a corrugation of said series of corrugations, said corrugation preferably having an open end at the window, said sealed and thermally insulating tank having at least one end piece for closing the open end of said at least one corrugation.

[0019] According to one embodiment, the window interrupts at least two directrices of corrugations of said at least one series of corrugations, and the through-conduit is centered on a position between two of said directrices of interrupted corrugations.

[0020] The arrangements and features described above for a series of parallel corrugations can, if necessary, be applied to several series of parallel corrugations extending in different directions.

[0021] According to one embodiment, the primary sealed membrane has a first series of corrugations and a second series of corrugations intersecting the first series of corrugations, the window interrupts at least two directrices of the corrugations of the first series of corrugations and at least two corrugation directrices of the second series of corrugations, and the through-conduit is centered at a position between two interrupted directrices of the corrugations of said first series of corrugations and two interrupted directrices of the corrugations of the directrices of said second series of corrugations.

[0022] According to one embodiment, the directrices of the corrugations of the first series of corrugations are perpendicular to the directrices of the corrugations of the second series of corrugations.

[0023] The aforementioned window can have different shapes, notably as a function of the shape of the through-conduit and/or the shape of the components of the primary sealed membrane.

[0024] According to one embodiment, the window is a quadrilateral with two sides parallel to the directrices of the corrugations of the first series of corrugations and two sides parallel to the directrices of the corrugations of the second series of corrugations. In particular, the window can be a square, a rectangle or a parallelogram.

[0025] According to one embodiment, the through-conduit has a circular section and passes through the center of the window.

[0026] According to one embodiment, the outer conduit comprises a first peripheral linking plate and a second peripheral linking plate, the second peripheral linking plate being

sealingly fastened to the first peripheral linking plate about the entirety of said first peripheral linking plate, the first peripheral linking plate extending parallel to the through-conduit towards the outside of said sealed and thermally insulating tank from the second peripheral linking plate, said second peripheral linking plate being sealingly fastened to the sealing plate and projecting towards the load-bearing structure parallel to the through-conduit.

[0027] According to one embodiment, the tank wall also has at least one closing plate that is arranged about the through-conduit on the primary thermally insulating blocks and that is linked sealingly to the through-conduit.

[0028] According to one embodiment, the closing plate consists of a one-piece metal plate surrounding the through-conduit.

[0029] According to one embodiment, at least one of said primary thermally insulating blocks has at least one slot, and the closing plate has at least one slot covered by one end piece and superposed on said slot of the primary thermally insulating block so as to allow an inerting gas to flow between the corrugation and the outer conduit.

[0030] According to one embodiment, the tank wall has a thermal protection sheet interposed between the primary thermally insulating blocks and the closing plate.

[0031] Advantageously, the thermal protection sheet is wrapped in one piece about the through-conduit.

[0032] Advantageously, the thermal protection sheet comprises at least one slot superposed on one slot of the primary thermally insulating block and positioned under one slot of the closing plate.

[0033] According to one embodiment, the through-conduit forms a passage between the inside of the sealed and thermally insulating tank and a vapor manifold arranged outside said sealed and thermally insulating tank.

[0034] Such a tank may be part of an onshore storage facility, for example for storing liquefied gas, or be installed on a coastal or deep-water floating structure, notably a liquefied natural gas carrier, an LPG transport ship, a floating storage and regasification unit (FSRU), a floating production, storage and unloading (FPSO) unit, inter alia.

[0035] According to one embodiment, the invention also provides a ship used to transport a cold liquid product, the ship having a double hull and a sealed and thermally insulating tank arranged in the double hull.

[0036] According to one embodiment, the invention also provides a use for a ship for loading or unloading a cold liquid product, in which a cold liquid product is channeled through insulated pipes to or from an onshore or floating storage facility to or from the sealed and thermally insulating tank on the ship.

[0037] According to one embodiment, the invention also provides a transfer system for a cold liquid, the system including a ship, insulated pipes arranged to connect the sealed and thermally insulating tank installed in the hull of the ship to an onshore or floating storage facility, and a pump for driving a flow of cold liquid product through the insulated pipes to or from the onshore or floating storage facility to or from the sealed and thermally insulating tank on the ship.

Short description of the figures

[0038] 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 fastened drawings.

[0039] [Figure 1] Figure 1 is a cross-section view of a tank wall according to one embodiment of the invention comprising a fluid collection device.

[0040] [Figure 2] Figure 2 is an enlarged cross-section view of the zone II in Figure 1.

[0041] [Figure 3] Figure 3 is a partial exploded perspective view of the tank wall zone shown in Figure 2.

[0042] [Figure 4] Figure 4 is a plan view along the axis of the through-conduit of the zone of the tank wall shown in Figure 2 showing the secondary thermally insulating barrier about the through-conduit, omitting the primary thermally insulating barrier.

[0043] [Figure 5] Figure 5 is a view similar to Figure 4 showing the primary thermally insulating barrier.

[0044] [Figure 6] Figure 6 is an exploded perspective view of a primary thermally insulating block that can be used in the primary thermally insulating barrier.

[0045] [Figure 7] Figure 7 is a view similar to Figure 5 showing the positioning of the thermal protection sheet and the thermal protection strips on the primary thermally insulating barrier.

[0046] [Figure 8] Figure 8 is a view similar to Figure 7 at an intermediate stage of assembly of the primary sealed membrane.

[0047] [Figure 9] Figure 9 is a view similar to Figure 8 at a more advanced stage of assembly of the primary sealed membrane.

[0048] [Figure 10] Figure 10 is a view similar to Figure 9 showing the primary sealed membrane.

[0049] [Figure 11] Figure 11 is a perspective view of an end piece that may be used in the manufacture of the primary sealed membrane shown in Figure 10.

[0050] [Figure 12] Figure 12 is a cut-away schematic view of a tank in a liquefied natural gas carrier and of a loading/unloading terminal for this tank.

Description of embodiments

[0051] With reference to Figure 1, a sealed and thermally insulating tank 1 has tank walls 2 fastened to the inner surface of corresponding walls of a load-bearing structure 3. The load-bearing structure 3 is for example the inner hull of a double-hulled ship or an on-shore structure. Figure 1 is a partial view of the sealed and thermally insulating tank 1 showing only a ceiling wall.

[0052] By convention, the terms "on," "above," "upper," and "top" usually refer to a position toward the inside of the sealed and thermally insulating tank 1, while the terms "under," "below," "lower," and "bottom" usually refer to a position toward the outside of the sealed and thermally insulating tank 1, regardless of the orientation of the tank wall 2 relative to the Earth's gravitational field.

[0053] The sealed and thermally insulating tank 1 may have different geometries, for example a prismatic geometry in the hull of a ship or a cylindrical geometry on land, or otherwise.

[0054] The following embodiments are described in relation to a sealed and thermally insulating tank 1 intended for the storage and/or transport of liquefied natural gas by sea. In variants that are not described, such a sealed and thermally insulating tank 1 may be a tank used to store other cold or hot products on land.

[0055] Figures 1 and 2 show a fluid collection device 4. Such a device comprises a through-conduit 5 passing through a tank wall 2, for example the ceiling wall of the sealed and thermally insulating tank 1.

[0056] With reference to Figure 1, the tank wall 2 has, successively, in a thickness direction from the inside of the sealed and thermally insulating tank 1 towards the load-bearing structure 3, a primary sealing membrane 6 in contact with the liquefied gas, a primary thermally insulating barrier 7, a secondary sealed membrane 8, and a secondary

thermally insulating barrier 9. The primary thermally insulating barrier 7, the secondary sealed membrane 8, and the secondary thermally insulating barrier 9 are essentially a set of prefabricated panels resting on mastic beads 11 and fastened to the load-bearing structure 3.

[0057] The fluid collection device 4 comprises a barrel 12 that extends outside the load-bearing structure 3, as well as the through-conduit 5, anchored inside the barrel 12. The barrel 12 and the through-conduit 5 are cylinders of circular section. However, other shapes are possible The load-bearing structure 3 has a circular opening 13. The barrel 12 is welded about the circular opening 13. The through-conduit 5 passes through the tank wall 2 at the center of the circular opening 13. Thus, the through-conduit 5 passes through the primary sealed membrane 6, the secondary sealed membrane 8, the primary thermally insulating barrier 7, and the secondary thermally insulating barrier 9, into the sealed and thermally insulating tank 1. In particular, the through-conduit 5 is connected to a vapor manifold outside the sealed and thermally insulating tank, which extracts this vapor and conveys the vapor to the propulsion system of the ship to power the ship or to a liquefaction system to subsequently return the liquefied gas to the tank.

[0058] The primary sealed membrane 6 is sealingly connected to the through-conduit 5. The secondary sealed membrane 8 is also sealingly connected to the through-conduit 5 except in a passage allowing a gas phase between the primary sealed membrane 6 and the secondary sealed membrane 8 to flow towards two secondary conduits 14, 15. The gas phase is typically dinitrogen or another inert gas. Thus, the space between the primary sealed membrane 6 and the secondary sealed membrane 8 forms a primary sealed space connected to the two secondary conduits 14, 15.

[0059] Furthermore, the barrel 12 is sealingly connected to the load-bearing structure 3. A layer of insulation 16 is evenly distributed over the outside of the through-conduit 5, which has a smaller diameter than the circular opening 13. In this way, the gap between the layer of insulation 16 and the circular opening 13 allows a gas phase to flow between the secondary thermally insulating barrier 9 and an intermediate space between the barrel 12 and the layer of insulation 16. The gas phase is typically dinitrogen or another inert gas. The intermediate space and the space between the load-bearing structure 3 and the secondary thermally insulating barrier 9 thus form a secondary sealed space.

[0060] The two secondary conduits 14, 15 extend parallel to the through-conduit 5 in the layer of insulation 16 from the outside of the barrel 12 to the primary sealed space. The first secondary conduit 14 provides a passage between the primary sealed space and a discharge member (not shown) that controls the gas phase in the primary space. The

second secondary conduit 15 provides a passage between the primary space and a pressure measurement device (not shown). In particular, these two secondary conduits 14, 15 enable the primary sealed space to be flushed with an inert gas, for example nitrogen.

[0061] Two other conduits (not shown) are welded to the barrel 12 and open into the secondary sealed space inside the barrel 12, also to enable management of the gas phase and measurement of the pressure in the secondary sealed space. The conduits linked to the secondary sealed space also enable the secondary sealed space to be flushed with an inert gas, for example nitrogen.

[0062] A zone II of the tank wall 2 through which the through-conduit 5 passes is described in more detail below with reference to Figures 2 to 10.

[0063] Two prefabricated panels 10a, 10b are placed near to the through-conduit 5. With reference to Figure 4, the prefabricated panel 10a, 10b has a secondary thermally insulating block 17 anchored against the load-bearing structure 3. The secondary thermally insulating block 17 has a rigid bottom panel 18 supported by the mastic beads 11 and a thermal insulation layer 19 made of polyurethane foam.

[0064] A first sealing layer 20 of composite material comprising, for example, a metal sheet and glass fiber layers soaked in resin adheres to the entire surface of the thermal insulation layer 19 of the secondary thermally insulating block 17. The first sealing layer 20 is a component of the secondary sealed membrane 8.

[0065] The prefabricated panel 10a, 10b also includes an upper thermally insulating block 21a, 21b. The upper thermally insulating block 21a, 21b has a thermal insulation layer 22 made of polyurethane foam that partially covers and adheres to the first sealing layer 20. A rigid top panel 23 covers the thermal insulation layer 22 and forms an element of the primary thermally insulating barrier 7 therewith.

[0066] As explained above with reference to Figure 1, the through-conduit 5 passes through the circular opening 13, the secondary thermally insulating barrier 9, the secondary sealed membrane 8, the primary thermally insulating barrier 7, and the primary sealed membrane 6. A circular closing plate 24 extends about the through-conduit 5 in a zone beyond the load-bearing structure 3. The closing plate 24 has an upper surface parallel to the tank wall 2, to which the layer of insulation 16 surrounding the through-conduit 5 is bonded. This closing plate 24 also has two orifices 25, 26 to which the two secondary conduits 14, 15 are welded.

[0067] The seal between the secondary thermally insulating barrier 9 and the through-conduit 5 is achieved by means of the closing plate 24, a first peripheral linking plate 27, a second peripheral linking plate 28, and a sealing plate 29. The first peripheral linking plate 27, which is tubular, is sealingly fastened to the closing plate 24 about the entire periphery thereof, and extends parallel to the through-conduit 5 into the sealed and thermally insulating tank 1 to form an outer conduit. Said peripheral linking plate is linked, at the end thereof opposite the closing plate 24 and via the second peripheral linking plate 28, which is also tubular, to the circular sealing plate 29 Thus, the closing plate 24, the sealing plate 29, and the peripheral linking plates 27, 28 form an inner space 30 in the outer conduit that is adjacent to the outer wall of the through-conduit 5. A second sealing layer 31 is sealingly fastened across the first sealing layer 20 and the sealing plate 29 to seal the secondary sealed membrane 8.

[0068] The sealing plate 29 has a circular passage 32 traversed by the through-conduit 5. The diameter of this circular passage 32 is larger than the diameter of the through-conduit 5 so as to leave a gap between the sealing plate 29 and the through-conduit 5. This gap enables the gas phase to flow from the primary sealed space between the primary sealed membrane 6 and the secondary sealed membrane 8 towards the inner space 30.

[0069] To discharge the vapors from the inner space 30, the two secondary conduits 14, 15 are connected sealingly to the closing plate 24. This architecture enables flushing with an inert gas. To provide insulation, the inner space 30 is filled with vapor- and gas-permeable insulation.

[0070] The second peripheral linking plate 28 is tubular and is welded to the lower surface of the sealing plate 29. The diameter of the inside of the second peripheral linking plate 28 is substantially equal to the external diameter of the first peripheral linking plate 27. Thus, the peripheral linking plates 27, 28 can be fitted together and cooperate slidingly where not welded. Thus, when welding the second peripheral linking plate 28 to the first peripheral linking plate 27, the gap between the sealing plate 29 and the load-bearing structure 3 can be adjusted to bring the sealing plate 29 precisely in line with the secondary sealed membrane 8. Moreover, fitting the first peripheral linking plate 27 and the second peripheral linking plate 28 together enables the through-conduit 5 to be centered on the opening 13, as well as enabling orientation of the sealing plate 29. The welds between the closing plate 24 and the first peripheral linking plate 27, between the first peripheral linking plate 27 and the second peripheral linking plate 28, and between the second peripheral linking plate 28 and the sealing plate 29 are made in such a way as to form a seal between these elements.

[0071] The closing plate 24, the sealing plate 29, the first peripheral linking plate 27, and the second peripheral linking plate 28 are metal elements, for example made of stainless steel.

[0072] With reference to Figure 1, to reduce the stresses exerted on the bonds made about the through-conduit 5, the through-conduit is anchored at a portion 33 of the through-conduit spaced apart from the load-bearing structure 3 in a direction away from the inside of the sealed and thermally insulating tank 1. This reduces the stress on the bonding of the tank wall 2. This anchoring comprises a frustoconical metal element 34 extending into the barrel 12.

[0073] With reference to Figures 1 and 2, fins 40 are arranged regularly in the inner space 30 between the through-conduit 5 and the first peripheral linking plate 27 to position and secure the first peripheral linking plate 27 relative to the through-conduit 5.

[0074] With reference to Figures 2 to 5, two primary thermally insulating blocks 35 are arranged across the secondary thermally insulating blocks 17 of the prefabricated panels 10a, 10b and the sealing plate 29 to form the primary thermally insulating barrier 7 between the through-conduit 5 and the prefabricated panels 10a, 10b. Like the upper thermally insulating block 21a, 21b, the primary thermally insulating block 35 has an insulating layer 36 bearing against the secondary thermally insulating barrier 9. A top panel 37 is arranged on top of the insulating layer 36.

[0075] The upper thermally insulating blocks 21a, 21b of the prefabricated panels 10a, 10b and the primary thermally insulating blocks 35 support the primary sealed membrane 6 made of metal plates with corrugations 38a, 38b. These corrugations 38a, 38b form elastic zones designed to absorb thermal contractions, and static and dynamic compressive forces. Such corrugated or chequered sheet metal sealing barriers are described in particular in FR 1379651 A, FR 1376525 A, FR 2781557 A and FR 2861060 A.

[0076] The primary sealed membrane 6 is sealingly connected to the through-conduit 5 by means of a flange 39 with an L-shaped cross section. The flange 39 is welded to the primary sealed membrane 6 and to the through-conduit 5.

[0077] Figure 3 shows the structure of the elements forming the tank wall 2 about the through-conduit 5 in greater detail.

[0078] The through-conduit 5 and the first peripheral linking plate 27 pass through the load-bearing structure 3 at the center of the opening 13. The first peripheral linking plate 27 is centered on the opening.

[0079] Glass wool packing is inserted into the inner space 30. As previously mentioned, this packing is porous to enable the gas phase to flow freely in the inner space 30 between the primary sealed space and the secondary conduits 14, 15 (not shown in Figure 3).

[0080] The sealing plate 29 is positioned to be precisely aligned with the secondary sealed membrane 8 by welding the second peripheral linking plate 28 to the first peripheral linking plate 27. To avoid the risk of burning the glass wool packing, thermal protection (not shown) is placed between the packing and the peripheral linking plates 27, 28.

[0081] With reference to Figures 3 to 5, the secondary thermally insulating barrier 9, the secondary sealed membrane 8, and the primary thermally insulating barrier 7 are made of two prefabricated panels 10a, 10b. Each of the prefabricated panels 10a, 10b about the through-conduit 5 is step-shaped with a secondary thermally insulating block 17 constituting an element of the secondary thermally insulating barrier 9, a first sealing layer 20 completely covering the upper surface of the secondary thermally insulating block 17, and a smaller upper thermally insulating block 21a, 21b constituting an element of the primary thermally insulating barrier 7. The upper thermally insulating block 21a, 21b of the prefabricated panel 10a, 10b has a U-shaped section when viewed from above and is positioned relative to the secondary thermally insulating block 17 so as to leave a peripheral zone of the first sealing layer 20 exposed.

[0082] Specifically, each secondary thermally insulating block 17 has a side 41 with a semicircular cutout to accommodate the first peripheral linking plate 27 and the second peripheral linking plate 28. The semicircle has a diameter greater than the diameter of the first peripheral linking plate 27 and the second peripheral linking plate 28, as shown in Figure 2, leaving a space for glass wool packing 73 to be inserted between the first and second peripheral linking plates 27, 28 and the secondary thermally insulating blocks 17.

[0083] The two secondary thermally insulating blocks 17 are designed to form spaces between said blocks in the form of two radial inter-panel shafts 42a, 42b. To ensure continuity of the secondary thermally insulating barrier 9, each of the two radial inter-panel shafts 42a, 42b is filled with glass wool packing (not shown) allowing the gas phase to flow through the secondary thermally insulating barrier 9, in particular for inerting the tank wall with an inert gas such as nitrogen.

[0084] The prefabricated panel 10a, 10b can be prefabricated by bonding with polyurethane foam and plywood for the primary and secondary thermally insulating barriers 7, 9. Thus, the secondary thermally insulating block 17 comprises the bottom panel 18 and the insulating foam layer 19 and the upper thermally insulating block 21a, 21b comprises the

insulating layer 22 and the top panel 23. The top panel 23 of the upper thermally insulating block 21a, 21b has transverse and longitudinal spotfaces designed to receive anchoring strips 43, onto which the primary sealed membrane 6 is welded, as described below.

[0085] The two prefabricated panels 10a, 10b are juxtaposed to surround the through-conduit 5. Each prefabricated panel 10a, 10b also has shafts 44 that enable access, during assembly, to the pins 71 previously welded to the load-bearing structure to anchor the prefabricated panels 10a, 10b.

[0086] The second sealing layer 31 is bonded across the first sealing layer 20 and to the sealing plate 29. The second sealing layer 31 also includes two radial sealing strips 31a, 31b arranged across the two secondary thermally insulating blocks 17 above the shafts 42a and 42b.

[0087] Two primary thermally insulating blocks 35 and two middle blocks 45 are positioned above the second sealing layer 31 and the first sealing layer 20 to complete the primary thermally insulating barrier 7. The middle blocks 45 are installed on the radial sealing strips 31a, 31b of the second sealing layer 31.

[0088] With reference to Figure 6, each of the primary thermally insulating blocks 35 has a lateral side 46 with a semicircular cutout 76 to accommodate the through-conduit 5, and straight interface portions 47 adjacent to the cutout 76. When the primary thermally insulating blocks 35 are assembled, the cutouts 76 define a diameter that is larger than the diameter of the through-conduit 5, as shown in Figure 2.

[0089] With reference to Figure 5, the two primary thermally insulating blocks 35 are designed to meet without touching at two interface portions 47. The two primary thermally insulating blocks 35 are positioned above the second sealing layer 31 such that the interface portions 47 have no overlap, in the thickness direction, with the radial inter-panel shafts 42a, 42b. In Figure 3, the direction D_1 of the interface portions 47 of the primary thermally insulating blocks 35 is perpendicular to the direction D_2 of the radial inter-panel shafts 42a, 42b.

[0090] With reference to Figures 9 and 10, the primary sealed membrane 6 is formed by a plurality of corrugated sealing plates 48, the inner faces of which is intended to be in contact with the fluid contained in the sealed and thermally insulating tank 1. The sealing plates 48 are thin metal elements, such as stainless-steel sheet. These corrugated sealing plates 48 are cut to form a square window 49 about the through-conduit 5 to allow the through-conduit 5 to pass through. In this case, the window 49 is square, which facilitates the cutting of the sealing plates 48 to the desired shape. However, the

windows 49 may be of different shapes, depending in particular on the geometry of the through-conduit 5.

[0091] The sealing plates 48 of the primary sealed membrane 6 have a plurality of corrugations 38a, 38b projecting towards the inside of the sealed and thermally insulating tank 1. More particularly, the primary sealed membrane 6 has a first series of corrugations 38a referred to as transverse corrugations and a second series of corrugations 38b referred to as longitudinal corrugations that are arranged perpendicular to one another. The first series of corrugations 38a is taller than the second series of corrugations 38b.

[0092] In Figure 9, the edges of the sealing plates 48 are shown using continuous lines. The sealing plates 48 are welded together in marginal overlap zones 77 to seal the primary sealed membrane 6. The welds are lap welds, and the related method is described in detail in patent FR 1387955 A, for example. The sealing plates 48 can be made in various shapes and sizes, and therefore the welding zones can be positioned differently.

[0093] Unlike the upper thermally insulating blocks 21a, 21b of the prefabricated panels 10a, 10b, the primary thermally insulating blocks 35 do not have anchor strips 43. In fact, to make the primary sealed membrane 6 about the through-conduit 5, a closing plate 51, as shown in Figures 3 and 8 to 10, placed on a thermal protection sheet 72, delimits a square of slightly larger size than the window 49 provided in the sealing plates 48. An opening is cut in the center of the closing plate 51 to allow the passage of the through-conduit 5. The closing plate 51 is sealingly welded to the through-conduit 5 via the flange 39.

[0094] With reference to Figures 7 to 9, the sealing plates 48 of the primary sealed membrane 6 are welded to the anchor strips 43 of the upper thermally insulating blocks 21a, 21b and the middle blocks 45. The welding of the sealing plates 48 to the anchor strips 43 enables the primary sealed membrane 6 to be held on the primary thermally insulating barrier 7. To prevent damage being caused, in particular, to the primary thermally insulating blocks 35 when the sealing plates 48 are welded together, thermal protection strips 50 are arranged on the primary thermally insulating blocks 35 at the edges of the sealing plates 48. The thermal protection sheet 72 and the thermal protection strips 50 are made of a heat-resistant material, for example a composite glass-fiber material. An opening is cut in the center of the thermal protection sheet 72 to allow the through-conduit 5 to pass through.

[0095] The primary sealed membrane 6 about the through-conduit 5 is completed firstly by welding the edges of the sealing plates 48 delimiting the window 49 to the closing plate

51, and secondly by sealingly closing the ends of the interrupted corrugations 38a, 38b with end pieces 52. Indeed, since the diameter of the through-conduit 5 is larger than the gap between the corrugations of the first series of corrugations 38a, some of the transverse corrugations with a directrix intersecting the through-conduit are interrupted by the window 49. Similarly, since the diameter of the through-conduit 5 is greater than the gap between the corrugations of the second series of corrugations 38b, some of the longitudinal corrugations with a directrix intersecting the through-conduit 5 are interrupted by the window 49 surrounding the through-conduit 5.

[0096] With reference to Figure 11, the end piece 52 has a two-part base plate 53, 54 designed to be sealingly welded respectively to the closing plate 51 and a sealing plate 48, and a shell 55 designed to be sealingly welded to the end of the corrugation. An indentation 56 between the portions 53, 54 of the base plate has a width substantially equal to the thickness of the sealing plate 48.

[0097] With reference to Figures 3, 5 and 6, the top panel 37 of a primary thermally insulating block 35 has four slots 57 extending through the top panel 37, the closing plate 51 has slots 69 superposed on the slots 57 of the primary thermally insulating blocks 35, and the thermal protection sheet 72 has slots 70 superposed on the slots 57 of the primary thermally insulating blocks 35 and positioned below the slots 69 of the closing plate 51. During installation of the primary sealed membrane 6, the end pieces 52 are superposed on the slots 57, 69, 70 so as to enable the gas phase in the corrugations 38a, 38b to flow towards the insulating layer 36 of the primary thermally insulating block 35. The insulating layer 36 also has connecting slots 74 positioned below the slots 57 of the top panel 37 from which three parallel slots 75 extend respectively towards the semicircular cutout 76 in the primary thermally insulating block 35. Thus, the gas phase that has passed through the top panel 37 can flow to the outside of the primary thermally insulating block 35, into the space between the primary thermally insulating block 35 and the through-conduit 5.

[0098] This specific structure of the primary thermally insulating blocks 35 coupled with the gap between the circular passage 32 and the through-conduit 5, and with the inner space 30 comprising a porous packing creates a circuit facilitating the flow of the gas phase in the primary sealed space, in particular from the corrugations 38a, 38b to the secondary conduits 14, 15, and vice versa. Similarly, as described above, the space between the opening 13 and the first peripheral linking plate 27 and between the load-bearing structure 3 and the secondary thermally insulating blocks 17 creates a circuit facilitating the flow of this gas phase between the secondary sealed space and the barrel

12. These circuits in particular enable the tank wall 2 to be inerted with an inert gas such as dinitrogen.

[0099] Figures 9 and 10 show that the size of the window 49 is in practice larger than the diameter of the through-conduit 5. Thus, the window 49 formed in the primary sealed membrane 6 would be liable to also interrupt corrugations in which the directrix is very close to the through-conduit 5 without actually intersecting the through-conduit 5.

[0100] The center of the through-conduit 5 is positioned between the directrices of the interrupted transverse corrugations 38a and between the directrices of the interrupted longitudinal corrugations 38b, and more precisely in the middle of these directrices, as illustrated in Figures 9 and 10. As a result of this positioning, the directrix intersects the through-conduit 5 in each case along a chord shorter than the diameter of the through-conduit 5. As a result, and in consideration of the space between the edge of the window 49 and the through-conduit 5, this positioning of the through-conduit 5 makes it possible to interrupt transverse corrugations 38a or longitudinal corrugations 38b over a shorter distance than in the case where the directrix intersects the through-conduit 5 along the greatest transverse or longitudinal dimension thereof, i.e. the diameter thereof, since the through-conduit 5 in this case is a cylinder of circular section. It is beneficial to interrupt the corrugations 38a, 38b of the primary sealed membrane 6 over the shortest possible distance, given that these interruptions are liable to locally reduce the flexibility of the primary sealed membrane 6, thereby increasing the possibility of local fatigue and wear.

[0101] The centering of the through-conduit 5 halfway between the interrupted transverse corrugations 38a and the interrupted longitudinal corrugations 38b provides an optimal result. However, other shapes for the through-conduit 5 and different centering can be considered. One principle that can be used to adapt the positioning of the through-conduit 5 between the corrugations 38a, 38b in each case is to choose a position that minimizes, or at least decreases, the dimension of the through-conduit 5 that is intersected by the directrix of the interrupted corrugation 38a, 38b. Where the specific geometry of the primary sealed membrane 6 means interrupting several corrugations 38a, 38b over different lengths, a relevant parameter for optimizing the positioning of the through-conduit 5 may be the length of the longest interruption or the cumulative length of the interruptions obtained.

[0102] The through-conduit 5 requires a window 49 that is approximately twice the size of the gap between two corrugations 38a, 38b, which are in this case equidistant. To achieve this, two corrugations 38a, 38b of each series are interrupted. However, this arrangement of the through-conduit 5 and the nearby tank wall 2 can be adapted to other

dimensions of the through-conduit 5. For example, for a larger through-conduit, the corresponding window 49 may interrupt a greater number of corrugations 38a, 38b in one or each series, such as three or four or more corrugations.

[0103] Although in the embodiment described above the through-conduit 5 passes through a ceiling wall of the sealed and thermally insulating tank 1, in another embodiment the through-conduit could pass through the tank wall 2 at the top of a side wall of the sealed and thermally insulating tank 1 or at any other location in said sealed and thermally insulating tank 1.

[0104] The sealed and thermally insulating tanks 1 described above may be used in different types of facilities such as onshore facilities or in a floating structure such as a liquefied natural gas carrier or other.

[0105] With reference to Figure 12, a cut-away view of a liquefied natural gas carrier 58 shows a sealed and thermally insulating tank 1 having an overall prismatic shape mounted in the double hull 59 of the liquefied natural gas carrier 58.

[0106] The tank wall 2 comprises a primary sealed membrane 6 intended to be in contact with the LNG contained in the sealed and thermally insulating tank 1, a secondary sealed membrane 8 arranged between the primary sealed membrane 6 and the double hull 59 of the liquefied natural gas carrier, and two thermally insulating barriers 7, 9 arranged respectively between the primary sealed membrane 6 and the secondary sealed membrane 8, and between the secondary sealed membrane 8 and the double hull 59 of the liquefied natural gas carrier 58.

[0107] In a known manner, the loading/unloading pipes 60 arranged on the upper deck of the liquefied natural gas carrier 58 can be connected, using appropriate connectors, to a sea or port terminal to transfer a cargo of liquefied gas, for example LNG, to or from the sealed and thermally insulating tank 1.

[0108] Figure 12 also shows a sea terminal comprising a loading/unloading point 61, an undersea line 62 and an onshore facility 63.

[0109] The loading/unloading point 61 is a static offshore facility comprising a moveable arm 64 and a column 65 holding the moveable arm 64. The moveable arm 64 carries a bundle of insulated hoses 66 that can connect to the loading/unloading pipes 60. The orientable moveable arm 64 can be adapted to all sizes of liquefied natural gas carriers 58. A connecting line (not shown) extends inside the column 65. The loading/unloading point 61 makes loading and unloading of the liquefied natural gas carrier 58 possible to

or from the onshore facility 63. This facility has liquefied-gas storage tanks 67 and connection lines 68 connected via the undersea line 62 to the loading/unloading point 61.

[0110] The undersea line 62 enables liquefied gas to be transferred between the loading/unloading point 61 and the onshore facility 63 over a large distance, for example 5 km, which makes it possible to keep the liquefied natural gas carrier 58 a long way away from the coast during loading and unloading operations.

[0111] To create the pressure required to transfer the liquefied gas, pumps carried on board the liquefied natural gas carrier 58 and/or pumps installed at the onshore facility 63 and/or pumps installed at the loading/unloading point 61 are used.

[0112] 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 within the scope of the invention.

[0113] 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.

[0114] In the claims, reference signs between parentheses should not be understood to constitute a limitation to the claim.

Claims

[Claim 1] Sealed and thermally insulating tank (1) arranged in a load-bearing structure (3) to contain a fluid, the sealed and thermally insulating tank (1) comprising:

- a tank wall (2) anchored against the load-bearing structure (3), the tank wall (2) having a multi-layer structure comprising successively, in a thickness direction from the outside to the inside of said sealed and thermally insulating tank (1), a secondary thermally insulating barrier (9), a secondary sealed membrane (8) carried by the secondary thermally insulating barrier (9), a primary thermally insulating barrier (7) carried by the secondary sealed membrane (8), and a primary sealed membrane (6) carried by the primary thermally insulating barrier (7) and which is intended to be in contact with the fluid contained in said sealed and thermally insulating tank (1), the multi-layer structure comprising a primary space arranged between the primary sealed membrane (6) and the secondary sealed membrane (8), the primary space containing the primary thermally insulating barrier (7), and
- a through-conduit (5) arranged through the tank wall (2),

the primary sealed membrane (6) being sealingly connected to the through-conduit (5), said tank wall (2) comprising about the through-conduit (5):

- secondary thermally insulating blocks (17) anchored against the load-bearing structure (3), the secondary thermally insulating blocks (17) forming the secondary thermally insulating barrier (9) about the through-conduit (5), each of said secondary thermally insulating blocks (17) having at least one lateral side extending in the thickness direction of the tank wall (2), said secondary thermally insulating blocks (17) being arranged in relation to one another so as to form a shaft (42a, 42b) between the opposing lateral sides of two adjacent secondary thermally insulating blocks (17),
- a sealing layer (20) covering the secondary thermally insulating blocks (17), the sealing layer (20) forming the secondary sealed membrane (8),
- a sealing plate (29) arranged parallel to the tank wall (2), the sealing plate (29) having an inner surface facing the inside of said sealed and thermally insulating tank (1), the inner surface being located at the same level as the sealing layer (20), the sealing plate being arranged about the through-

conduit (5), the secondary sealed membrane (8) being extended to the sealing plate (29),

- an outer conduit (27, 28) extending parallel to the through-conduit (5) about the through-conduit (5), the outer conduit (27, 28) being in communication with the primary space to allow an inerting gas to flow between the primary space and the outer conduit (27, 28),
- primary thermally insulating blocks (35) arranged on the secondary sealed membrane (8), the primary thermally insulating blocks forming the primary thermally insulating barrier (7) about the through-conduit (5), a first and a second of said primary thermally insulating blocks (35) each having a lateral side extending in the thickness direction of the tank wall (2), the lateral side (46) having a cut-out portion (76) intended to receive a portion of the through-conduit (5) and at least one interface portion (47) adjacent to the cut-out portion (76), the interface portion (47) of said first primary thermally insulating block (35) being arranged opposite the interface portion (47) of said second primary thermally insulating block (35),

said secondary thermally insulating blocks (17) and said first and second primary thermally insulating blocks (35) being arranged in relation to one another such that the interface portion (47) of said first primary thermally insulating block (35) and the interface portion (47) of said second primary thermally insulating block (35) have no overlap, in the thickness direction, with the shaft (42a, 42b) between two adjacent secondary thermally insulating blocks (17).

[Claim 2] Sealed and thermally insulating tank (1) according to Claim 1, in which the sealing layer (20) is a first sealing layer covering the secondary thermally insulating blocks (17), and in which said tank wall comprises a second sealing layer (31) sealingly fastened across the first sealing layer (20) and the inner surface of the sealing plate (29) about the through-conduit (5), the second sealing layer (31) extending the secondary sealed membrane (8) to the sealing plate (29).

[Claim 3] Sealed and thermally insulating tank (1) according to Claim 2, in which the second sealing layer (31) comprises at least two sealing strips (31a, 31b), each sealing strip (31a, 31b) being arranged across two adjacent secondary thermally insulating blocks (17).

[Claim 4] Sealed and thermally insulating tank (1) according to Claim 3, in which the two sealing strips (31a, 31b) of the second sealing layer (31) are aligned with one another, on both sides of the through-conduit (5) so as to cover the shaft (42a, 42b).

[Claim 5] Sealed and thermally insulating tank (1) according to Claim 3 or 4, in which the two sealing strips (31a, 31b) of the second sealing layer (31) are positioned perpendicular to said at least one interface portion (47) of the first primary thermally insulating block (35) and said at least one interface portion (47) of the second primary thermally insulating block (35).

[Claim 6] Sealed and thermally insulating tank (1) according to one of Claims 2 to 5, in which the tank wall (2) comprises two prefabricated panels (10a, 10b) arranged on either side of the through-conduit (5), each of the prefabricated panels comprising a lower thermally insulating block forming a secondary thermally insulating block (17), the first sealing layer (20) covering the secondary thermally insulating block (17), and an upper thermally insulating block (21a, 21b) arranged on a central zone of the first sealing layer (20) and of the lower thermally insulating block without covering a peripheral zone of said first sealing layer (20), the upper thermally insulating block (21a, 21b) being part of the primary thermally insulating barrier (6), said primary thermally insulating blocks (35) being arranged between the upper thermally insulating blocks (21a, 21b) of the two prefabricated panels (10a, 10b) on said peripheral zone of the first sealing layer (20) of the two prefabricated panels (10a, 10b) and on said shaft (42a, 42b).

[Claim 7] Sealed and thermally insulating tank (1) according to Claim 6, in which the primary sealed membrane (6) has sealing plates (48) sealingly connected to each other at edges (100) of the sealing plates (48), and in which the upper thermally insulating blocks (21a, 21b) of the two prefabricated panels (10a, 10b) have anchoring strips (43) at said edges (100) of the sealing plates (48) to anchor the sealing plates (48) to said prefabricated panels (10a, 10b), the primary thermally insulating blocks (35) having thermal protection strips (50) at said edges (100) of the sealing plates (48) so that the sealing plates (48) are not anchored to said primary thermally insulating blocks (35).

[Claim 8] Sealed and thermally insulating tank (1) according to one of Claims 1 to 7, in which the primary sealed membrane (6) comprises at least one series

of corrugations comprising corrugations (38a, 38b) extending along directrices parallel to each other, said corrugations (38a, 38b) projecting towards the inside of said sealed and thermally insulating tank (1), and in which a window (49) interrupts at least one directrix of a corrugation (38a, 38b) of said series of corrugations, said corrugation (38a, 38b) preferably having an open end at the window (49), said sealed and thermally insulating tank (1) having at least one end piece (52) for closing the open end of said at least one corrugation (38a, 38b).

[Claim 9] Sealed and thermally insulating tank (1) according to one of Claims 1 to 8, in which the outer conduit (27, 28) comprises a first peripheral linking plate (27) and a second peripheral linking plate (28), the second peripheral linking plate (28) being sealingly fastened to the first peripheral linking plate (27) about the entirety of said first peripheral linking plate (27), the first peripheral linking plate (27) extending parallel to the through-conduit (5) towards the outside of said sealed and thermally insulating tank (1) from the second peripheral linking plate, said second peripheral linking plate (28) being sealingly fastened to the sealing plate (29) and projecting towards the load-bearing structure (3) parallel to the through-conduit (5).

[Claim 10] Sealed and thermally insulating tank (1) according to one of Claims 1 to 9, in which the tank wall (2) also has at least one closing plate (51) that is arranged about the through-conduit (5) on the primary thermally insulating blocks (35) and that is linked sealingly to the through-conduit (5).

[Claim 11] Sealed and thermally insulating tank (1) according to Claim 8 in combination with Claim 10, in which at least one of said primary thermally insulating blocks (35) has at least one slot (57), and in which the closing plate (51) has at least one slot (69) covered by one end piece (52) and superposed on said slot (57) of the primary thermally insulating block (35) so as to allow an inerting gas to flow between the corrugation (38a, 38b) and the outer conduit.

[Claim 12] Sealed and thermally insulating tank (1) according to one of Claims 10 or 11, in which the tank wall (2) has a thermal protection sheet (72) interposed between the primary thermally insulating blocks (35) and the closing plate (51).

[Claim 13] Sealed and thermally insulating tank (1) according to one of Claims 1 to 12, in which the through-conduit (5) forms a passage between the

inside of the sealed and thermally insulating tank (1) and a vapor manifold arranged outside said sealed and thermally insulating tank (1).

[Claim 14] Ship (58) used to transport a cold liquid product, the ship (58) having a double hull (59) and a sealed and thermally insulating tank (1) as claimed in one of Claims 1 to 13 placed inside the double hull (59).

[Claim 15] Use of a ship (58) as claimed in Claim 14 for loading or unloading a cold liquid product, in which a cold liquid product is channeled through insulated pipes (66) to or from an onshore or floating storage facility (63) to or from the sealed and thermally insulating tank (1) on the ship (58).

[Claim 16] Transfer system for a cold liquid, the system including a ship (58) as claimed in Claim 14, insulated pipes (66) arranged to connect the sealed and thermally insulating tank (1) installed in the hull of the ship (58) to an onshore or floating storage facility (63) and a pump for driving a flow of cold liquid product through the insulated pipes (66) to or from the onshore or floating storage facility (63) to or from the sealed and thermally insulating tank (1) on the ship (58).