TANK WALL COMPRISING A SEALING MEMBRANE HAVING A CORRUGATION WITH A REINFORCED CURVILINEAR PORTION

Technical field

The invention relates to the field of sealed tanks with a corrugated sealing membrane for storing and/or transporting a fluid such as liquefied gas.

Sealed membrane type tanks are employed in particular for storing liquefied natural gas (LNG), which is stored at atmospheric pressure at approximately -163°C, or to store liquefied petroleum gas (LPG). These tanks may be installed on land or on a floating structure. In the case of a floating structure, the tank may be intended to transport liquefied gas or to receive liquefied gas serving as fuel for the propulsion of the floating structure.

Technological background

Known in the prior art are corrugated sealing membrane tanks in which the sealing membrane, intended to be in contact with the liquefied gas contained in the tank, is reinforced with the aid of reinforcement elements. The reinforcement elements are disposed under the corrugations of the sealing membrane, between said sealing membrane and the thermally insulating barrier supporting that sealing membrane. Such reinforcement elements enable reduction of the stresses that are liable to be caused in the sealing membrane by a multitude of factors, including thermal shrinking when cooling the tank, the effect of bending of the beam of the ship, and the dynamic pressure due to the movement of the cargo, in particular because of swell. These reinforcement elements are generally hollow in order to enable gas to circulate between the corrugations and the thermally insulating barrier through the reinforcement elements. Such tanks are described in particular in the documents FR2936784, FR2963818 and FR3039248.

The reinforcement elements disclosed in the aforementioned documents are generally produced from rectilinear profiles and are therefore placed in the rectilinear portions of the corrugations.

The applicant has nevertheless noted that there also exists a need to reinforce the curvilinear portions of the corrugations. Such curvilinear portions of the corrugations are present in particular in specific zones of the tank, for example in a corner zone between two walls, in the zone of a support base intended to guide a loading/offloading tower, or in the zone of a dome intended to evacuate gas or liquid.

Summary

An idea on which the invention is based is to propose a sealed and thermally insulating tank wall including a sealing membrane equipped with a corrugation having a curvilinear portion and further including a curvilinear reinforcement device that is simple to produce and that enables reliable reinforcement of said curvilinear portion.

In accordance with one embodiment, the invention provides a tank wall including a thermally insulating barrier and a sealing membrane resting on the thermally insulating barrier, the sealing membrane including a corrugation having a curvilinear portion developed in a curvilinear direction and at least one curvilinear reinforcement device arranged inside the curvilinear portion, between the sealing membrane and the thermally insulating barrier, in such a manner as to reinforce said curvilinear portion, said curvilinear reinforcement device including a plurality of reinforcement sections that each have a profiled shape developed in a rectilinear direction, the curvilinear reinforcement device further including a connection member connecting said reinforcement sections in such a manner as to keep them in a position in which, projected in a plane parallel to the tank wall, the rectilinear direction of each of the reinforcement sections is oriented tangentially to the curvilinear direction

Thus the curvilinear portion of the corrugation is reinforced by means of a curvilinear reinforcement device that is able to provide a reliable support by means of reinforcement sections that have a rectilinear profiled shape and are consequently simpler to produce than reinforcement elements formed in a curvilinear profile.

In accordance with advantageous other embodiments, such a tank wall may have one or more of the following features.

In accordance with one embodiment, each reinforcement section includes an opening in which the connection member is nested.

In accordance with one embodiment, each reinforcement section includes a sole resting against the thermally insulating barrier.

In accordance with one embodiment, each sole includes two lateral walls and a plane lower wall that rests against the thermally insulating barrier and connects the two lateral walls, said opening being defined by the lateral walls and the lower wall. Thus with such a sole the forces induced on the cargo by the swell are distributed in a more uniform manner over the insulating barrier.

In accordance with one embodiment, the connection member is a rail that has a curvilinear part extending in the curvilinear direction of the curvilinear portion and has a curvilinear internal edge and a curvilinear external edge having a greater curvilinear than that of the curvilinear internal edge.

In accordance with one embodiment, the curvilinear internal wall or the curvilinear external wall includes alternating projections and hollows forming a crenellation, each projection being housed in the opening in one of the reinforcement sections. Thus the hollows between the projections enable creation of clearances facilitating the placement of the reinforced sections in the curvilinear part of the connection member. In accordance with one embodiment, the crenellation is formed in the internal curvilinear edge of the rail. In accordance with another embodiment, the crenellation is formed in the curvilinear external edge of the rail.

In accordance with one embodiment, at least one of the reinforcement sections has a hollow envelope and intersecting reinforcement webs that extend inside the hollow envelope from one edge to the other of said hollow envelope. This enables increased stiffness of the reinforcement sections.

In accordance with one embodiment, the reinforcement webs cross over in a plane of symmetry of the reinforcement section.

In accordance with one embodiment, each reinforcement section includes two reinforcement webs disposed in an X shape.

In accordance with one embodiment, each reinforcement section includes a support portion that has a shape matching the interior shape of the corrugation. In

accordance with one embodiment, the support portion has a semi-elliptical dome exterior shape.

In accordance with one embodiment, the curvilinear portion has an internal curvilinear edge and an external curvilinear edge having a greater curvature than the internal curvilinear edge, at least one of the reinforcement sections having two ends each of which is inclined relative to the rectilinear direction of said reinforcement section in such a manner that said reinforcement section widens from the internal curvilinear edge to the external curvilinear edge of the curvilinear portion.

In accordance with one embodiment, the reinforcement sections at the level of the internal curvilinear edge are back-to-back.

In accordance with one embodiment, the two ends of the reinforcement section each extend in a plane that is orthogonal to a tangent to the curvilinear direction at the intersection between said plane and the curvilinear direction.

In accordance with one embodiment, the two ends of said reinforcement section each extend in a plane parallel to the direction of thickness of the tank wall.

In accordance with one embodiment, the angles formed by the plane of two ends of each reinforcement section relative to the rectilinear direction of said reinforcement section are equal and opposite.

In accordance with one embodiment, the corrugation includes two rectilinear portions disposed on respective opposite sides of the curvilinear portion in line with the latter, a reinforcement element being disposed in each of the two rectilinear portions, between the sealing member and the thermally insulating barrier, the connection member being nested in an opening formed in at least one of the reinforcement elements.

In accordance with one embodiment, the curvilinear portion is disposed near a corner zone of said tank wall.

In accordance with another embodiment, the curvilinear portion is disposed near a singular zone of said tank wall in which the flatness of the sealing membrane is interrupted. In accordance with one embodiment, the singular zone includes a

support base intended to guide a loading/offloading tower. In accordance with another embodiment, the singular zone includes a dome intended to evacuate gas or liquid.

In accordance with one embodiment, the invention also provides a tank including a tank wall as mentioned above.

In accordance with one embodiment, the invention also provides a ship including a support structure and a tank as mentioned above anchored in said support structure.

In accordance with one embodiment, the invention also provides a method of loading or offloading such a ship in which a fluid is routed through insulated pipes from or to a floating or terrestrial storage installation to or from the tank of the ship.

In accordance with one embodiment, the invention also provides a system for transferring a fluid, the system including the aforementioned ship, insulated pipes arranged in such a manner as to connect the tank installed in the hull of the ship to a floating or terrestrial storage installation and a pump for driving a fluid through the insulated pipes from or to the floating or terrestrial storage installation to or from the tank of the ship.

Brief description of the figures

The invention will be better understood and other objects, details, characteristics and advantages thereof will become more clearly apparent in the course of the following description of a plurality of particular embodiments of the invention, given by way of nonlimiting illustration only with reference to the appended drawings.

- **Figure 1** is a partial schematic view of a portion of a wall of a sealed and thermally insulating tank in which the sealing membrane is represented cut away.

- **Figure 2** is a perspective view showing in particular a curvilinear portion of a corrugation and as if by transparency a curvilinear reinforcement device intended to reinforce said curvilinear portion.

- **Figure 3** is a view from above of the curvilinear portion of the corrugation and of the curvilinear reinforcement device from figure 2.

- **Figure 4** is a perspective view showing reinforcement elements intended to be disposed in rectilinear portions of the corrugations and a curvilinear reinforcement device intended to be disposed in a curvilinear portion of a corrugation.

- **Figure 5** is a sectional view of a wave reinforcement element or of a reinforcement section intended to be disposed in a low corrugation.

- **Figure 6** is a sectional view of a reinforcement element or of a reinforcement section intended to be disposed in a high corrugation.

- **Figure 7** is a perspective view showing in detail the connection member of the curvilinear reinforcement device shown in figures 2 to 4.

- **Figure 8** is a diagrammatic cutaway representation of a methane tanker ship tank and a terminal for loading/offloading that tank.

Detailed description of embodiments

Referring to figure 1, there is described a wall 1 for a sealed and thermally insulating tank intended to store a liquefied gas. The liquefied gas may in particular be a liquefied natural gas (LNG) or a liquefied petroleum gas (LPG).

Each wall 1 has a multilayer structure that includes in succession, from the exterior to the interior, in the direction of thickness of the wall, at least one primary thermally insulating barrier 2 resting directly or indirectly against a support structure, not shown in figure 1, and a primary sealing membrane 3 intended to be in contact with the liquefied gas contained in the interior space of the tank. Each wall 1 may optionally further include a secondary thermally insulating barrier resting against the support structure and a secondary sealing membrane anchored to the secondary thermally insulating barrier and against which the primary thermally insulating barrier rests.

The support structure is for example formed by the double hull of a ship but may more generally be formed of any type of rigid partition having appropriate mechanical properties.

In figure 1 the primary thermally insulating barrier 2 includes a plurality of thermally insulative elements 4 that are anchored to the support structure, either directly or anchored to a secondary thermally insulating barrier, itself anchored to the

support structure. The thermally insulative elements 4 are juxtaposed to one another and can jointly form a plane support surface to which the primary sealing membrane 3 is anchored. To anchor the primary sealing membrane 3 to the thermally insulative elements 4, each thermally insulative element 4 is equipped with metal plates 4 for anchoring the edge of the metal plates of the primary sealing membrane 3. The metal plates 5 extend in two mutually perpendicular directions. Each thermally insulative element 5 includes a layer 6 of polymer foam and at least one rigid internal plate 7, for example of plywood, that is fixed to the polymer foam layer 6.

The metal plates 23 are placed in recesses formed on the internal surface of the internal plate 7 so that the internal surface of the metal plates 23 is flush with the internal surface of the internal plate 7.

The primary sealing membrane 3 includes a plurality of corrugated metal plates that are welded to one another with an overlap in a sealed manner and welded to the metal plates 23 in such a manner as to anchor the primary sealing membrane 3 to the primary thermally insulating barrier 2.

Each metal plate includes a first series of parallel corrugations, termed high corrugations 8, and a second series of parallel corrugations, termed low corrugations 9, that extend perpendicularly to the corrugations 8 of the first series. Note that the terms “high” and “low” are relative terms and indicate that the so-called low corrugations 9 have a height less than the so-called high corrugations 8. Moreover, in an embodiment that is not shown, the corrugations 8, 9 have identical heights.

At the level of the crossover between two corrugations 8, 9 the primary sealing member 3 includes a node zone 10. The node zone 10 includes a central portion 11 having a summit and projecting toward the interior of the tank. Moreover, the central portion 11 is flanked on the one hand by a pair of concave corrugations 12 formed in the crest of the high corrugation 8 and on the other hand by a pair of reinforcements 13 into which the low corrugation 9 penetrates.

The corrugations 8, 9 of the metal plates render the primary sealing membrane 3 flexible in order to be able to be deformed by thermal and mechanical loads generated by the liquefied gas stored in the tank.

By way of example, the corrugated metal plates may in particular be made of stainless steel, aluminum, invar ®, that is to say an alloy of iron and of nickel the coefficient of expansion of which is typically between 1.2×10^{-6} and 2×10^{-6} K^{-1} inclusive, or from a high manganese content iron alloy the coefficient of expansion of which is typically of the order of 7×10^{-6} K^{-1}. However, other metals or alloys may equally be envisaged. By way of example, the metal plate has a thickness of approximately 1.2 mm. Other thicknesses can equally be envisaged, knowing that thickening the metal plate leads to an increase in its cost and generally increases the stiffness of the corrugations.

As represented in figure 1, the tank wall 1 includes a plurality of reinforcement elements 14, 15 that are arranged inside the corrugations 8, 9 and disposed between the primary sealing membrane 3 and the primary thermally insulating barrier 2. Such reinforcement elements 14, 15 aim to support and to reinforce the corrugations 8, 9 of the primary sealing membrane 3.

Each reinforcement element 14, 15 includes a hollow envelope that constitutes the main body of the reinforcement element 14, 15 and that is inserted in a corrugation 8, 9 of the primary sealing membrane 3. Each reinforcement element 14, 15 has a profiled shape of constant section. However, the two longitudinal ends 16, 17 of each reinforcement element 14 intended to be disposed in one of the high corrugations 8 are cut on a plane inclined relative to the longitudinal axis of said reinforcement element 14. The two longitudinal ends 18, 19 of the reinforcement elements 15 intended to be disposed in the low corrugations 9 may for their part be cut orthogonally to the longitudinal direction of said reinforcement elements 15.

Each reinforcement element 14, 15 may be fabricated with any required length. The length of the reinforcement element 14, 15 is preferably substantially equal to the intercorrugation gap between the corrugations that intersect the corrugation in which said reinforcement element 14, 15 is inserted. To be more precise, for the reinforcement elements 14 intended to reinforce the high corrugations 8, the length of the hollow envelope at the summit is for example equal to the length of the portion of the high corrugation that has a uniform section between two node zones 11. This uniform section portion ends where the high corrugation 8 has a slight

lateral constriction marking the beginning of the node zone 11. Moreover, the inclination of the longitudinal ends 16, 17 of the hollow reinforcement elements 14 substantially corresponds to the inclination of that lateral constriction with the result that the hollow envelope of said reinforcement element approaches as closely as possible the node zone 11 to optimize the support of the high corrugation 8.

By way of example, the reinforcement element 14, 15 are made of metal, such as aluminum or an alloy or a polymer material such as polyethylene, polycarbonate or polyetherimide, advantageously reinforced by fibers such as glass fibers.

Figures 5 and 6 respectively represent the section of a reinforcement element 15, 14 intended to reinforce a low corrugation 9 and a high corrugation 8. As represented in those figures, the hollow envelope includes a sole 20 at the bottom and a support portion 21 at the top.

The support portion 21 may be produced with various geometries, as shown for example in the document FR2936784, in particular as a function of the geometry of the corrugations 8, 9 of the primary sealing membrane 3. The exterior shape of the support portion 21 is preferably matched to the interior shape of the corrugation 8, 9 in which the reinforcement element 14, 15 is inserted, in such a manner as to offer an effective support to substantially all the surface of the corrugation 8, 9. In the embodiment represented, the exterior shape of the section of the support portion 21 is a semi-elliptical dome. If the reinforcement element 14, 15 is made of a material having a different thermal behavior to the primary sealing membrane 3, its dimensions must take account of that difference to support the corrugation 8, 9 effectively at the temperature of use, for example approximately -162°C for liquefied natural gas.

Moreover, the sole 20 has a lower wall 22 that is plane and therefore rests against the internal plate 7 of the thermally insulative elements 5 and two lateral walls 24, 25 that are interconnected by the lower wall 22. The two lateral walls 24, 25 are extended upwards by the support portion 21. The lower wall 22 and the lateral walls 24, 25 define an opening 26 through the reinforcement element 14, 15 in the longitudinal direction of said reinforcement element 14, 15 in which a connection member described hereinafter is intended to be nested.

The support portion 21 includes intersecting reinforcement webs 27, 28 that extend from one edge to the other of the hollow envelope and that cross at the level of a plane A of symmetry of the reinforcement element 14, 15. In the embodiment represented, the support portion 21 includes two reinforcement webs 27, 28 disposed in an X shape.

Moreover, returning to figure 1, it is seen that the reinforcement elements 14, 15 are interconnected by connection members 29. Such connection members 29 enable stable alignment of the reinforcement elements 14 intended to be disposed in the high corrugations 8, on the one hand, and/or the reinforcement elements 15 intended to be disposed in the low corrugations 9, on the other hand.

Each connection member 29 consists of a rail 30 that is disposed facing a node zone 11 of the primary sealing membrane 3. The rail 30 has two ends 31, 32 that are respectively nested in an opening 26 formed in the sole 20 of both of the two reinforcement elements 14 disposed in the high corrugation 8, 9 on respective opposite sides of said node zone 11.

Moreover, in the embodiment represented, a spacer 33 for supporting the low part of the high corrugation 8 is disposed in line with the longitudinal ends 16, 17 of the reinforcement elements 14. Each spacer 33 is hollow and includes a lower wall, an upper wall and two lateral walls connecting the upper wall and the lower wall. The lower wall of the spacer 33 extends in line with the lower wall 22 of the sole 20 of the adjacent reinforcement element 14. Moreover, the edge of the lateral walls of each spacer 33 that faces the longitudinal ends 16, 17 of the adjacent reinforcement element 14 is beveled so as to come to be pressed against the beveled end of the reinforcement element 14.

Moreover, the rail 30 advantageously has a cruciform shape in such a manner as to define two opposite lugs 34, 35 that are respectively nested in an opening 26 formed in both of the reinforcement elements 15 disposed in the low corrugation 9, on respective opposite sides of the node zone 11.

There is now described with reference to figures 2 to 4 and 7 a zone of the primary sealing membrane 3 in which one of the corrugations 8 has a curvilinear

portion 36 and a curvilinear reinforcement device 37 is disposed inside said curvilinear portion 36 in order to enforce it.

Figures 2 and 3 represent a corner zone between two walls of the tank. The primary sealing membrane 3 of one of the walls here includes a curvilinear portion 36 extending in a curvilinear direction d1. The curvilinear direction d1 corresponds more particularly to the direction of the summit of the corrugation in said curvilinear portion 36.

The curvilinear portion 36 is formed in a junction part 38 that is welded with an overlap to parallelepipedal metal plates, as shown in figure 1. The junction part 38 is also welded with an overlap to a corner piece 39. The corner piece 39 includes two wings 40, 41 that are parallel to the respective adjacent walls. The corner part 40 is corrugated and enables continuity of the corrugations of the primary sealing membrane 3 to be assured in the corner zone between the two walls. The curvilinear portion 36 thus enables deviation of the corrugation to be assured. Such an arrangement is in particular liable to be encountered in a tank of polyhedral general shape having two cofferdam walls of octagonal shape interconnected by eight walls extending in the longitudinal direction of the tank, namely a bottom wall and a ceiling wall that are horizontal, two vertical lateral walls, two oblique upper walls each connecting one of the lateral walls to the ceiling wall, and two oblique lower walls each connecting one of the lateral walls to the bottom wall. To be more precise, the primary sealing membrane 3 includes such curvilinear portions 36 on the cofferdam walls at the level of the corner zone of said cofferdam walls and the oblique upper and lower walls.

A curvilinear reinforcement device 37 shown in detail in figures 3 and 4 is arranged inside the curvilinear portion 36 between the primary sealing membrane 3 and the primary thermally insulating barrier 2. The curvilinear reinforcement device 36 includes a plurality of reinforcement sections 42, 43, 44 and a connection member 45 connecting said reinforcement sections 42, 43, 44 so that they are positioned. In the embodiment represented the curvilinear reinforcement device 37 includes three reinforcement sections 42, 43, 44. However, in other embodiments the curvilinear reinforcement device 37 may include only two reinforcement sections or a number of reinforcement sections greater than or equal to three.

The reinforcement sections 42, 43, 44 are made of metal, such as aluminum or an alloy, or of polymer material, such as polyethylene, polycarbonate or polyetherimide, advantageously reinforced by fibers, such as glass fibers.

Each reinforcement section 42, 43, 44 includes a hollow envelope and has a profiled shape that is developed in a rectilinear direction d2, d3, d4. The rectilinear direction d2, d3, d4 of the reinforcement sections 42, 43, 44 corresponds to the direction of the neutral fiber of said reinforcement sections 42, 43, 44. Each of the reinforcement sections 42, 43, 44 is advantageously obtained by cutting a rectilinear profile of constant section.

In the embodiment represented the curvilinear portion 36 is disposed in line with a high corrugation 8 and therefore has a section substantially similar to that of a high corrugation 8. Also, the section of each reinforcement section 42, 43, 44 is identical to the section, represented in figure 6, of the reinforcement elements 15 intended to be positioned inside the high corrugations 8. However, in other embodiments not represented the curvilinear portion 36 is disposed in line with a low corrugation 9 and therefore has a section substantially similar to that of a low corrugation 9. Alternatively, the curvilinear portion 31 may have a shape different from that of the high or low corrugation that it extends. In a case of this kind the reinforcement sections 42, 43, 44 then have a section different from that of the reinforcement elements 14, 15 disposed in the high corrugations 8 and low corrugations 9.

The connection member 45 is curvilinear and is developed in the curvilinear direction d1 of the curvilinear portion 36. Moreover, each of the reinforcement sections 42, 43, 44 has an opening 26 in which the connection member 45 is nested. The connection member 45 therefore enables positioning of each of the reinforcement sections 42, 43, 44 in a position such that, projected in a plane parallel to the wall 1, the rectilinear direction d2, d3, d4 of said reinforcement section 42, 43, 44 is oriented tangentially or substantially tangentially to the curvilinear direction d1 of the curvilinear portion 36.

The two ends of the connection member 45 are advantageously also nested in openings 26 formed in both of the two rectilinear wave reinforcements 14 that are

positioned in the two rectilinear portions of the corrugation connected to the curvilinear portion 36.

As represented in figure 3, the two ends 46, 47 of each reinforcement section 42, 43, 44 are beveled, that is to say form an angle relative to the rectilinear direction d2, d3, d4 of said reinforcement section 42, 43, 44. Thus, as represented in figure 3, projected in a plane parallel to the wall, each reinforcement section 42, 43, 44 has a trapezoidal shape. In other words, each reinforcement section 42, 43, 44 has two beveled ends 46, 47 each of which is inclined relative to the rectilinear direction d2, d3, d4 of said reinforcement section 42, 43, 44 in such a manner that said reinforcement section 42, 43, 44 widens from the internal edge 48 to the external edge 49 of the curvilinear portion 36, that is to say from the edge having the smallest radius of curvature to the edge having the greatest radius of curvature. Such an arrangement enables a larger support area to be offered for the surface of the curvilinear portion 36 of the corrugation. In a manner that is not represented, the reinforcement sections 42, 43, 44 may be back-to-back in the portion in contact with the internal edge 48.

Each end 46, 47 advantageously extends in a plane that is parallel to the direction of thickness of the wall. Moreover, the angle formed by the plane of each end 46, 47 relative to the rectilinear direction d2, d3, d4 of the reinforcement section 42, 43, 44 is such that said plane of each end 46, 47 is orthogonal or substantially orthogonal to the tangent to the curvilinear direction d1 at the intersection of said plane with said curvilinear direction d1.

In accordance with one embodiment, the two beveled ends 46, 47 of the reinforcement section 42, 43, 44 each extend in a plane that is orthogonal to a tangent to the curvilinear direction d1 at the intersection between said plane and the curvilinear direction d1.

The angles formed by the planes of two ends of each reinforcement section 42, 43, 44 relative to the rectilinear direction d2, d3, d4 of said reinforcement section 42, 43, 44 are advantageously equal and opposite. To the extent that the profiled shape of the reinforcement sections 42, 43, 44 is symmetrical, this enables the reinforcement sections 42, 43, 44 to be cut one after the other in a rectilinear profile of constant section, without wasting material.

In accordance with another embodiment, as represented in figure 4, the two ends of the reinforcement sections 42, 43, 44 extend in a plane orthogonal to the rectilinear direction d2, d3, d4 of said reinforcement section 42, 43, 44.

Figure 7 represents a connection member 45 in accordance with one embodiment. In that embodiment the connection member 45 is a curvilinear rail that includes a curvilinear part 50 intended to extend in the curvilinear direction d1 of the curvilinear portion 36 of the corrugation. The curvilinear rail has a rectangular section substantially corresponding to the dimensions of the opening 26 formed in the reinforcement sections 42, 43, 44. The connection member 45 thus has an internal curvilinear edge 51 and an external curvilinear edge 52 that has a radius of curvature greater than that of the internal curvilinear edge 51.

In the figure 7 embodiment the internal curvilinear edge features a crenellation formed by alternating projections 53 and hollows 54. Each of the projections 53 is intended to come to be housed in the opening 26 of one of the reinforcement sections 42, 43, 44. The hollows 54 between the projections 53 therefore enable creation of a clearance facilitating the placement of the reinforcement sections 42, 43, 44 in the curvilinear part 50 of the connection member 45. In an alternative embodiment the crenellation is formed in the external curvilinear edge 52 of the connection member 45.

Note that although in the embodiments represented and described hereinabove the curvilinear portion of the corrugation is formed in a primary sealing membrane and the curvilinear reinforcement device is disposed between said primary sealing membrane and a primary thermally insulating barrier, the curvilinear portion may equally be formed in a secondary sealing membrane, the curvilinear reinforcement device then being disposed between the secondary sealing membrane and a secondary thermally insulating barrier.

Moreover, in accordance with another embodiment not represented, the curvilinear portion is not formed near a corner zone of the wall but near a support base intended to guide a loading/offloading tower. By way of example, such rectilinear portions are in particular described with reference to and shown in figure 9 of the document WO2011157915.

In accordance with another embodiment not represented the curvilinear portion of the corrugation may be formed in a zone of the ceiling wall of the tank through which passes a gas dome structure intended to extract vapor phase from the internal space of the tank to a vapor collector disposed outside the tank.

In accordance with another embodiment not represented the curvilinear portion of the corrugation may be formed in a zone of the ceiling wall of the tank that is equipped with a liquid dome structure including a cover from which is suspended a loading/offloading tower intended to load liquefied gas into the tank and/or to offload it therefrom.

The technique described hereinabove for producing a tank wall may be used in different types of LNG tank in a terrestrial installation or in a floating structure such as a methane tanker or other ship.

Referring to figure 8, a cutaway of a methane tanker ship 70 shows a sealed and insulated tank 71 of prismatic general shape mounted in the double hull 72 of the ship. The wall of the tank 71 includes a primary sealing barrier intended to be in contact with the LNG contained in the tank, a secondary sealing barrier arranged between the primary sealing barrier and the double hull 72 of the ship, and two insulating barriers respectively arranged between the primary sealing barrier and the secondary sealing barrier and between the secondary sealing barrier and the double hull 72.

In a manner known in itself loading/offloading pipes 73 disposed on the top deck of the ship may be connected by means of appropriate connectors to a maritime or harbor terminal to transfer a cargo of LNG from or to the tank 71.

Figure 8 shows an example of a maritime terminal including a loading and offloading station 75, an underwater pipe 76 and a terrestrial installation 77. The loading and offloading station 75 is a fixed off-shore installation including a mobile arm 74 and a tower 78 that supports the mobile arm 74. The mobile arm 74 carries a bundle of insulated flexible tubes 79 that can be connected to the loading/offloading pipes 73. The orientable mobile arm 74 adapts to all methane tanker loading gauges. A connecting pipe that is not shown extends inside the tower 78. The loading and offloading station 75 enables loading and offloading of the methane tanker 70 from or

to the terrestrial installation 77. The latter includes liquefied gas storage tanks 80 and connecting pipes 81 connected via the underwater pipe 76 to the loading or offloading station 75. The underwater pipe 76 enables transfer of the liquefied gas between the loading or offloading station 75 and the terrestrial installation 77 over a great distance, for example 5 km, which enables the methane tanker ship 70 to remain at a great distance from the coast during loading and offloading operations.

Pumps onboard the ship 70 and/or pumps equipping the terrestrial installation 77 and/or pumps equipping the loading and offloading station 75 are used to generate the pressure necessary to transfer the liquefied gas.

Although the invention has been described in connection with a plurality of particular embodiments, it is obvious that it is in no way limited to them and that it encompasses all technical equivalents and combinations of the means described if the latter fall within the scope of the invention.

The use of the verb "to include" or "to comprise" and conjugate forms thereof do not exclude the presence of elements or steps other than those stated in a claim.

In the claims, any reference sign between parentheses should not be interpreted as a limitation of the claim.

CLAIMS

1. A tank wall (1) including a thermally insulating barrier (2) and a sealing membrane (3) resting on the thermally insulating barrier (2), the sealing membrane (3) including a corrugation having a curvilinear portion (36) developed in a curvilinear direction (d1) and at least one curvilinear reinforcement device (37) arranged inside the curvilinear portion (36), between the sealing membrane (3) and the thermally insulating barrier (2), in such a manner as to reinforce said curvilinear portion (36), said curvilinear reinforcement device (37) including a plurality of reinforcement sections (42, 43, 44) that each have a profiled shape developed in a rectilinear direction (d2, d3, d4), the curvilinear reinforcement device (37) further including a connection member (45) connecting said reinforcement sections (42, 43, 44) in such a manner as to keep them in a position in which, projected in a plane parallel to the tank wall (1), the rectilinear direction (d2, d3, d4) of each of the reinforcement sections (42, 43, 44) is oriented tangentially to the curvilinear direction (d1).

2. The tank wall (1) as claimed in claim 1, in which each reinforcement sections (42, 43, 44) includes an opening (26) in which the connection member (45) is nested.

3. The tank wall (1) as claimed in claim 2, in which each reinforcement section (42, 43, 44) includes a sole (20) resting against the thermally insulating barrier (2).

4. The tank wall (1) as claimed in claim 3, in which each sole (20) includes two lateral walls (24, 25) and a plane lower wall (22) that rests against the thermally insulating barrier (2) and connects the two lateral walls (24, 25), said opening (26) being defined by the lateral walls (24, 25) and the lower wall (22).

5. The tank wall (1) as claimed in any one of claims 1 to 4, in which the connection member (45) is a rail that has a curvilinear part (50) extending in the curvilinear direction (d1) of the curvilinear portion (36) that has a curvilinear internal edge (51) and a curvilinear external edge (52) having a greater curvilinear than that of the curvilinear internal edge (51).

6. The tank wall (1) as claimed in claim 5, in which the curvilinear internal wall (51) or the curvilinear external wall (52) includes alternating projections (53) and hollows (54) forming a crenellation, each projection (53) being housed in the opening (26) in one of the reinforcement sections (42, 43, 44).

7. The tank wall (1) as claimed in claim 6, in which the crenellation is formed in the curvilinear internal edge (51) of the rail.

8. The tank wall (1) as claimed in any one of claims 1 to 7, in which at least one of the reinforcement sections (42, 43, 44) has a hollow envelope and intersecting reinforcement webs (27, 28) that extend inside the hollow envelope from one edge to the other offset hollow envelope.

9. The tank wall (1) as claimed in any one of claims 1 to 8, in which the curvilinear portion (36) has an internal curvilinear edge (48) and an external curvilinear edge (49) having a greater curvature than the internal curvilinear edge (48) and in which at least one of the reinforcement sections (42, 43, 44) has two ends (46, 47) each of which is inclined relative to the rectilinear direction (d2, d3, d4) of said reinforcement section in such a manner that said reinforcement section (42, 43, 44) widens from the internal curvilinear edge (48) to the external curvilinear edge (49) of the curvilinear portion (36).

10. The tank wall as claimed in any one of claims 1 to 9, in which the corrugation includes two rectilinear portions disposed on respective opposite sides of the curvilinear portion (36) in line with said curvilinear portion (36), a reinforcement element (14) being disposed in each of the two rectilinear portions, between the sealing member (3) and the thermally insulating barrier (2), and in which the connection member (45) is nested in an opening (26) formed in at least one of the reinforcement elements (14).

11. The tank wall (1) as claimed in any one of claims 1 to 10, in which the curvilinear portion is disposed near a corner zone of said tank wall (1).

12. The tank wall (1) as claimed in any one of claims 1 to 10, in which the curvilinear portion is disposed near a singular zone of said tank wall (1) in which the flatness of the sealing member (3) is interrupted.

13. A sealed and thermally insulating tank including at least one tank wall (1) as claimed in any one of claims 1 to 12.

14. A ship (70) including a support structure and a tank (1) as claimed in claim 13 anchored in said support structure.

15. A system for transferring a fluid, the system including a ship (70) as claimed in claim 14, insulated pipes (73, 79, 76, 81) arranged in such a manner as to connect the tank (71) installed in the hull of the ship to a floating or terrestrial storage installation (77) and a pump for driving a fluid through the insulated pipes from or to the floating or terrestrial storage installation to or from the tank of the ship.

16. A method of loading or offloading a ship (70) as claimed in claim 14 in which a fluid is routed through insulated pipes (73, 79, 76, 81) from or to a floating or terrestrial storage installation (77) to or from the tank (71) of the ship.