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 with membranes, for the storage and/or transportation of fluid such as a cryogenic fluid, and tanks embedded onboard a vessel or another floating structure and filled with a liquefied fuel gas to supply a propulsion system of the vessel or other floating structure, notably in a vessel propelled by liquefied natural gas. The liquefied natural gas or LNG is primarily composed of methane.

Technological background

[0002] A sealed and thermally insulating tank is known from the document WO2019030448 for the storage and the transportation of liquefied natural gas, incorporated in a bearing structure such as the double-hull of a vessel intended to transport liquefied natural gas, for example a methane tanker. The tank comprises a multilayer structure having, in succession, in the thicknesswise direction from the outside to the inside of the tank, a thermally insulating barrier borne by the bearing structure and a sealing membrane intended to be in contact with the liquefied natural gas contained in the tank and resting on the insulating barrier.

[0003] The sealing membrane is composed of a plurality of corrugated sheets of standard dimensions comprising a series of corrugations parallel to one another and thus allowing the sealing membrane to be deformed under the effect of the thermal stresses generated by the fluid stored in the tank. The thermally insulating barrier comprises a plurality of juxtaposed insulating panels of standard dimensions. To simplify the production of the tank, the standard dimensions of the insulating panels are chosen to be an integer multiple of a wave pitch of the corrugations. A vessel for transporting liquefied natural gas such as a methane tanker is dimensioned to accommodate such a tank, but the dimension of the bearing structure is subject to construction tolerances.

[0004] Also known is a vessel propelled by liquefied natural gas, or an “LNG Fueled Ship” or LFS. When the vessel is a methane tanker, the cargo tanks have a very great capacity, for example of the order of 100 000 to 200 000 m3. When the vessel is carrying another cargo and the tank is used only for fuel, the capacity is significantly smaller, for example from 5000 to 25 000 m3 depending on the size of the vessel and the length of the journeys to be made.

Summary

[0005] One idea on which the invention is based is to propose a sealed and thermally insulating tank capable of being incorporated in a space of any dimension, for example in a vessel or a floating structure.

[0006] According to one embodiment, the invention proposes a sealed and thermally insulating tank incorporated in a bearing structure.

[0007] According to one embodiment, the bearing structure is polyhedral, said tank comprising a plurality of tank walls including a first wall and a second wall that are parallel to a first direction of the tank and spaced apart in a second direction of said tank, the tank walls further including two end walls orthogonal to the first direction of the tank and connecting the first wall and the second wall, possibly via first intermediate walls arranged between the first wall and the two end walls and/or via second intermediate walls arranged between the second wall and the two end walls, each tank wall being borne by a corresponding bearing wall of the bearing structure,

each tank wall having a multilayer structure successively comprising, in the thicknesswise direction from the outside to the inside of the tank, a thermally insulating barrier held against the corresponding bearing wall and a sealing membrane borne by the thermally insulating barrier,

the sealing membrane of each of the first wall, the second wall and the end walls comprising a series of corrugations parallel to one another and at right angles to the transverse corners parallel to a third direction of the tank and formed at the intersections between the first wall or the second wall, the end walls and, if necessary, the intermediate walls arranged between them, the parallel corrugations being spaced apart so as to form, in the third direction:

- a plurality of identical regular intervals, each regular interval being formed between two adjacent corrugations, and
- at least one singular interval different from the regular interval, and

wherein the at least two adjacent corrugations spaced apart by the singular interval are continued uninterrupted at at least three of said transverse corners, preferably at a number of transverse corners greater than half a total number of the transverse corners.

[0008] According to embodiments, such a sealed and thermally insulating tank can comprise one or more of the following features.

[0009] According to one embodiment, the first wall is a bottom wall of the tank.

[0010] According to one embodiment, the second wall is a ceiling wall of the tank.

[0011] According to one embodiment, the first direction is a longitudinal direction of the tank.

[0012] According to one embodiment, the second direction is a vertical direction of the tank.

[0013] According to one embodiment, the third direction is a transverse direction of the tank.

[0014] According to one embodiment, the first intermediate walls are lower chamfer walls arranged between the bottom wall and the two end walls.

[0015] According to one embodiment, the second intermediate walls are upper chamfer walls arranged between the ceiling wall and the two end walls.

[0016] According to one embodiment, the total number of the transverse corners can be equal to 4, 6 or 8.

[0017] According to one embodiment, the at least two adjacent corrugations spaced apart by the singular interval are continued uninterrupted at all the transverse corners except one so as to form an open ring all around the tank.

[0018] According to one embodiment, the at least two adjacent corrugations spaced apart by the singular interval are continued uninterrupted at all the transverse corners so as to form a closed ring all around the tank.

[0019] Such a tank is advantageous in that the regular interval makes it possible to simplify the production of the tank while the singular interval makes it possible to adapt the dimension of the tank to the dimensions of the bearing structure, for example a space in the hull of a vessel. In particular, when the bearing structure does not have dimensions that are integer multiples of the regular interval, the singular interval makes it possible to compensate for the dimensional differences between the bearing structure and the sealing membrane having standard dimensions. The tank is thus adapted to bearing structures, notably of vessels or floating structures, that have any dimensions with less complex and less costly production.

[0020] The spaces between adjacent corrugations can comprise one or more singular intervals. These singular intervals can be arranged in different ways in the tank.

[0021] According to one embodiment, the corrugations of each of the first wall, the second wall and the end walls, and if necessary the intermediate walls, form two singular intervals or more separated by at least one regular interval.

[0022] According to one embodiment, the corrugations of each of the first wall, the second wall and the end walls, and if necessary the intermediate walls, form two or more consecutive singular intervals. “Consecutive singular intervals” is understood to mean that

the two or more singular intervals are on either side of one and the same corrugation, that is to say that no regular interval is formed between these singular intervals.

[0023] The provision of such consecutive singular intervals tends to concentrate the singular intervals in a single zone of each wall of the tank, which allows for an optimization of the design of the tank. Furthermore, the cost of production of the tank is reduced, because fewer parts of particular design are necessary to produce the singular intervals.

[0024] According to one embodiment, for each of the first wall, the second wall and the end walls, and if necessary the intermediate walls, the singular intervals are arranged symmetrically on either side of a median line of said wall. Such an arrangement allows for a less complex production of the tank, notably a construction that is essentially symmetrical on either side of the median line.

[0025] According to one embodiment, the tank comprises at least one special zone comprising, for example, a third intermediate wall of the tank, a loading and offloading riser, a pump support foot, a gas collector, a sump and/or a liquid dome, and said or each singular interval is arranged at a distance from said special zone greater than or equal to the transverse dimension (that is to say the dimension in the third direction) of a regular interval. Such an arrangement facilitates the production of the corrugations continually over the entire length of the tank walls.

[0026] Conversely, the corrugations of the membrane, and in particular the corrugations spaced apart by the singular interval, can have local discontinuities on certain tank walls when these corrugations cross or pass in proximity to a special zone comprising an obstacle, for example a loading and offloading riser, a pump support foot, a gas collector, a sump and/or a liquid dome.

[0027] According to one embodiment, the tank walls further include two side walls parallel to the first direction and connected, respectively, to the first wall or the second wall by two third intermediate walls, and the special zone comprises said third intermediate walls.

[0028] The singular intervals can be dimensioned in different ways. When there are several thereof, the singular intervals can be identical or not. According to one embodiment, the singular intervals have different dimensions in the third direction. According to one embodiment, the transverse dimension (that is to say the dimension in the third direction) of at least one, in particular each, singular interval is the sum of the transverse dimension of a regular interval and a negative or positive predetermined constant whose absolute value is less than the dimension of a regular interval, in particular less than half the dimension in the third direction of a regular interval.

[0029] The predetermined constant can be determined as a function of the remainder of the integer division of a dimension of the bearing structure in the transverse direction by a predetermined integer number. In particular, the predetermined constant is chosen to be greater than a predetermined minimum threshold relating to a construction requirement.

[0030] According to one embodiment, the regular intervals have a standard transverse dimension known per se.

[0031] According to one embodiment, at least one, several, some or each, of the corrugations spaced apart by a regular interval is continued uninterrupted at substantially all the transverse corners so as to form an open or closed ring all around the tank outside of the special zone.

[0032] The thermally insulating barrier can be produced in different ways. According to one embodiment, the thermally insulating barrier of each of the first wall, the second wall and the end walls, and if necessary the first and second intermediate walls, comprises:
rows of insulating panels oriented at right angles to the transverse corners and juxtaposed according to a repeated pattern in the third direction, and in line with said or each singular interval, at least one row of singular insulating panels having a width different from a width of the repeated pattern.

[0033] According to one embodiment, the width of the repeated pattern is an integer multiple of the transverse dimension of the regular interval.

[0034] According to one embodiment, the width of the singular insulating panel is less than the width of the repeated pattern.

[0035] According to one embodiment, the width of the singular insulating panel is a function of the regular interval and of the singular interval.

[0036] The singular intervals can be formed in different ways. According to one embodiment, the sealing membrane of each of the first wall, the second wall and the end walls, and if necessary the first and second intermediate walls, is formed by a plurality of rectangular metal sheets having the series of corrugations.

[0037] According to one embodiment, at least one metal sheet comprises a corrugation arranged in line with a first edge of a row of insulating panels or of a row of singular insulating panels and a corrugation arranged in line with a second edge opposite the first edge.

[0038] According to one embodiment, at least one singular interval is arranged between two corrugations of one and the same metal sheet.

[0039] According to another embodiment, said or each singular interval is formed between a first corrugation arranged on a first of said metal sheets adjacent to an edge of said first metal sheet and a second corrugation arranged on a second of said metal sheets adjacent to the first metal sheet, the second corrugation being adjacent to an edge of the second metal sheet turned toward said first metal sheet.

[0040] According to one embodiment, a dimension of the second metal sheet in the third direction is an integer multiple of the regular interval. In particular, the dimension of a metal sheet can be equal to the dimension of a row of insulating panels in the third direction.

[0041] According to one embodiment, the edge of the first sheet is a joggled edge forming a part with a level difference with respect to a central portion of said first sheet and configured for lap welding of the first metal sheet onto the second metal sheet. In particular, the singular interval is adjusted by adjusting the distance of the joggled edge with respect to the first corrugation adjacent to said joggled edge.

[0042] According to one embodiment, the welding of the first metal sheet and of the second metal sheet is performed at a distance greater than 50 mm, in particular greater than 100 mm, from the corrugation adjacent to the edge of the second sheet.

[0043] According to one embodiment, the edge of the first metal sheet and the edge of the second metal sheet are welded to one another in line with one of said rows of singular insulating panels.

[0044] According to one embodiment, at least one singular insulating panel comprises a metal anchoring strip arranged opposite the first metal sheet and the second metal sheet, and wherein the second metal sheet is welded to said metal anchoring strip.

[0045] According to one embodiment, the first metal sheet comprises a number of corrugations less than or equal to the number of corrugations of the second metal sheet.

[0046] According to one embodiment, the number of corrugations of the first metal sheet is a function of the difference between the singular interval and the regular interval. The number of corrugations of the first metal sheet can be less than the number of corrugations of the second sheet if the transverse dimension of the singular interval is greater than the transverse dimension of the regular interval. The number of corrugations of the first metal sheet can be equal to the number of corrugations of the second metal sheet if the transverse dimension of the singular interval is less than the transverse dimension of the regular interval.

[0047] According to one embodiment, the tank walls further include two side walls parallel to the first direction and connected respectively to the first wall or the second wall, possibly

via two third intermediate walls, and to the end walls, possibly via two fourth intermediate walls.

[0048] According to one embodiment, the third intermediate walls are longitudinal chamfer walls of the tank.

[0049] According to one embodiment, the fourth intermediate walls are vertical chamfer walls of the tank.

[0050] According to one embodiment, the sealing membrane of each of the first wall, the second wall and the side walls comprises a series of first additional corrugations parallel to one another and at right angles to longitudinal corners parallel to the first direction of the tank and formed at the intersections between the first wall or the second wall, the side walls and, if necessary, the third intermediate walls, and the first additional corrugations are spaced apart so as to form, in the first direction:

- a plurality of identical regular intervals, each regular interval being formed between two adjacent first additional corrugations, and
- at least one singular interval different from the regular interval, and

the at least two adjacent first additional corrugations spaced apart by the singular interval are continued uninterrupted at at least three of said longitudinal corners, preferably at a number of longitudinal corners greater than half a total number of the longitudinal corners.

[0051] According to one embodiment, the total number of the longitudinal corners is equal to 4, 6 or 8.

[0052] According to one embodiment, the sealing membrane of each of the end walls and of the side walls comprises a series of second additional corrugations parallel to one another and at right angles to vertical corners parallel to the second direction of the tank and formed at the intersections between the end walls, the side walls and, if necessary, the fourth intermediate walls, and the second additional corrugations are spaced apart so as to form, in the second direction:

- a plurality of identical regular intervals, each regular interval being formed between two adjacent second additional corrugations, and
- at least one singular interval different from the regular interval, and

the at least two adjacent second additional corrugations spaced apart by the singular interval are continued uninterrupted at at least three of said vertical corners, preferably at a number of vertical corners greater than half a total number of the vertical corners.

[0053] According to one embodiment, the total number of the longitudinal corners is equal to 4, 6 or 8.

[0054] Such a tank can form part of an onshore storage installation, for example for storing liquefied gas, or be installed in a floating, coastal or deep water structure, notably a methane tanker vessel, an LPG transport vessel, a floating storage and regasification unit (FSRU), a floating production and storage offshore (FPSO) unit, and the like.

[0055] According to another aspect of the invention, a vessel is proposed comprising a double-hull and such a tank incorporated in said double-hull as bearing structure.

[0056] According to one embodiment, the invention also provides a method for loading or offloading such a vessel, wherein a fluid is conveyed through insulated pipelines from or to a floating or onshore storage installation to or from the tank of the vessel.

[0057] According to one embodiment, the invention also provides a transfer system for a fluid, the system comprising the abovementioned vessel, insulated pipelines arranged so as to connect the tank installed in the hull of the vessel to a floating or onshore storage installation and a pump for driving a fluid through the insulated pipelines from or to the floating or onshore storage installation to or from the tank of the vessel.

[0058] According to one embodiment, said tank is configured as a fuel tank for a propulsion system of the vessel.

Brief description of the figures

[0059] The invention will be better understood, and other aims, details, features and advantages thereof will become more clearly apparent from the following description of several particular embodiments of the invention, given in a purely illustrative and nonlimiting manner, with reference to the attached drawings.

[0060] [fig.1] figure 1 is a partial cross-sectional perspective view of a polyhedral tank incorporated in a bearing structure.

[0061] [fig.2] figure 2 is a perspective schematic representation of the tank.

[0062] [fig. 3] figure 3 is a spread-out and truncated view of an end of the tank and of figure 2.

[0063] [fig.4] figure 4 is a cross-sectional view along the line VI-VI of figure 2.

[0064] [fig. 5] figure 5 is a cross-sectional view along the line VII-VII of figure 2, according to a first exemplary embodiment.

[0065] [fig. 6] figure 6 is a cross-sectional view along the line VII-VII of figure 2, according to a second exemplary embodiment.

[0066] [fig. 7] figure 7 is an enlarged view of the zone V according to figure 5 or figure 6.

[0067] [fig. 8] figure 8 is a perspective schematic representation of a vessel provided with an LNG propulsion system and a tank as fuel tank for the propulsion system.

[0068] [fig. 9] figure 9 is a schematic representation similar to figure 8, showing a variant of the tank as fuel tank for the propulsion system.

[0069] [fig. 10] figure 10 is a perspective view of the tank of figures 8 and 9, according to another variant, the tank being taken in the same orientation as in figures 8 and 9.

[0070] [fig. 11] figure 11 is a cutaway schematic representation of a methane tanker vessel tank and of a terminal for loading/offloading this tank.

Description of the embodiments

[0071] Figures 1 and 2 show a perspective view of a tank 100 for storing a liquefied gas, such as liquefied natural gas (LNG).

[0072] The tank 100 is arranged in a bearing structure which can notably be formed by or in the hull or the double-hull of a vessel or of a floating structure. The bearing structure comprises a plurality of bearing walls 102 defining the general form of the tank 100, usually a polyhedral form.

[0073] The tank 100 comprises a plurality of tank walls borne by the bearing structure including:

- a ceiling wall 104 and a bottom wall 106 parallel to a longitudinal direction 101 of the tank,
- two end walls 108 connecting the bottom wall 106 and the ceiling wall 104, and
- two side walls 110 connected on either side to the ceiling wall 104 and the bottom wall 106 via the upper longitudinal chamfer walls 114, respectively the lower longitudinal chamfer walls 112.

[0074] In figure 3, the end wall 108, the ceiling wall 104 and the bottom wall 106 are represented according to a view spread out in the plane of the end wall 108.

[0075] Each of the bottom wall 106, the ceiling wall 104 and the end walls 108 comprises a sealing membrane designed to be in contact with the product present in the tank 100 and arranged on a thermally insulating barrier that is not represented in figures 1-3. The sealing membrane comprises series of corrugations 118 parallel to one another and at right angles to transverse corners 107 formed by the bottom wall 106 or the ceiling wall 104 and the end walls 108. The corrugations 118 are spaced apart from one another in a transverse direction 103 at right angles to the longitudinal direction 101. The spaces between the corrugations comprise a plurality of regular intervals 120 and two singular intervals 122 arranged symmetrically on either side of a median line 124 of the bottom wall 106, of the

ceiling wall 104 and of the end walls 108. The dimension of the singular intervals 122 in the transverse direction 103 is different from the dimension of the regular intervals 120 in the transverse direction 103.

[0076] The corrugations 118 spaced apart by the singular interval 122 on the end walls 108 are each prolonged uninterrupted by a corresponding corrugation of the bottom wall 106 and a corresponding corrugation of the ceiling wall 104. Likewise, the corrugations 118 of the end walls 108 spaced apart by the regular interval 120 are each prolonged uninterrupted apart from the corrugations 118 overlooking the longitudinal chamfer walls 112 and 114.

[0077] As a variant, a discontinuity of the corrugations 118 may exist at one or more of the transverse corners 107. Preferably, the corrugations 118 uninterruptedly cross at least three transverse corners 107.

[0078] In the example represented in figure 3, a singular interval 122 is formed on each side of the median line 124 of the bottom wall 106. As a variant, two or more singular intervals 122 can be formed on each side of the median line 124. In particular, two or more singular intervals 122 can be formed on each side of the median line 124. “Consecutive singular intervals 122” is understood to mean that the two or more singular intervals 122 are on either side of one and the same corrugation, that is to say that no regular interval 120 is formed between these singular intervals 122. Still as a variant, the or the two or more singular intervals 122, whether consecutive or not, can be formed on just one side of the median line 124 of the bottom wall 106.

[0079] The tank 100 further comprises a liquid dome 116 crossing the ceiling wall 104 of the tank 100 in a heightwise direction 105. The liquid dome 116 can contain a riser 69 for loading and offloading the tank 100. In particular, the liquid dome 116 is arranged at a distance from the end wall 108 and at mid-width of the ceiling wall 104 in the transverse direction 103. In particular, each singular interval 122 is arranged at a distance equal to a regular interval 120 or more of the liquid dome 116. Furthermore, each singular interval 122 is arranged at a distance greater than a regular interval 120 of each of the longitudinal chamfer walls 114 and 112.

[0080] In the figures, the dimensions in the transverse direction 103 are referred to by width.

[0081] A width L of the bottom wall 106 and of the ceiling wall 108 is expressed as follows:

[0082] [eq. 1]

$$L = po_{reg} \times N + X$$

with po_{reg} being the width of the regular interval 120,

N being an integer number, and

X being a relative number.

[0083] Preferably, the integer multiple N is chosen such that X lies between $-po_{reg}/2$ and $+po_{reg}/2$.

[0084] The width po_{reg} is chosen according to a sealed tank construction standard and can have different values, for example 340 mm or 500 mm.

[0085] Preferably, the singular interval 122 is dimensioned as follows

[0086] [eq 2]

$$po_{sing} = po_{reg} + X/2 \quad (2)$$

po_{sing} being the width of the singular interval 122.

[0087] According to the equation (2), X/2 lies between $-po_{reg}/4$ and $+po_{reg}/4$, thus ensuring a singular interval 122 that has dimensions that remain greater than a minimum dimension making difficulty-free manufacture possible.

[0088] Figure 4 is a cross-sectional view along the line VI-VI of figures 1 and 2 corresponding to a zone of the tank 100 comprising only regular intervals 120.

[0089] Figure 4 shows the bottom wall 106 comprising the thermally insulating barrier 202 arranged on a bearing wall 102 of the bearing structure and is held against the bearing wall 102 by fixing means 204. The fixing means 204 can be any suitable type of fixing means such as threaded studs protruding toward the interior of the tank 100.

[0090] In particular, the thermally insulating barrier 202 is formed by a plurality of rows of insulating panels 202_1 and 202_2 juxtaposed in the transverse direction 103. Each row comprises insulating panels 202_1 and 202_2 juxtaposed in the longitudinal direction 101 for the bottom wall 106 and the ceiling wall 108 and in the heightwise direction 105 for the end walls 108.

[0091] The bottom wall 106 further comprises the sealing membrane 206 borne by a face of the thermally insulating barrier 202 opposite the bearing wall 102_1. Preferably, the sealing membrane 206 comprises a plurality of metal sheets 207_1 and 207_2 each having a substantially rectangular form. The metal sheets 207 are, for example, made of Invar®: that is to say an alloy of iron and nickel with an expansion coefficient typically of between $1.2x10^{-6}$ and $2x10^{-6}$ K^{-1}, or from an alloy of iron with high manganese content with an expansion coefficient typically of the order of $7x10^{-6}$ K^{-1}. Alternatively, the metal sheets 207 can also be made of stainless steel or of aluminum.

[0092] The metal sheets 207_1 and 207_2 are connected to the insulating panels 202_1 and 202_2 by welding of the metal sheets 207_1 and 207_2 to anchoring strips 210 provided in the insulating panels 202_1 and 202_2, for example metal plates extending over a part of said insulating panels 202_1 and 202_2. Advantageously, the anchoring strips 210 are arranged in recesses provided in the insulating panels 202_1 and 202_2 and fixed to the insulating panels 202_1 and 202_2 by screws, rivets or staples for example. In particular, the welding of the metal sheets 207_1 and 207_2 to the anchoring strips 210 is done by spot welding.

[0093] The sealing membrane 206 comprises the corrugations 118 spaced apart by the regular interval 120 and is arranged such that a first corrugation 118 is in line with a first edge 212_1 of the row of insulating panels 202_1 and a second corrugation 118 is in line with a second edge 212_2 opposite the first edge 212_1. The width of the insulating panel 202_1 bearing corrugations separated by the regular interval 120 only is an integer multiple of the width po_{reg}. Gaps may exist between the rows of insulating panels 202_1 and 202_2. Preferably, the gaps between the rows of insulating panels 202_1 and 202_2 are negligible. In particular, the gaps between the rows of insulating panels 202_1 and 202_2 can be filled with a heat-insulating lining such as glass wool, rock wool, etc.

[0094] Dimensional example:

the width of the insulating panel 202_1 is equal to 3060 mm,

the width of the metal sheet 207_1 is equal to 3060 mm,

po_{reg} is equal to 340 mm, and

the number M_1 of corrugations 118 of the metal sheet 207_1 is equal to 9.

[0095] Figure 5 corresponds to a zone of the tank 100 comprising a singular interval 122 produced according to a first embodiment.

[0096] In particular, in this embodiment, the width of the singular interval 122 calculated by the equation (2) is greater than the width of the regular interval 120.

[0097] The sealing membrane 206 comprises a metal sheet 207_3 comprising the singular interval 122 and is disposed on a row of singular insulating panels 202_3. The width of the singular insulating panels 202_3 is different from, in particular less than, the width of the insulating panels 202_1. Preferably, the width of the singular insulating panels 202_3 is calculated as follows:

[0098] [eq. 3]

$$L_{sing} = po_{reg} \times (M_3-1) + po_{sing} \quad \text{for } po_{sing} > po_{reg}$$

with L_{sing} being the width of the singular insulating panels 202_3, and

M_3 being the number of corrugations 118 of the metal sheet 207_3.

[0099] Preferably, the metal sheet 207_3 comprises a number M_3 of corrugations 118 less than the number M_1 of corrugations 118 of the metal sheet 207_1 when the width of the singular interval 122 is greater than the width of the regular interval 120. That way, the width of the singular insulating panels 202_3 is less than the width of the insulating panels 202_1 to limit the impact of the structural modifications of the tank 100.

[0100] Dimensional example:

For the number M_1 of corrugations 118 of the metal sheet 207_1 equal to 9, the number M_3 of corrugations 118 is equal to 8.

[0101] Figure 6 corresponds to a zone of the tank 100 comprising a singular interval 122 produced according to a second embodiment.

[0102] In this second embodiment, the width of the singular interval 122 calculated by the equation (2) is less than the width of the regular interval 120.

[0103] The sealing membrane 206 in this case comprises a metal sheet 207_4 comprising the singular interval 122 and arranged on a row of singular insulating panels 202_4. Preferably, the width of the singular insulating panels 202_4 is calculated as follows:

[0104] [eq. 4]

$$L_{sing} = po_{reg} \times (M_4-1) + po_{sing} \quad \text{for } po_{sing}<po_{reg}$$

with M_4 being the number of corrugations 118 of the metal sheet 207_3.

[0105] In this second embodiment, the number M_3 of corrugations 118 is equal to the number M_1 of corrugations 118 of the metal sheet 207_1. In fact, since the width of the singular interval 122 is less than the width of the regular interval 120, the width of the singular insulating panels 202_4 remains less than the width of the insulating panels 202_1.

[0106] In particular, the rows of singular insulating panels 202_3 and 202_4 are arranged adjacent to a row of insulating panels 202_1. Preferably, the rows of singular insulating panels 202_3 and 202_4 are separated from one another by at least one row of insulating panels 202_1.

[0107] The ceiling wall 104 and the end walls 108, although not represented in the figures, comprise the same elements as the bottom wall 106 represented in figures 4 to 6.

[0108] In particular, the singular interval 122 is formed between two adjacent metal sheets 302 and 304 of the sealing membrane 206, as represented in figure 7.

[0109] The singular interval 122 is formed between a first corrugation 118_1 arranged on the side of a first edge 306 of the first metal sheet 302 and a second corrugation 118_2 arranged

on the side of a second edge 308 of the second metal sheet 304. The first edge 306 is a joggled edge having a fold of the first metal sheet 302 to form a level difference of the edge 306 with respect to the first metal sheet 302 greater than the thickness of the second metal sheet 304. This arrangement allows the second metal sheet 304 to be overlapped by the first metal sheet 302 at a distance 310 from the first corrugation 118_1 and at a distance 312 from the second corrugation 118_2. The singular interval 122 is the sum of the two distances 312 and 310.

[0110] In particular, the metal sheets 302 and 308 are supplied with standard dimensions, for example the distance 312 is half the regular interval 120. The folding of the metal sheet 302 makes it possible to modify its width to adjust the distance 310 and therefore the width of the singular interval 122 to the desired value without modifying the second metal sheet 304. This arrangement makes it possible to simplify the cost and the production of the tank 100 for vessels with any dimensions.

[0111] Preferably, the first metal sheet 302 and the second metal sheet 304 are assembled by welding the first edge 306 to the second edge 308 in line with a row of singular insulating panels 202_3 or 202_4. Furthermore, the second edge 308 can be welded to the anchoring strip 210 of a row of singular insulating panels 202_3 or 202_4. The welding of the metal sheets 302 and 304 is preferentially done by spot welding.

[0112] Advantageously, the distance 310 and the distance 312 are greater than a predetermined threshold to avoid damaging the corrugations 118_1 or 118_2 by the welding of the metal sheets 302 and 304, for example this predetermined threshold being equal to 100 mm.

[0113] In the examples described hitherto, the singular intervals 122 have identical dimensions in the transverse direction 103. However, as a variant, the singular intervals 122 can have different dimensions in the transverse direction 103.

[0114] In a way that is known per se, each of the tank walls can comprise a second thermally insulating barrier arranged between the thermally insulating barrier 202 and the bearing structure and a second sealing membrane contained between the thermally insulating barrier 202 and the second thermally insulating barrier. The sealing membrane 206 can further comprise a second series of corrugations at right angles to the first series of corrugations 118. Furthermore, the longitudinal chamfer walls 112 and 114 and the side walls 110 can comprise a multilayer structure comprising, in the thicknesswise direction from the bearing structure toward the interior of the tank 100: a secondary thermally insulating barrier, a secondary sealing membrane, a primary thermally insulating barrier and a primary sealing membrane.

[0115] Referring to figure 8, various possible modifications with respect to the embodiment described above will now be described.

[0116] In the embodiment described above, the longitudinal direction 101 of the tank can correspond to the longitudinal direction of the vessel, in particular a methane tanker vessel, in which the tank 100 is installed, but this is not obligatory. Thus, figure 8 represents an embodiment in which the longitudinal direction of the tank 100 corresponds to the widthwise direction of the vessel 170 in which the tank is installed. Thus, the transverse corners 107 of the tank extend parallel to a longitudinal axis A-A of the vessel 170 and the singular interval or intervals 122 are formed between corrugations 118 which extend at right angles to the longitudinal axis A-A of the vessel 170.

[0117] Moreover, the tank geometry can comprise upper chamfer walls 114 and lower chamfer walls 112 as in figures 1 to 3, or only upper chamfer walls 114 or only lower chamfer walls 112 or no chamfer wall as illustrated in figure 8.

[0118] Moreover, the tank geometry can comprise longitudinal chamfer walls oriented parallel to the longitudinal direction 101 of the tank as illustrated in figures 1 to 3 or, conversely, it can comprise chamfer walls transversal to the corrugations 118, oriented obliquely to the longitudinal direction 101 of the tank and disposed between the end walls 108 and the ceiling wall 104 and/or the bottom wall 106. The chamfer walls transversal to the corrugations 118 are not represented in figures 2 and 3 but can be easily designed from figure 2, if the orientation of the corrugations 118 and of the arrow 101 are turned mentally by 90° about a vertical axis.

[0119] For example, the tank 100 of figure 8 could comprise upper chamfer walls and/or lower chamfer walls parallel to the longitudinal axis A-A of the vessel 170, and therefore chamfer walls transversal to the corrugations 118, such that the total number of transverse corners 107 would be greater than four, for example equal to six or eight.

[0120] In all cases, the corrugations 118 spaced apart by the or each singular interval 122 uninterruptedly cross at least half of the transverse corners 107, preferably all the transverse corners 107, except, possibly, just one. In other words, a discontinuity of the corrugations 118 can exist at one or more of the transverse corners 107, but preferably at only one of the transverse corners 107, or none of them.

[0121] In fact, inasmuch as the corrugations 118 spaced apart by the or each singular interval 122 uninterruptedly cross all of the transverse corners 107 except just one, these corrugations nevertheless form a ring encircling the entire tank 100. The ring is open in

this case. The ring is closed if all the transverse corners 107 are uninterruptedly crossed by the corrugations 118.

[0122] Figure 8 illustrates, finally, that the tank 100 can be a fuel tank for a propulsion system 65 fed with fuel gas from the tank 100 by a supply device 66 that is otherwise known. The vessel 170 can have various applications: transportation of passengers, transportation of goods, in particular in containers or in bulk, etc.

[0123] Figure 9 is a schematic representation similar to figure 8, showing a variant of the tank 100.

[0124] As was mentioned previously, the sealing membrane 206 can further comprise second corrugations at right angles to the corrugations 118. In figure 9, two of these second corrugations 138 are represented. The number 127 denotes the longitudinal corners formed by the bottom wall 106 or the ceiling wall 104 and the side walls 110, which are therefore transversal to the second corrugations 138.

[0125] The second corrugations 138 extend at right angles to the corrugations 118 and therefore parallel to the transverse direction 103. The second corrugations 138 are spaced apart from one another in the longitudinal direction 101. In a way similar to the corrugations 118, the spaces between the second corrugations 138 comprise a plurality of regular intervals (not represented) and one or more singular intervals 142 (of which just one is represented in figure 9). The dimension of the singular interval or intervals 142 in the longitudinal direction 101 is different from the dimension of the regular intervals in the longitudinal direction 101.

[0126] The second corrugations 138 spaced apart by the singular interval 142 on the side walls 110 are each prolonged uninterrupted by a corresponding second corrugation of the bottom wall 106 and a corresponding second corrugation of the ceiling wall 104.

[0127] In all cases, the second corrugations 138 spaced apart by the or each singular interval 142 uninterruptedly cross at least half of the longitudinal corners 127, preferably all the longitudinal corners 127, possibly except just one. In other words, a discontinuity of the second corrugations 138 can exist at one or more of the longitudinal corners 127, but preferably at just one of the longitudinal corners 127 or none of them.

[0128] The singular interval or intervals 142 may or may not be produced in a way similar to the singular intervals 122 already described. In particular, the singular intervals 142 may or may not have a dimension transversal to the second corrugations 138, that is to say parallel to the longitudinal direction 101, equal to the transverse dimension of the singular

intervals 122. The singular intervals 142 can have dimensions transversal to the second corrugations 138 that are identical to one another or else different.

[0129] Figure 10 represents another embodiment of the tank 100, taken in the same orientation as in figure 9. In this embodiment, the side walls 110 and the end walls 108 have horizontal corrugations 158 parallel to one another and spaced apart in the vertical direction 105. Only two of these horizontal corrugations 158 are represented in figure 9. The number 147 denotes the vertical corners formed by the side walls 110 and the end walls 108.

[0130] The horizontal corrugations 158 are spaced apart in the vertical direction 105. In a way similar to the corrugations 118, the spaces between the horizontal corrugations 158 comprise a plurality of regular intervals (not represented) and one or more singular intervals 162 (just one of which is represented in figure 10). The dimension of the singular interval or intervals 162 in the vertical direction 105 is different from the dimension of the regular intervals in the vertical direction 105.

[0131] The horizontal corrugations 158 spaced apart by the singular interval 162 uninterruptedly cross at least half of the vertical corners 147, preferably all the vertical corners 147, possibly except for just one. In other words, a discontinuity of the horizontal corrugations 158 can exist at one or more of the vertical corners 147, but preferably at just one of the vertical corners 147 or none of them.

[0132] The singular interval or intervals 162 may or may not be produced in a way similar to the singular intervals 142 and 122 already described. In particular, the singular intervals 162 may or may not have a dimension transversal to the horizontal corrugations 158, that is to say parallel to the vertical direction 105, equal to the transverse dimension of the singular intervals 142 and/or 122. The singular intervals 162 can have dimensions transversal to the second corrugations 158 that are identical to one another or else different.

[0133] In a way not represented in figure 10, the tank geometry can possibly have vertical chamfer walls, oriented parallel to the vertical direction 105 of the tank, and disposed between the side walls 110 and the end walls 108. The vertical corners 147 are then formed by the vertical chamfer walls, the side walls 110 and the end walls 108. The horizontal corrugations 158 uninterruptedly cross at least half of these vertical corners 147, preferably all the vertical corners 147, possibly except just one of them.

[0134] The singular intervals of all the embodiments represented previously can be combined in various ways to facilitate the dimensional adjustment of the tank in one or more dimensions of the space.

[0135] The technique described above for producing a sealed and thermally insulating tank for storing a fluid can also be used in different types of tanks, for example to constitute a tank for liquefied natural gas (LNG) in an onshore installation or in a floating structure such as a methane tanker vessel or the like, for example any vessel propelled using LNG.

[0136] Referring to figure 11, a cutaway view of a methane tanker vessel 70 shows a sealed and insulated tank 71 of generally prismatic form mounted in the double-hull 72 of the vessel.

[0137] As is known per se, loading/offloading pipelines 73 disposed on the top deck of the vessel can be connected, by means of appropriate connectors, to a maritime or port terminal to transfer a cargo of LNG from or to the tank 71.

[0138] Figure 11 represents an example of a maritime terminal comprising a loading and offloading station 75, a submarine pipe 76 and an onshore installation 77. The loading and offloading station 75 is a fixed offshore installation comprising a mobile arm 74 and a riser 78 which supports the mobile arm 74. The mobile arm 74 bears a bundle of insulated flexible pipes 79 that can be connected to the loading/offloading pipelines 73. The orientable mobile arm 74 adapts to all methane tanker templates. A link pipe not represented extends inside the riser 78. The loading and offloading station 75 allows the methane tanker 70 to be loaded and offloaded from or to the onshore installation 77. The latter comprises liquefied gas storage tanks 80 and link pipes 81 connected by the submarine pipe 76 to the loading or offloading station 75. The submarine pipe 76 allows the liquefied gas to be transferred between the loading or offloading station 75 and the onshore installation 77 over a great distance, for example 5 km, which makes it possible to keep the methane tanker vessel 70 at a great distance from the coast during the loading and offloading operations.

[0139] To generate the pressure necessary to the transfer of the liquefied gas, pumps installed in the vessel 70 and/or pumps with which the onshore installation 77 is equipped and/or pumps with which the loading and offloading station 75 is equipped are implemented.

[0140] A fairly similar installation can be employed to fuel up a vessel propelled by LNG.

[0141] Although the invention has been described in relation to several particular embodiments, it is perfectly clear that it is in no way limited thereto and that it encompasses

all the technical equivalents of the means described and the combinations thereof provided that they fall within the framework of the invention.

[0142] The use of the verb “comprise” or “include” and its conjugate forms does not preclude the presence of elements or steps other than those stated in a claim.

[0143] In the claims, any reference symbol between parentheses should not be interpreted as a limitation of the claim.

Claims

[Claim 1] A sealed tank (100) incorporated in a polyhedral bearing structure, said tank comprising a plurality of tank walls including a first wall (106) and a second wall (104) that are parallel to a first direction (101) of said tank and spaced apart in a second direction (105) of said tank, the tank walls further including two end walls (108) orthogonal to the first direction of the tank and connecting the first wall and the second wall, possibly via first intermediate walls arranged between the first wall and the two end walls (108) and/or via second intermediate walls arranged between the second wall and the two end walls (108), each tank wall being borne by a corresponding bearing wall (102) of the bearing structure,

each tank wall having a multilayer structure successively comprising, in the thicknesswise direction from the outside to the inside of the tank, a thermally insulating barrier (202) held against the corresponding bearing wall and a sealing membrane (206) borne by the thermally insulating barrier,

the sealing membrane of each of the first wall, the second wall and the end walls comprising a series of corrugations (118) that are parallel to one another and at right angles to transverse corners (107) parallel to a third direction (103) of the tank and formed at the intersections between the first wall or the second wall, the end walls and, if necessary, the intermediate walls arranged between them, the parallel corrugations being spaced apart so as to form, in the third direction:

- a plurality of identical regular intervals (120), each regular interval being formed between two adjacent corrugations, and

- at least one singular interval (122) different from the regular interval, and

wherein the at least two adjacent corrugations spaced apart by the singular interval (122) are continued uninterrupted at at least three of said transverse corners (107), preferably at a number of transverse corners greater than half of a total number of the transverse corners.

[Claim 2] The tank as claimed in claim 1, wherein the total number of the transverse corners (107) is equal to 4, 6 or 8.

[Claim 3] The tank as claimed in claim 1 or 2, wherein the at least two adjacent corrugations spaced apart by the singular interval are continued uninterrupted at all the transverse corners except one, so as to form an open ring all around the tank.

[Claim 4] The tank as claimed in claim 1 or 2, wherein the at least two adjacent corrugations spaced apart by the singular interval are continued uninterrupted at all the transverse corners so as to form a closed ring all around the tank.

[Claim 5] The tank as claimed in any one of claims 1 to 4, wherein the corrugations of each of the first wall, the second wall and the end walls, and if necessary the intermediate walls, form two singular intervals or more separated by at least one regular interval, or form two or more consecutive singular intervals.

[Claim 6] The tank as claimed in claim 5, wherein, for each of the first wall, the second wall and the end walls, and if necessary the intermediate walls, the singular intervals are arranged symmetrically on either side of a median line of said wall.

[Claim 7] The tank as claimed in any one of claims 1 to 6, wherein the singular intervals have different transverse dimensions.

[Claim 8] The tank as claimed in any one of claims 1 to 7, wherein the transverse dimension of at least one, in particular each, singular interval is the sum of the transverse dimension of a regular interval and a negative or positive predetermined constant whose absolute value is less than the dimension of a regular interval, in particular less than half the dimension of a regular interval.

[Claim 9] The tank as claimed in any one of claims 1 to 8, comprising at least one special zone and wherein said or each singular interval is arranged at a distance from said special zone greater than or equal to the transverse dimension of a regular interval.

[Claim 10] The tank as claimed in claim 9, wherein the tank walls further include two side walls (110) parallel to the first direction (101) and connected, respectively, to the first wall or the second wall by two third intermediate walls (112, 114), and wherein the special zone comprises said third intermediate walls.

[Claim 11] The tank as claimed in any one of claims 1 to 10, wherein the thermally insulating barrier of each of the first wall, the second wall and the end walls, and if necessary the first and second intermediate walls, comprises:

rows of insulating panels oriented at right angles to the transverse corners and juxtaposed according to a repeated pattern in the third direction, and in line with said or each singular interval, at least one row of singular insulating panels having a width different from a width of the repeated pattern.

[Claim 12] The tank as claimed in any one of claims 1 to 11, wherein the sealing membrane of each of the first wall, the second wall and the end walls, and if necessary the first and second intermediate walls, is formed by a plurality of rectangular metal sheets having the series of corrugations,

and wherein said or each singular interval is formed between a first corrugation arranged on a first of said metal sheets adjacent to an edge of said first metal sheet and a second corrugation arranged on a second of said metal sheets adjacent to the

first metal sheet, the second corrugation being adjacent to an edge of the second metal sheet turned toward said first metal sheet.

[Claim 13] The tank as claimed in claim 12, wherein the edge of the first sheet is a joggled edge forming a part with a level difference with respect to a central portion of said first sheet and configured for lap welding of the first metal sheet onto the second metal sheet.

[Claim 14] The tank as claimed in either one of claims 12 and 13 taken in combination with claim 11, wherein the edge of the first metal sheet and the edge of the second metal sheet are welded to one another in line with one of said rows of singular insulating panels.

[Claim 15] The tank as claimed in claim 14, wherein at least one singular insulating panel comprises a metal anchoring strip arranged opposite the first metal sheet and the second metal sheet, and wherein the second metal sheet is welded to said metal anchoring strip.

[Claim 16] The tank as claimed in any one of claims 12 to 15, wherein the first metal sheet comprises a number of corrugations less than or equal to the number of corrugations of the second metal sheet.

[Claim 17] The tank as claimed in any one of claims 1 to 16, wherein the tank walls further include two side walls (110) parallel to the first direction (101) and connected respectively to the first wall (106) or the second wall (104), possibly via two third intermediate walls, and to the end walls (108), possibly via two fourth intermediate walls.

[Claim 18] The tank as claimed in claim 17, wherein the sealing membrane of each of the first wall (106), the second wall (104) and the side walls (110) comprise a series of first additional corrugations (138) parallel to one another and at right angles to longitudinal corners (127) parallel to the first direction (101) of the tank and formed at the intersections between the first wall (106) or the second wall (104), the side walls (110) and, if necessary, the third intermediate walls, and the first additional corrugations (138) are spaced apart so as to form, in the first direction (101):

- a plurality of identical regular intervals, each regular interval being formed between two adjacent first additional corrugations (138), and
- at least one singular interval (142) different from the regular interval, and

wherein the at least two adjacent first additional corrugations (138) spaced apart by the singular interval (142) are continued uninterrupted at at least three of said longitudinal corners (127), preferably at a number of longitudinal corners greater than half of a total number of the longitudinal corners.

[Claim 19] The tank as claimed in claim 17 or 18, wherein the sealing membrane of each of the end walls (108) and the side walls (110) comprises a series of second additional corrugations (158) parallel to one another and at right angles to vertical corners (147) parallel to the second direction (105) of the tank and formed at the intersections between the end walls (108), the side walls (110) and, if necessary, the fourth intermediate walls, and the second additional corrugations (158) are spaced apart so as to form, in the second direction (105):

- a plurality of identical regular intervals, each regular interval being formed between two adjacent second additional corrugations, and
- at least one singular interval (162) different from the regular interval, and

wherein the at least two adjacent second additional corrugations (158) spaced apart by the singular interval (162) are continued uninterrupted at at least three of said vertical corners (147), preferably at a number of vertical corners greater than half a total number of the vertical corners.

[Claim 20] A vessel (70, 170) comprising a double-hull and a tank (100) as claimed in any one of claims 1 to 19 incorporated in said double-hull as bearing structure.

[Claim 21] The vessel (170) as claimed in claim 20, wherein said tank (100) is configured as a fuel tank for a vessel propulsion system (65).

[Claim 22] A transfer system for a fluid, the system comprising the vessel (70, 170) as claimed in claim 20 or 21, insulated pipelines arranged so as to connect the tank (100) installed in the hull of the vessel (70, 170) to a floating or onshore storage installation, and a pump for driving a fluid through the insulated pipelines from or to the floating or onshore storage installation to or from the tank (100) of the vessel (70, 170).

[Claim 23] A method for loading or offloading a vessel (70, 170) as claimed in claim 20 or 21, wherein a fluid is conveyed through insulated pipelines from or to a floating or onshore storage installation to or from the tank (100) of the vessel (70, 170).