

Description

Title of the invention: Sealed and thermally insulating tank

Technical field

[0001] The invention relates to the field of sealed and thermally insulating tanks for storing and/or transporting a liquefied gas, such as tanks for transporting liquefied petroleum gas (also referred to as LPG) having for example a temperature of between -50°C and 0°C , or for transporting liquefied natural gas (LNG) at approximately -163°C at atmospheric pressure.

[0002] These tanks can be installed on shore or on a floating structure. In the case of a floating structure, the tank can be intended for transporting liquefied gas or for receiving liquefied gas used as a fuel to propel the floating structure.

Technological background

[0003] A sealed and thermally insulating tank comprising a tank wall held on a bearing structure is known from the prior art, the tank wall including, in the thickness direction from the outside toward the inside of the tank, a secondary thermally insulating barrier held on the bearing structure, a secondary sealing membrane held on the secondary thermally insulating barrier, a primary thermally insulating barrier held on the secondary sealing membrane and a corrugated primary sealing membrane held on the primary thermally insulating barrier. Such a sealed and thermally insulating tank may notably be used in the transport of liquefied gas, such as liquefied natural gas (LNG), notably on board a floating structure such as a ship.

[0004] It is known practice to produce the primary sealing membrane by assembling a plurality of corrugated sheets, the corrugations of which advantageously run perpendicular to one another. The corrugations give the primary sealing membrane a certain flexibility that allows it to deform under the effect of thermal and mechanical stresses, and notably those generated by the liquefied gas stored in the tank and those associated with the deformation of the bearing structure. The primary sealing membrane is anchored on the insulating panels of the primary thermally insulating barrier. To do this, each sheet is arranged straddling several insulating panels of the primary thermally insulating barrier. Furthermore, the sheets are welded to each other along their edges and are also welded along their edges to anchoring elements which are fixed to said insulating panels. More particularly, the sheets are welded to anchoring elements which are arranged along the edges of the sheets, on either side of each corrugation.

[0005] The applicant company has observed that, in a tank of the above-mentioned type, the corrugations of the primary sealing membrane are not stressed uniformly. In particular, because the primary thermally insulating barrier is discontinuous, which is to say made up of insulating panels juxtaposed with one another, it does not behave uniformly when the bearing structure deforms and/or under the effect of the thermal and mechanical stresses generated by the liquefied gas stored in the tank. Thus, the applicant company has observed that the corrugations positioned in a zone straddling a first anchoring element fixed to a first insulating panel and a second anchoring element fixed to a second insulating panel are more highly stressed than the other corrugations. Now, it is important to ensure that the stresses are distributed as uniformly as possible between the corrugations of the primary sealing membrane, notably so as to optimize the life of the primary sealing membrane.

Summary

[0006] One idea behind the invention is that of proposing a sealed and thermally insulating tank in which the stresses experienced by the primary sealing membrane are more uniformly distributed between the corrugations thereof.

[0007] According to one embodiment, the invention is aimed at a wall of a sealed and thermally insulating tank for storing a liquefied gas, said wall comprising at least one thermally insulating barrier and a sealed membrane which is anchored to said thermally insulating barrier and is intended to be in contact with the liquefied gas, the thermally insulating barrier comprising a first insulating panel and a second insulating panel arranged along a first edge of the first insulating panel, the first and second insulating panels being respectively equipped with at least one first anchoring element and at least one second anchoring element to which elements the sealing membrane is welded; the sealing membrane comprising corrugations separated from each other by flat portions and in which at least one of the flat portions is arranged straddling the first and the second insulating panels and is welded on the one hand to the first anchoring element and on the other hand to the second anchoring element.

[0008] Thus, the planar portion of the sealing membrane which is arranged straddling the adjacent insulating panels, performs a function of mechanically connecting the insulating panels. This prevents said insulating panels from moving apart and contributes to more evenly distributing the deformation of the load-bearing structure over the primary thermally insulating barrier. Indeed, the behavior of the assembly consisting of the thermally insulating barrier and of the sealing membrane is dictated here by the fact that the insulating panels generally have a stiffness lower than that of the sealing membrane. It is

therefore the deformations of the sealing membrane that govern those of the insulating panels. This therefore makes it possible to stress the corrugations of the sealing membrane more uniformly.

[0009] According to embodiments, such a tank wall may comprise one or more of the following features.

[0010] According to one embodiment, the stiffness of the first and second insulating panels is less than the stiffness of a planar portion of the sealing membrane. This ensures that the deformations of the thermally insulating barrier are dictated by the deformations of the sealing membrane. By way of example, the stiffness of the first and second insulating panels is three times lower than the stiffness of a planar portion of the sealing membrane.

[0011] According to one embodiment, the first and the second anchoring elements are arranged so that their centers are separated from each other by a distance of between 8 and 25 cm and preferably between 10 and 20 cm.

[0012] According to one embodiment, the first anchoring elements are arranged at least along the first edge of the first insulating panel and the second anchoring elements are arranged at least along the edge of the second panel which is adjacent to the first edge of the first insulating panel.

[0013] According to one embodiment, the sealing membrane comprises first corrugations running parallel to a first direction and second corrugations running parallel to a second direction, the first direction being perpendicular to the second direction.

[0014] According to one embodiment, the corrugations are continuous, that is to say uninterrupted.

[0015] According to one embodiment, the first and the second insulating panels have a parallelepipedal shape and each have two opposite edges parallel to the first direction and two opposite edges parallel to the second direction.

[0016] According to one embodiment, the first and second insulating panels are respectively equipped with several first anchoring elements and with several second anchoring elements, and several of the planar portions are arranged straddling the first and the second insulating panels and are each welded to one of the first anchoring elements and to one of the second anchoring elements.

[0017] According to one embodiment, the sealing membrane is welded to the at least one first anchoring element and to the at least one second anchoring element by plug welding or by through-transmission welding.

[0018] According to one embodiment, the at least one first anchoring element and the at least one second anchoring element each comprise a metal plate which is fixed in a bored recess made in one of the first and second insulating panels.

[0019] According to one embodiment, the sealing membrane comprises a plurality of corrugated metal sheets, each corrugated metal sheet having edges which are each lap-welded to an edge of an adjacent corrugated metal sheet.

[0020] According to one embodiment, at least one of the planar portions which is arranged straddling the first and the second insulating panels and is welded to the first and to the second anchoring elements is made in one piece, which is to say from a single corrugated metal sheet.

[0021] According to one embodiment, the planar portion which is arranged straddling the first and the second insulating panels and is welded to the first and to the second anchoring elements belongs to a first edge portion of one of the corrugated metal sheets; the first edge portion being overlapped by a second edge portion of an adjacent corrugated metal sheet, the first edge portion being welded to the first anchoring member by means of a first plug weld and being welded to the second anchoring member by means of a second plug weld, the second edge portion overlapping the second plug weld and at least part of the first plug weld and being sealingly fillet-welded to the first edge portion.

[0022] According to one embodiment, the planar portion which is arranged straddling the first and the second insulating panels and is welded to the first and to the second anchoring elements is made from a first and a second edge portions of two adjacent corrugated metal sheets which are lap-welded to one another.

[0023] According to one embodiment, the first edge portion is intended to be overlapped by the second edge portion, the first edge portion being welded to the first anchoring member by means of a weld, for example a plug weld, the second edge portion being welded to the second anchoring member, overlapping at least part of the weld and being fillet-welded in a sealed manner to the first edge portion.

[0024] According to one embodiment, the first and the second insulating panels each have thermal protection elements facing the edges of the corrugated metal sheets.

[0025] According to one embodiment, the thermal protection elements are formed of a sheet of aluminum or a composite film containing at least one aluminum foil associated with at least one glass-fiber mat.

[0026] According to one embodiment, the thermally insulating barrier comprises a third insulating panel arranged along a second edge of the first insulating panel, a fourth

insulating panel arranged along a third edge of the first insulating panel and a fifth insulating panel arranged along a fourth edge of the first insulating panel, the third, fourth and fifth insulating panels being respectively equipped with third, fourth and fifth anchoring elements, the sealing membrane comprising planar portions arranged straddling the first and the third insulating panels which are each welded on the one hand to one of the first anchoring elements and on the other hand to one of the third anchoring elements, planar portions arranged straddling the first and the fourth insulating panels which are each welded on the one hand to one of the first anchoring elements and on the other hand to one of the fourth anchoring elements and planar portions arranged straddling the first and the fifth insulating panels which are each welded on the one hand to one of the first anchoring elements and on the other hand to one of the fifth anchoring elements.

[0027] According to one embodiment, the first anchoring elements are arranged at least along the first edge of the first insulating panel and the second anchoring elements are arranged at least along the edge of the second panel which is adjacent to the first edge of the first insulating panel.

[0028] According to one embodiment, the first anchoring elements are arranged along the first, second, third and fourth edge of the first insulating panel.

[0029] According to one embodiment, the anchoring elements of each insulating panel are arranged along the four edges of said insulating panel.

[0030] According to one embodiment, the first and the second edges of the first insulating panel are contiguous, the wall comprising a sixth panel which is arranged along an edge of the second insulating panel and along an edge of the third insulating panel and which is equipped with sixth anchoring elements.

[0031] According to one embodiment, one of the planar portions is arranged straddling the first, the second, the third and the sixth insulating panels and is fixed to one of the first anchoring elements, to one of the second anchoring elements and to one of the third anchoring elements and to one of the sixth anchoring elements.

[0032] According to one embodiment, the first and the second insulating panels have relaxation slots facing the corrugations of the sealing membrane, and more particularly facing each of the corrugations of the sealing membrane which face said first and second insulating panels.

[0033] According to one embodiment, the at least one first anchoring element and the at least one second anchoring element are respectively placed on an edge portion of the first

insulating panel and of the second insulating panel which portion is delimited by at least one of the relaxation slots of the first or second insulating panel.

[0034] According to one embodiment, each relaxation slot adjacent to one of the edges of the first or of the second panel delimits with the relaxation slots which are perpendicular to it, a plurality of edge zones, which are each equipped with a first or second anchoring element.

[0035] According to one embodiment, the sealing membrane is a primary sealing membrane and the thermally insulating barrier is a primary thermally insulating barrier, the wall further comprising a secondary thermally insulating barrier held against a bearing structure and a secondary sealing membrane fixed to the secondary thermally insulating barrier and arranged between the secondary thermally insulating barrier and the primary thermally insulating barrier.

[0036] According to one embodiment, the invention relates to a sealed and thermally insulating tank having an abovementioned wall.

[0037] A tank according to one of the abovementioned embodiments may form part of an onshore storage facility, for example for storing LNG, or may be installed in an inshore or offshore floating structure, in particular an ethane or methane tanker, a floating storage and regasification unit (FSRU), a floating production storage and offloading (FPSO) unit and the like. In the case of a floating structure, the tank may be intended for receiving liquefied natural gas serving as fuel for propulsion of the floating structure.

[0038] According to one embodiment, the invention provides a ship for transporting a fluid, which ship has a hull, such as a double hull, and an abovementioned tank arranged in the hull.

[0039] According to one embodiment, the invention also provides a method for loading or unloading such a ship, wherein a fluid is conveyed through insulated pipelines from or to a floating or onshore storage facility to or from the ship's tank.

[0040] According to one embodiment, the invention also provides a transfer system for transferring a fluid, the system comprising the aforesaid ship, insulated pipelines arranged so as to connect the tank installed in the hull of the ship to a floating or onshore storage facility, and a pump for driving a stream of fluid through the insulated pipelines from or to the floating or onshore storage facility to or from the ship's tank.

Brief description of the figures

[0041] The invention will be better understood and further aims, details, features and advantages thereof will become more clearly apparent during the following description of

a plurality of particular embodiments of the invention, given merely for illustration and without limitation, with reference to the attached drawings.

[0042] [Fig. 1] Figure 1 is a schematic view in cross section of the multilayer structure of a tank wall.

[0043] [Fig. 2] Figure 2 is a cutaway partial view of a tank wall.

[0044] [Fig. 3] Figure 3 is a perspective view of a corrugated metal sheet of a primary sealing membrane.

[0045] [Fig. 4] Figure 4 is a partial view, from above, of the primary thermally insulating barrier.

[0046] [Fig. 5] Figure 5 is a partial view, in section, of a primary anchoring device according to one embodiment.

[0047] [Fig. 6] Figure 6 is a cutaway schematic depiction of a ship having a tank for storing liquefied natural gas and of a terminal for loading/offloading from this tank.

[0048] [Fig. 7] Figure 7 is a schematic sectional view illustrating the overlap between the edges of two adjacent corrugated metal sheets in the embodiment of figures 2 to 4.

[0049] [Fig. 8] Figure 8 is a cutaway partial view of a tank wall similar to that of figure 2, according to another embodiment.

[0050] [Fig. 9] Figure 9 is a schematic sectional view illustrating the overlap between the edges of two adjacent corrugated metal sheets in the embodiment of figure 8.

[0051] [Fig. 10] Figure 10 is a schematic sectional view illustrating the overlap between the edges of two adjacent corrugated metal sheets according to a variant of the embodiment of figure 8.

[0052] [Fig. 11] Figure 11 is a schematic sectional view illustrating the overlap between the edges of two adjacent corrugated metal sheets according to another variant of the embodiment of figure 8.

[0053] [Fig. 12] Figure 12 is a cutaway partial view of a tank wall according to another embodiment variant.

[0054] [Fig. 13] Figure 13 is a cutaway partial view of a tank wall similar to the views of figures 2 and 8 according to yet another embodiment variant.

[0055] [Fig. 14] Figure 14 is a detailed sectional view of an anchoring element according to the embodiment of figure 13.

[0056] [Fig. 15] Figure 15 is a perspective view of an insulating panel according to another embodiment variant.

[0057] [Fig. 16] Figure 16 illustrates an anchoring element intended to be fixed to the insulating panel of figure 14.

Description of the embodiments

[0058] By convention, the terms “external” and “internal” are used to define the relative position of one element relative to another, with reference to the outside and inside of the tank.

[0059] Figure 1 schematically depicts the multilayer structure of a wall 1 of a sealed and thermally insulating tank for storing a liquefied gas. Each wall 1 comprises, from the outside toward the inside of the tank, a secondary thermally insulating barrier 2 comprising secondary panels 3 anchored to a bearing structure 4, a secondary sealing membrane 5 resting against the secondary thermally insulating barrier 2, a primary thermally insulating barrier 6 comprising primary panels 7 resting against the secondary sealing membrane 5 and anchored to the secondary panels 3 and a primary sealing membrane 8 which rests against the primary thermally insulating barrier 6 and which is intended to be in contact with the liquefied gas contained in the tank.

[0060] The bearing structure 4 may notably be formed by the hull or double hull of a ship. The bearing structure 4 comprises a plurality of walls defining the overall shape of the tank, usually a polyhedral shape.

[0061] In connection with figure 2, it may be seen that the secondary thermally insulating barrier 2 comprises a plurality of secondary panels 3. The secondary panels 3 are anchored to the bearing structure 4 by means of secondary anchoring devices, not depicted. The secondary panels 3 have a parallelepipedal overall shape and are arranged in mutually parallel secondary rows. By way of example, in the embodiment illustrated, the secondary panels 3 have an insulating polymer foam layer 9 sandwiched between an external sheet 10 and an internal sheet 11. The external sheet 10 and the internal sheet 11 are, for example, made of plywood and bonded to the insulating polymer foam layer 9. The insulating polymer foam can in particular be a polyurethane-based foam, optionally glass-fiber reinforced. The structure of the secondary panel 3 is described hereinabove by way of example. Also, in another embodiment, the secondary panels 3 are able to adopt another overall structure, for example that described in document WO2012/127141. In another embodiment, the secondary thermally insulating barrier 2 comprises secondary panels 3 having at least two different types of structure, for example the two aforementioned structures, depending on whereabouts in the tank they are installed.

[0062] The secondary sealing membrane 5, illustrated partially in figure 2, comprises a continuous layer of metal strakes 12, having two parallel turned-up edges. The strakes 12

are welded by their turned-up edges to parallel welding supports which are housed in grooves made in the internal sheet 11 of the secondary panels 3. The strakes 12 are for example made of Invar®: i.e. an alloy of iron and nickel, the coefficient of expansion of which is typically between 1.2×10^{-6} and $2 \times 10^{-6} \cdot K^{-1}$. It is also possible to use alloys of iron and manganese the coefficient of expansion of which is typically of the order of 7 to $9 \times 10^{-6} \cdot K^{-1}$. In another embodiment, the metal membrane has corrugations and may for example be made from the same alloys as the strakes.

[0063] Moreover, the primary thermally insulating barrier 6 comprises a plurality of primary panels 7 which are anchored to the secondary thermally insulating barrier 2 by means of primary anchoring devices, as described later on in connection with figure 5. The primary panels 7 have a parallelepipedal overall shape and are arranged in mutually parallel rows.

[0064] The primary panels 7 may have a multilayer structure similar to the structure of the secondary panels 3. Thus, according to the embodiment depicted, the primary panels 7 comprise, in succession, in the thickness direction of the wall 1, an external sheet 13, for example of plywood, an insulating polymer foam layer 14, and an internal sheet 15, for example of plywood. The insulating polymer foam layer 14 is, for example, a polyurethane-based foam, optionally glass-fiber reinforced. The structure of the primary panel 7 is described hereinabove by way of example.

[0065] As illustrated in figure 2, the external sheet 13 of the primary panels 7 has grooves which accept the turned-up edges of the strakes 12 of the secondary sealing membrane 5.

[0066] Moreover, the primary sealing membrane 8 is obtained by assembling a plurality of corrugated metal sheets 16, one of which is depicted in figure 3. The corrugated metal sheets 16 are, for example, made of stainless steel or of aluminum. The primary sealing membrane 8 has a thickness comprised between 1 and 2 mm and preferably comprised between 1.2 and 1.8 mm. Each corrugated metal sheet 16 has two series of mutually perpendicular corrugations 17, 18. The corrugations 17, 18 are separated from each other by planar portions 19 of rectangular and advantageously square shape. The corrugated metal sheets 16 are rectangular and preferably have width and length dimensions which are integer multiples of a spacing between corrugations and also integer multiples of the dimensions of the primary panels 7. In this embodiment, the corrugations 17, 18 are continuous and intersect one another. In a variant embodiment which has not been depicted, each of the corrugations 17, 18 has corrugated portions interspersed with planar portions. The corrugations are therefore discontinuous. Advantageously, the corrugated portions do not intersect one another.

[0067] As depicted in figure 2, the corrugated metal sheets 16 of the primary sealing membrane 8 are welded to anchoring elements 20. According to one embodiment, the anchoring elements 20 are metal plates which are housed in bored recesses provided in the internal sheet 15 and fixed thereto by bonding and/or by means of fasteners, such as rivets or screws for example. The corrugated metal sheets 16 are arranged straddling several primary panels 7 and are arranged so that their edges as well as their corrugations 17, 18 are oriented parallel or perpendicular to the edges of the primary panels 7.

[0068] The corrugated metal sheets 16 of the primary sealing membrane 8 are anchored along the edges of each of the primary panels 7. Each planar portion 19 of the primary sealing membrane 8 which straddles at least two primary panels 7 is fixed, on the one hand, to an anchoring element 20 which is fixed to one of the primary panels 7 and, on the other hand, to another anchoring element 20 which is fixed to the other of the adjacent primary panels 7. Advantageously, the two anchoring elements 20 to which one of the planar portions 19 is welded and which are respectively fixed to two adjacent primary panels 7 are arranged in such a way that their centers are separated from each other by a distance of between 8 and 25 cm and preferably of between 10 and 20 cm. This makes it possible to limit the level of stress likely to be exerted on the welds of the corrugated metal sheets 16 at the anchoring elements 20, in particular due to the phenomena of deformation of the hull by the swell or by sloshing.

[0069] Thus, in this embodiment, the anchoring of the primary sealing membrane 8 is achieved not at the edges of the corrugated metal sheets 16 but in planar portions corresponding to the edges of each of the primary panels 7. The planar portions 19 arranged straddling at least two adjacent primary panels 7, thus perform a function of mechanically connecting the primary panels 7. This prevents the primary panels 7 from moving apart and contributes to more evenly distributing the deformation of the load-bearing structure 4 over the primary thermally insulating barrier 6. It will also be observed that certain planar portions 19 which straddle four corner zones of four adjacent primary panels 7 are anchored to anchoring elements 20 belonging to each of the four adjacent primary panels 7.

[0070] Furthermore, as illustrated in figure 2, each primary panel 7 comprises relaxation slots 21 each extending facing a respective corrugation 17, 18 of the primary sealing membrane 8. These relaxation slots 21 make it possible to take full advantage of the corrugations 17, 18 since they allow the primary sealing membrane 8 to deform without imposing excessive mechanical stresses on the primary panels 7.

[0071] In the embodiment depicted, each primary panel 7 faces three corrugations 17 running parallel to a first direction and three corrugations 18 running parallel to a second direction perpendicular to the first direction. Also, each primary panel 7 comprises three relaxation slots 21 running parallel to the first direction and each arranged facing one of the corrugations 17 and three relaxation slots 21 running parallel to the second direction and each arranged facing one of the corrugations 17, 18. The relaxation slots 21 are therefore separated by a spacing corresponding to the spacing between the corrugations 17, 18 parallel to said relaxation slots 21. However, each relaxation slot 21 adjacent to one of the edges of a primary panel 7 is separated from said edge by a distance corresponding substantially to half the spacing between the corrugations parallel to said relaxation slot. Each relaxation slot 21 adjacent to one of the edges of a primary panel 7 delimits with the relaxation slots which are perpendicular to it, a plurality of edge zones, which are each equipped with an anchoring element 20.

[0072] The corrugated metal sheets 16 of the primary sealing membrane 8 are fixed by welding to the anchoring elements 20.

[0073] According to a first embodiment illustrated in figure 2, the corrugated metal sheets 16 are anchored to the anchoring elements 20 using plug welds 22. To do this, the corrugated metal sheets 16 have at least one through-hole which is in the form of a slot in the embodiment depicted but is capable of having any other shape and in particular a circular shape. The through-hole is made in line with each anchoring element 20. Each of said holes is filled with weld material in order to make the connection between the primary sealing membrane 8 and the anchoring elements 20.

[0074] According to another embodiment, the corrugated metal sheets 16 are anchored to the anchoring elements 20 by through-transmission welding, namely welding using a laser source with no filler material. In this case the corrugated metal sheets 16 do not have any holes.

[0075] Moreover, the corrugated metal sheets 16 of the primary sealing membrane 8 are lap-welded along their edges.

[0076] In the embodiment of figures 2 to 4, the edges of the corrugated metal sheets 16 are offset from the edges of the primary panels 7. Also, as shown in figure 4, the internal sheet of the primary panels 7 advantageously comprises, along the edges of the corrugated metal sheets 16, thermal protection elements 23. The thermal protection elements 23 are, for example, formed of a sheet of aluminum or a composite film containing at least one aluminum foil associated with at least one glass-fiber mat. The thermal protection elements 23 are advantageously housed in bored recesses formed in the internal sheet 15 of the

primary panels 7 and are arranged in each gap between an edge and a relaxation slot 21 or between two relaxation slots 21. The thermal protection elements 23 are fixed to the internal sheet 15 of the primary panels 7 by bonding and/or stapling. The thermal protection elements 23 protect the primary panels 7 and notably the insulating polymer foam layer 14 thereof against temperatures liable to damage them during the operations of welding the metal sheets to one another along their edges.

[0077] In the embodiment shown in figure 3, the corrugations 17, 18 are not arranged symmetrically with respect to the two median axes, illustrated in chain line in figure 3. Each median axis is parallel to two opposite edges of the corrugated metal sheet 16 and divides it into two equal portions. More particularly, each corrugation 17, 18 which is adjacent and parallel to one of the edges that are intended to be overlapped by an edge of another corrugated metal sheet 16 is placed at a greater distance d_1 or d_2 from the adjacent edge than the distance d_3 , d_4 between the corrugation 17, 18, which is adjacent and parallel to the opposite edge which is intended to overlap an edge of an adjacent metal sheet, and said opposite edge. This makes it possible to increase the width of the zones of overlap between the edges of the adjacent corrugated metal sheets 16.

[0078] As shown schematically in figure 7, in the zones of overlap between two adjacent metal sheets 16 which are arranged straddling two adjacent primary panels 7, it is the edge of the corrugated metal sheet 16 which is overlapped by an adjacent edge of another neighboring metal sheet that is welded to the two anchoring elements belonging respectively to each of the two adjacent primary panels 7. It is thus understood that by increasing the width of the overlap, as proposed above in relation to figure 3, at least part of the plug welds 22 is covered. This makes it possible to limit the length of plug welds 22 critical for the fluidtightness of the primary sealing membrane 8 and the fluidtightness of which must, as such, be ensured. Alternatively, the plug weld 22 can be replaced by a through-transmission weld and a fillet weld on certain anchoring elements 20.

[0079] According to an embodiment which has not been depicted, in order to limit the number of thermal protection elements 23 to be installed, the anchoring elements 20 which are arranged close to an edge of one of the corrugated metal sheets 16 extend, along the edge of the corrugated metal sheet 16, from the edge of the primary panel 7 as far as the relaxation slot 21 adjacent and parallel to said edge of the primary panel 7. Thus, in this zone, said anchoring element 20 serves both for anchoring the primary sealing membrane 8 and for thermal protection of the primary panels 7 during the lap welding of the edges of the corrugated metal sheets 16 to one another.

[0080] According to another embodiment, not depicted, the corrugated metal sheets 16 of the primary sealing membrane 8 are also anchored to the primary thermally insulating barrier 6 at their edges. In this case, the thermal protection elements 23, illustrated in figure 4, are replaced by metal anchoring elements.

[0081] As depicted in figure 5, the primary panels 7 have cutouts 24 at their corners, such that their external sheet 13 extends beyond the insulating polymer foam layer 14 and the internal sheet 15 thereof. Thus, the external sheet 13 forms, at the corners of the primary panels 7, a bearing zone 25 that is intended to collaborate directly or indirectly with a hold-down plate 26 of a primary anchoring device 27. Furthermore, in the embodiment depicted, a block 28 is added to the external sheet 13, said block 28 having a shape similar to that of the bearing zone 25 and collaborating with the hold-down plate 26 to anchor the primary panel 7. Each primary anchoring device 27 collaborates with four bearing zones 25 belonging respectively to the corners of four adjacent primary panels 7. Each primary anchoring device 27 comprises a stud 29 which projects from one of the secondary panels 3, a hold-down plate 26 which is fixed to the end of the stud 29 and which bears against the four bearing zones 25 of the four adjacent primary panels 7 so as to hold them against the secondary thermally insulating barrier 2. The hold-down plate 26 has a bore slipped over the stud 29. A nut 30 engages with a threaded end of the stud 29 so as to secure the hold-down plate 26. Furthermore, according to one advantageous embodiment, elastic Belleville washers are slipped over the stud 29, between the nut 30 and the hold-down plate 26, thereby elastically anchoring the primary panels 7 on the secondary thermally insulating barrier 2.

[0082] The stud 29 is fixed to a base 31 which is itself fixed to the internal sheet 11 of the secondary panels 3. In order to achieve this, the base 31 comprises, for example, a screw thread which engages with a complementing threaded end of the stud 29. Furthermore, the internal sheet 11 of the secondary panels 3 has a cutout in which the base 31 is housed. The cutout has an internal section of a first diameter and an external section of a second diameter greater than the first diameter so as to create a stepped shoulder. The base 31 has a shape that complements that of the cutout. Thus, the internal face of the base 31 lies flush with the internal face of the internal sheet 11 of the secondary panels 3 so as to form a planar support surface supporting the secondary sealing membrane 5. Furthermore, the base 31 has an external section of a greater diameter than its internal section such that the external section of said base is in abutment against the shoulder of the cutout. The base 31 is also bonded to the secondary panel 3.

[0083] Moreover, the stud 29 passes in a sealed manner through an orifice formed in the secondary sealing membrane 5.

[0084] The embodiment depicted in figure 8 differs from the embodiment described above in that the corrugated metal sheets 16 of the primary sealing membrane 8 are substantially aligned with respect to the rows of primary panels 7. In other words, the edges of corrugated metal sheets 16 run along some of the edges of primary panels 7. In order to achieve that, the corrugated metal sheets 16 preferably have width and length dimensions which are entire values or integer multiples of a spacing between corrugations and also integer multiples of the dimensions of the primary panels 7, disregarding the dimensions of the zones of overlap between adjacent corrugated metal sheets 16. Thus, in the embodiment illustrated in figure 8, two of the edges of each corrugated metal sheet 16 have a length which is substantially equal to three times the side length of the primary panels 7, while the second other edges have a length which is substantially equal to the side length of the primary panels 7.

[0085] Figure 9 illustrates a zone of overlap between two adjacent corrugated metal sheets 16 in the embodiment of figure 8. In this embodiment, the two edge portions of the adjacent corrugated metal sheets 16 which are arranged one overlapping the other are welded to the anchoring elements 20 by means of a plug weld 22 or by through-transmission welding. The two edge portions are welded to each other by means of a weld, for example a fillet weld, which is arranged between the two anchoring elements 20 which are fixed respectively to each of the two adjacent primary panels. Such an embodiment makes it possible to use corrugated metal sheets having limited dimensions and whose corrugations 17, 18 are centered with respect to the two median axes of the corrugated metal sheets.

[0086] Figure 10 illustrates a zone of overlap between two adjacent corrugated metal sheets 16 according to an embodiment variant. In this embodiment variant, the two edge portions which are arranged one overlapping the other are each welded to one of the anchoring elements 20 by means of a plug weld 22 or by through-transmission welding, as in the variant of figure 9. However, in this embodiment, the edge portion which overlaps covers at least part of the plug weld 22 or through-transmission weld of the other edge portion. To do this, the corrugated metal sheets 16 have a structure in which the corrugations are not arranged symmetrically with respect to the two median axes, as described and depicted in relation to figure 3.

[0087] Finally, in the embodiment of figure 11, it is the edge portion which is intended to be overlapped by the other edge portion that is welded by means of plug welds 22 to the two anchoring elements 20 belonging respectively to each of the two adjacent primary panels 7. The other edge portion then covers the plug welds 22 in line with the anchoring elements 20 fixed to each of the two adjacent primary panels. This makes it possible to limit still

further the length of plug welds 22 critical for the fluidtightness of the primary sealing membrane 8 and the fluidtightness of which must, as such, be ensured.

[0088] Figure 12 illustrates another embodiment. This embodiment differs from that described and illustrated in relation to figures 2 to 4 only in that the corrugations 17, 18 of the corrugated metal sheets 16 are arranged symmetrically with respect to the two median axes and in that the edges of the corrugated metal sheets 16 that overlap an adjacent edge of another corrugated metal sheet do not overlap any plug weld 22. This makes it possible to limit the dimensions of the corrugated metal sheets 16.

[0089] Figures 13 and 14 illustrate another embodiment. This embodiment differs from the embodiment described in relation to figure 8 in terms of the structure of the anchoring elements 20 and in terms of the type of welding carried out in order to attach the corrugated metal sheets 16 to the anchoring elements 20.

[0090] As illustrated in figure 14, the anchoring elements 20 comprise a base 32 which is fixed to a primary insulating panel 7 and a sealing collar 33 which is welded in a sealed manner to the primary sealing membrane 8 and is fixed to the base 32. To do this, the base 32 comprises a tapped bore 34 into which is screwed a threaded shank 35 that passes through an orifice made in the primary sealing membrane 8. The sealing collar 33 bears against the internal face of the primary sealing membrane 8 and is welded to the primary sealing membrane 8 all around the orifice so as to ensure sealing.

[0091] Figures 15 and 16 illustrate another embodiment of the invention. In this embodiment, the anchoring element 20 consists of an insert in the form of a disk 36 which is received in a bored recess formed in the internal surface of a primary insulating panel 7 and which is fixed to said primary insulating panel 7. In the embodiment illustrated, the disk-shaped insert 36 is equipped with a threaded shank 37 which is received in a tapped hole made in a metal part 38 fixed to the primary insulating panel 7.

[0092] With reference to figure 6, a cut-away view of a methane carrier 70 shows a sealed and insulated tank 71 with a generally prismatic shape mounted in the double hull 72 of the ship. The wall of the tank 71 has a primary sealing membrane intended to be in contact with the LNG contained in the tank, a secondary sealing membrane 5 arranged between the primary sealing membrane and the double hull 72 of the ship, and two thermally insulating barriers arranged between the primary sealing membrane and the secondary sealing membrane and between the secondary sealing membrane and the double hull 72, respectively.

[0093] In a manner known *per se*, loading/offloading pipelines 73 arranged on the upper deck of the ship can be connected, by means of appropriate connectors, to a maritime or harbor terminal in order to transfer a cargo of LNG from or to the tank 71.

[0094] Figure 6 also shows an example of a maritime terminal having a loading and offloading station 75, an underwater pipe 76 and an onshore facility 77. The loading and offloading station 75 is a fixed offshore facility having a mobile arm 74 and a tower 78 that supports the mobile arm 74. The mobile arm 74 carries a bundle of insulated flexible hoses 79 that can be connected to the loading/offloading pipelines 73. The orientable mobile arm 74 can adapt to suit all sizes of methane carrier. A connecting pipe, not depicted, extends up inside the tower 78. The loading and offloading station 75 makes it possible to load and offload from the methane carrier 70 from or to the onshore facility 77. The latter has liquefied-gas storage tanks 80 and connecting pipes 81 connected by the underwater pipe 76 to the loading or offloading station 75. The underwater pipe 76 makes it possible to transfer the liquefied gas between the loading or offloading station 75 and the onshore facility 77 over a long distance, for example 5 km, allowing the methane carrier 70 to be kept standing off shore by a long distance during the loading and offloading operations.

[0095] In order to generate the pressure needed for transferring the liquefied gas, use is made of the pumps carried on board the ship 70 and/or of the pumps with which the onshore facility 77 is equipped and/or of the pumps with which the loading and offloading station 75 is equipped.

[0096] Although the invention has been described in connection with several particular embodiments, it is quite obvious that it is in no way limited thereto and that it comprises all the technical equivalents of the means described as well as their combinations, if these come within the scope of the invention.

[0097] In the claims, any reference symbol between parentheses should not be interpreted as imposing a limitation on the claim.

Claims

- [Claim 1] A wall (1) of a sealed and thermally insulating tank for storing a liquefied gas, said wall (1) comprising at least one thermally insulating barrier (6) and a sealing membrane (8) which is anchored to said thermally insulating barrier (6) and is intended to be in contact with the liquefied gas, the thermally insulating barrier (6) comprising a first insulating panel (7) and a second insulating panel (7) arranged along a first edge of the first insulating panel, the first and second insulating panels (7) being respectively equipped with at least one first anchoring element (20) and with at least one second anchoring element (20) to which elements the sealing membrane (8) is welded; the sealing membrane (8) comprising corrugations (17, 18) separated from each other by planar portions (19) and wherein at least one of the planar portions (19) is arranged straddling the first and the second insulating panels (7) and is welded on the one hand to the first anchoring element (20) and on the other hand to the second anchoring element (20).
- [Claim 2] The wall (1) as claimed in claim 1, wherein the sealing membrane (8) comprises first corrugations (17) running parallel to a first direction and second corrugations (18) running parallel to a second direction, the first direction being perpendicular to the second direction.
- [Claim 3] The wall (1) as claimed in any one of claims 1 to 2, wherein the first and the second insulating panels (7) have a parallelepipedal shape and each have two opposite edges parallel to the first direction and two opposite edges parallel to the second direction.
- [Claim 4] The wall (1) as claimed in any one of claims 1 to 3, wherein the first and second insulating panels (7) are respectively equipped with several first anchoring elements (20) and with several second anchoring elements (20), and wherein several of the planar portions (19) are arranged straddling the first and the second insulating panels (7) and are each welded to one of the first anchoring elements (20) and to one of the second anchoring elements (20).
- [Claim 5] The wall (1) as claimed in any one of claims 1 to 4, wherein the sealing membrane (8) is welded to the at least one first anchoring element (20) and to the at least one second anchoring element (20) by plug welding (22) or by through-transmission welding.
- [Claim 6] The wall (1) as claimed in any one of claims 1 to 5, wherein the at least one first anchoring element (20) and the at least one second anchoring element (20) each

comprise a metal plate which is fixed in a bored recess made in one of the first and second insulating panels (7).

[Claim 7] The wall (1) as claimed in claim 6, wherein the metal plate has the shape of a square, a rectangle or a disk.

[Claim 8] The wall as claimed in any one of claims 1 to 7, wherein the first and the second insulating panels (7) have relaxation slots facing the corrugations (17, 18) of the sealing membrane (8).

[Claim 9] The wall (1) as claimed in claim 8, wherein the at least one first anchoring element (20) and the at least one second anchoring element (20) are respectively placed on an edge portion of the first insulating panel (7) and of the second insulating panel (8) which portion is delimited by at least one of the relaxation slots of the first or second insulating panel (7).

[Claim 10] The wall (1) as claimed in any one of claims 1 to 9, wherein the sealing membrane (8) comprises a plurality of corrugated metal sheets (16), each corrugated metal sheet (16) having edges which are each lap-welded to an edge of an adjacent corrugated metal sheet (16).

[Claim 11] The wall (1) as claimed in claim 10, wherein the planar portion which is arranged straddling the first and the second insulating panels (7) and is welded to the first and to the second anchoring elements (20) is made in one piece from a single corrugated metal sheet (16).

[Claim 12] The wall (1) as claimed in claim 11, wherein the planar portion which is arranged straddling the first and the second insulating panels (7) and is welded to the first and to the second anchoring elements (20) belongs to a first edge portion of one of the corrugated metal sheets (16); the first edge portion being overlapped by a second edge portion of an adjacent corrugated metal sheet (16), the first edge portion being welded to the first anchoring member (20) by means of a first plug weld (22) and being welded to the second anchoring member (20) by means of a second plug weld (22), the second edge portion overlapping the second plug weld (22) and at least part of the first plug weld (22) and being sealingly fillet-welded to the first edge portion.

[Claim 13] The wall (1) as claimed in claim 10, wherein the planar portion which is arranged straddling the first and the second insulating panels (7) and is welded to the first and to the second anchoring elements (20) is made from a first and a second edge portions of two adjacent corrugated metal sheets (16) which are lap-welded to one another.

[Claim 14] The wall as claimed in claim 14, wherein the first edge portion is intended to be overlapped by the second edge portion, the first edge portion being welded to the first anchoring member (20) by means of a weld, the second edge portion being welded to the second anchoring member (20), overlapping at least part of the weld and being fillet-welded in a sealed manner to the first edge portion.

[Claim 15] The wall (1) as claimed in claim 10, wherein the first and the second insulating panels (7) each have thermal protection elements (23) facing the edges of the corrugated metal sheets (16).

[Claim 16] The wall (1) as claimed in claim 15, wherein the thermal protection elements (23) are formed of a sheet of aluminum or a composite film containing at least one aluminum foil associated with at least one glass-fiber mat.

[Claim 17] The wall (1) as claimed in any one of claims 1 to 16, wherein the thermally insulating barrier (6) comprises a third insulating panel (7) arranged along a second edge of the first insulating panel (7), a fourth insulating panel (7) arranged along a third edge of the first insulating panel (7) and a fifth insulating panel (7) arranged along a fourth edge of the first insulating panel (7) and wherein the third, fourth and fifth insulating panels (7) are respectively equipped with third, fourth and fifth anchoring elements (20), the sealing membrane (8) comprising planar portions (19) arranged straddling the first and the third insulating panels (7) which are each welded on the one hand to one of the first anchoring elements (20) and on the other hand to one of the third anchoring elements (20), planar portions (19) arranged straddling the first and the fourth insulating panels (7) which are each welded on the one hand to one of the first anchoring elements (20) and on the other hand to one of the fourth anchoring elements (20) and planar portions (19) arranged straddling the first and the fifth insulating panels (7) which are each welded on the one hand to one of the first anchoring elements (20) and on the other hand to one of the fifth anchoring elements (20).

[Claim 18] A sealed and thermally insulating tank comprising a wall (1) as claimed in any one of claims 1 to 17.

[Claim 19] A ship (70) for transporting a fluid, the ship comprising a hull (72) and a tank (71) as claimed in claim 18, arranged in the hull.

[Claim 20] A transfer system for transferring a fluid, the system comprising a ship (70) as claimed in claim 19, insulated pipelines (73, 79, 76, 81) arranged so as to connect the tank (71) installed in the hull of the ship to a floating or onshore storage facility (77), and a pump for driving a fluid through the insulated pipelines from or to the floating or onshore storage facility to or from the ship's tank.

[Claim 21] A method for loading or unloading a ship (70) as claimed in claim 19, wherein a fluid is conveyed through insulated pipelines (73, 79, 76, 81) from or to a floating or onshore storage facility (77) to or from the ship's tank (71).