

Description

Title of the invention: Sealed and thermally insulating tank

Technical domain

[1] The invention relates to the field of sealed, thermally insulated membrane tanks for storing
5 and/or transporting fluids, such as a liquefied gas.

[2] Sealed thermally insulated membrane tanks are notably used to store liquefied natural gas (LNG), which is stored at atmospheric pressure at around -163°C. These tanks can be installed on land or on floating structures. In a floating structure, the tank can be used to transport liquefied natural gas or to receive the liquefied natural gas used as fuel to power
10 the floating structure.

Technological background

[3] Document WO-A-89/09909 discloses a sealed thermally insulating storage tank for liquefied natural gas arranged in a load-bearing structure including walls with a multi-layer structure, specifically (from the outside of the tank to the inside of the tank), a secondary
15 thermally insulating barrier anchored to the load-bearing structure, a secondary sealed membrane that is supported by the secondary thermally insulating barrier, a primary thermally insulating barrier that is supported by the secondary sealed membrane and a primary sealed membrane that is supported by the thermally insulating barrier and that is designed to be in contact with the liquefied natural gas stored in the tank. The primary
20 insulating barrier comprises an assembly of rigid plates that are held using welding supports of the secondary sealed membrane.

[4] In one embodiment, the primary sealed membrane is formed by an assembly of rectangular sheets with corrugations in two perpendicular directions, in which said sheets are lap welded together and the edges of said sheets are welded to the metal strips
25 fastened to the rabbets along the edges of the plates of the primary insulating barrier.

Summary

[5] One idea at the heart of the invention involves providing a tank wall that combines the advantages of a secondary membrane formed by parallel strakes, the robustness of which has been demonstrated, and a corrugated primary membrane that can provide very good
30 strength against accidental denting and other stresses, for example resulting from thermal contraction, cargo movements and/or deformation of the ship girder when at sea.

- [6] Another idea at the heart of the invention involves providing a tank wall that is relatively simple to manufacture and that enables the use of different types of corrugated sealed membranes as the primary membrane.
- [7] Another idea at the heart of the invention involves providing a tank that enables the use of identical or similar insulating panels on the different tank walls, while facilitating the continuity of the corrugations between adjacent walls.
- [8] For this purpose, the invention proposes a sealed thermally insulating tank built into a load-bearing structure, notably a polyhedral load-bearing structure, the tank having one or more tank walls fastened to one or more load-bearing walls of the load-bearing structure.
- [9] According to one embodiment, the tank walls have a transverse end wall and a plurality of longitudinal walls linked to the end wall, the plurality of walls including a first wall linked to the end wall at a first edge and a second wall adjacent to the first wall and linked to the end wall at a second edge,
- each of the longitudinal walls and the end wall having a sealed membrane that is designed to be in contact with a product contained in the tank and an insulating barrier arranged between the sealed membrane and the load-bearing structure,
- the insulating barrier of the longitudinal walls includes rows of insulating panels oriented longitudinally and juxtaposed according to a repeating pattern and the insulating barrier of the end wall has rows of insulating panels oriented in a direction parallel or perpendicular to the second wall and juxtaposed according to repeating pattern,
- the sealed membrane of the end wall having a first series of corrugations parallel to the second wall and spaced apart by a first pitch y and a second series of corrugations perpendicular to the second wall and spaced apart by the first pitch y ,
- the sealed membrane of each longitudinal wall having a plurality of longitudinal corrugations, the longitudinal corrugations of the second wall being spaced apart by said first pitch y and connected continuously to the second series of corrugations of the end wall at the second edge, the longitudinal corrugations of the first wall being spaced apart by a second pitch z that is greater than the first pitch y and connected continuously to one of the first and second series of corrugations of the end wall by an angular arrangement at the first edge and including a plurality of deviation corrugations,
- and the angle between a plane of the first wall and a plane of the second wall and the ratio between the first pitch y and the second pitch z are defined in relation to one another.

[10] According to advantageous embodiments, such a tank may have one or more of the following features.

[11] According to one embodiment, the ratio between the second pitch z and the first pitch y is equal to the sine or cosine of the angle between the plane of the first wall and the plane of the second wall.

[12] According to one embodiment, the repeating pattern of the rows of insulating panels of the end wall and the repeating pattern of the rows of insulating panels of the first wall share a predetermined dimension,

and the angle between the plane of the first wall and the plane of the second wall is selected such that said dimension of the repeating pattern is firstly a first integer multiple n_1 of the first pitch y and secondly a second integer multiple n_2 , which is less than the first multiple n_1 , of the second pitch z ,

said angle being a function of the arc cosine or the arc sine of the ratio between the second integer multiple n_2 and the first integer multiple n_1 . For example, $n_2/n_1 = 2/3$. This angular arrangement enables a single dimension of the repeating pattern to be obtained, while being a multiple of the pitch, for any of the walls of the tank. One advantage of this arrangement is to provide a tank that enables the use of identical insulating panels on the first wall and the end wall, and even also on the second wall. Another advantage of this arrangement is to obtain a simpler tank that is less costly to manufacture.

[13] According to one embodiment, the rows of panels of the end wall are perpendicular to the second wall and the longitudinal corrugations of the first wall are connected continuously to the first series of corrugations of the end wall,

and in which the angle between the plane of the first wall and the plane of the second wall is equal to the arc cosine of the ratio between the second multiple n_2 and the first multiple n_1 .

[14] According to one embodiment, the rows of panels of the end wall are parallel to the second wall and the longitudinal corrugations of the first wall are connected continuously to the second series of corrugations of the end wall,

and the angle between the plane of the first wall and the plane of the second wall is equal to the arc sine of the ratio between the second multiple n_2 and the first multiple n_1 .

[15] Choosing an angle between the plane of the first wall and the plane of the second wall of which the cosine and the sine is the rational number n_2/n_1 can be a requirement that is difficult to satisfy in certain situations. According to another embodiment that leaves

greater scope to set this angle, for example to a value of 45° or to any other value, the dimension of the repeating pattern of the rows of insulating panels of the end wall is different from, and in particular greater than, the dimension of the repeating pattern of the rows of insulating panels of the first wall.

5 [16] According to one embodiment, the dimension of the repeating pattern of the rows of insulating panels of the end wall is an integer multiple of the first pitch y .

[17] According to one embodiment, the dimension of the repeating pattern of the rows of insulating panels of the first wall is an integer multiple of the second pitch z .

10 [18] According to one embodiment, the second wall is horizontal and the longitudinal corrugations of the first wall are connected continuously to the first series of corrugations of the end wall.

In this case, in the first wall, the membrane can also include at least one additional longitudinal corrugation adjacent to an edge of the first wall connected continuously to a corrugation of the second series of corrugations of the end wall. As a result, the maximum
15 distance between two continuous corrugations can be kept below a given threshold, including at the interface between two adjacent longitudinal walls.

[19] According to one embodiment, the second wall is vertical and the longitudinal corrugations of the first wall are connected continuously to the first series of corrugations of the end wall.

20 [20] According to one embodiment, a deviation corrugation has a first end extending a longitudinal corrugation and a second end extending a corrugation of the first series of corrugations or the second series of corrugations.

[21] The tank walls can also have a single sealed membrane and a single insulating barrier, depending on the nature of the cargo to be stored. The tank walls can also have several
25 sealed membranes alternating with several insulating barriers. According to a corresponding embodiment, the sealed membrane is a primary membrane and the insulating barrier is a primary insulating barrier, and each of the longitudinal walls and the end wall also include a secondary sealed membrane that is arranged between the primary sealed membrane and the load-bearing structure, and a secondary insulating barrier that
30 is arranged between the secondary membrane and the load-bearing structure, said secondary insulating barrier having secondary rows of insulating panels oriented in the same direction as the primary rows of said wall and juxtaposed in a repeating pattern,

the secondary membrane including a plurality of strakes that are parallel to one another, each of the strakes having a flat central portion bearing on an upper surface of the secondary panels and two raised edges projecting towards the inside of the tank, the distance between the two edges being the dimension of the strake,

5 the strakes and the secondary rows of the end wall being horizontal and the strakes and the secondary rows of the longitudinal walls being oriented longitudinally,

and the dimension of the repeating pattern of the primary rows and the dimension of the repeating pattern of the secondary rows are the same on each of the longitudinal walls and the end wall.

10 [22] According to one embodiment, the strakes and the secondary rows of the end wall are horizontal and the strakes and the secondary rows of the longitudinal walls are oriented longitudinally.

[23] According to one embodiment, the dimension of the repeating pattern of the primary rows and the dimension of the repeating pattern of the secondary rows are the same on
15 each of the longitudinal walls and the end wall.

[24] According to one embodiment, in the first wall, the dimension of the repeating pattern of the secondary panels is an integer multiple of the dimension of the strakes.

[25] According to one embodiment, in the end wall and/or the second wall, the dimension of the repeating pattern of the secondary panels is an integer multiple of the dimension of
20 the strakes.

[26] According to one embodiment, in the first wall and/or the end wall and/or the second wall, the second pitch and the dimension of the strakes are the same.

[27] The invention also provides a tank wall structure that can be used to make each of the longitudinal walls and the end walls or for some of these tank walls.

25 [28] According to a corresponding embodiment, the tank wall, notably the first wall, the second wall and/or the end wall, has a primary sealed membrane designed to be in contact with a product contained in the tank, a secondary sealed membrane arranged between the primary sealed membrane and the load-bearing wall, a primary insulating barrier arranged between the primary sealed membrane and the secondary sealed membrane
30 and a secondary insulating barrier arranged between the secondary sealed membrane and the load-bearing wall,

the secondary insulating barrier has a plurality of secondary rows parallel to a first direction, a secondary row comprising a plurality of juxtaposed parallelepiped secondary insulating

panels, the secondary rows being juxtaposed in a second direction perpendicular to the first direction in a repeating pattern,

the secondary sealed membrane has a plurality of strakes that are parallel to the first direction and made of an alloy with a low coefficient of expansion, the coefficient of expansion of which is for example less than or equal to $7 \cdot 10^{-6} \text{ K}^{-1}$, a strake having a flat central portion bearing on an upper surface of the secondary insulating panels and two raised edges projecting towards the inside of the tank in relation to the central portion, the strakes being juxtaposed in the second direction in a repeating pattern and welded together sealingly at the raised edges, anchoring flanges anchored to the secondary insulating panels and parallel to the first direction being arranged between the juxtaposed strakes to hold the secondary sealed membrane on the secondary insulating barrier,

in which the dimension of the repeating pattern of the secondary rows is an integer multiple of the dimension of a strake in the second direction,

in which the load-bearing wall carries secondary retaining members that are arranged at the interfaces between the secondary rows and that cooperate with the secondary insulating panels to hold the secondary insulating panels on the load-bearing wall,

and in which the primary insulating barrier has a plurality of primary rows parallel to the first direction, one or each primary row having a plurality of juxtaposed parallelepiped primary insulating panels and for example overlapping a secondary row or straddling at least two secondary rows, the primary rows being juxtaposed in the second direction in a repeating pattern, the dimension of the repeating pattern of the primary rows being equal to the dimension of the repeating pattern of the secondary rows in the second direction.

[29] According to one embodiment, the tank wall is a longitudinal wall and the first direction is a longitudinal direction.

[30] According to one embodiment, the tank wall is an end wall and the first direction is parallel or perpendicular to said second wall.

[31] According to one embodiment, primary retaining members, for example carried by the secondary retaining members or by the secondary insulating panels, are arranged at the interfaces between the primary rows and cooperate with the primary insulating panels to hold the primary insulating panels on the secondary sealed membrane.

[32] According to one embodiment, the primary rows are offset in the second direction by a fraction, for example half, of the dimension of the repeating pattern of the secondary rows, in relation to the secondary rows. This offsetting helps to limit or eliminate vertical

alignments between primary retaining members and secondary retaining members, which limits occurrences of heat bridges caused by such alignments.

- [33] Another advantage of offsetting the primary rows in the first and/or second direction is to provide a more uniform distribution of the forces passing through the membranes and the primary insulation that impact the secondary insulating panels and the load-bearing wall. Indeed, in this case, a compressive force exerted on a primary insulating panel is distributed over several, for example two or four, underlying secondary insulating panels.
- [34] According to one embodiment, the interfaces between the primary insulating panels in a primary row are offset in the first direction in relation to the interfaces between the secondary insulating panels in the two secondary rows on which the primary row is superposed.
- [35] Preferably, in this case, the primary retaining members are carried by the secondary insulating panels away from the edges of the secondary insulating panels, for example at the centers of the secondary insulating panels.
- [36] Such primary retaining members can be provided on all of the secondary retaining members or on all of the secondary insulating panels, for example if the primary insulating panel has the same dimensions as the secondary insulating panel, or on some of the secondary retaining members or some of the secondary insulating panels, for example if the primary insulating panel is longer than the secondary insulating panel or if the primary insulating panel is only offset in the first direction.
- [37] According to one embodiment, a primary retaining member has a plate fastened to a cover plate of the secondary insulating panel beneath the secondary sealed membrane and a rod attached to said plate, rigidly or with horizontal play, sealingly traversing the secondary sealed membrane towards the primary insulating barrier.
- [38] According to one embodiment, the primary sealed membrane has first corrugations parallel to the first direction that are arranged in a repeating pattern in the second direction and flat portions positioned between the first corrugations and bearing on an upper surface of the primary insulating panels, and the dimension of the repeating pattern of the primary rows is an integer multiple of the dimension of the repeating pattern of the first corrugations, specifically an integer multiple of the pitch y or z , the primary sealed membrane having a plurality of rows of sheets parallel to the first direction, a row of sheets comprising a plurality of rectangular sheets welded together sealingly at the edge zones, with or without reciprocal overlapping, the rows of sheets being juxtaposed in the second direction and

welded together sealingly, the dimension of a row of sheets in the second direction being an integer multiple of the dimension of the repeating pattern of the primary rows.

[39] The repeating pattern of the first corrugations can be a repeating pattern comprising one corrugation, where the pitch is regular, or several corrugations, where the pitch is irregular. A repeating pattern comprising a single corrugation means that the first corrugations are spaced apart by a first regular spacing, in other words the pitch, in the second direction and the dimension of the repeating pattern is equal to this first regular spacing. This case, the dimension of the repeating pattern of the primary rows is an integer multiple of said first regular spacing. A repeating pattern comprising several corrugations means that the spacing between the corrugations is not necessarily regular, but that all of the spacings repeat at a regular interval, referred to as the dimension of the repeating pattern of the corrugations.

[40] According to one embodiment, the rows of sheets are offset in the second direction in relation to the primary rows such that the welded joints between the rows of sheets are positioned away from the interfaces between the primary rows, i.e. notably away from the retaining members.

[41] These features mean that the welded joints between the rows of sheets of the primary sealed membrane can essentially be made away from the edges of the primary insulating panels parallel to the first direction, and therefore on a surface having a high level of flatness. This results in a lower risk of local weld variations and a higher level of quality in the obtained membrane.

[42] According to one embodiment, a primary row has a plurality of juxtaposed parallelepiped primary insulating panels in a repeating pattern and a row of sheets of the primary sealed membrane has a plurality of rectangular sheets juxtaposed in a repeating pattern, the dimension of the repeating pattern of the rectangular sheets being an integer multiple of the dimension of the repeating pattern of the primary insulating panels in the first direction.

[43] According to one embodiment, the edges of the rectangular sheets are offset in the first direction in relation to the edges of the primary insulating panels parallel to the second direction, such that the welded joints between the rectangular sheets are positioned away from the edges of the primary insulating panels parallel to the second direction.

[44] According to one embodiment, the primary insulating panels and/or the secondary insulating panels are square-shaped.

- [45] The repeating pattern of the primary rows and/or the repeating pattern of the secondary rows can, but need not, have an interstice in the second direction. If there is an interstice between two rows, the dimension of the repeating pattern is equal to the sum of the dimension of the primary or secondary insulating panel and the dimension of the interstice.
- 5 [46] Similarly, the repeating pattern of the primary or secondary insulating panels in a primary or secondary row can, but need not, have an interstice in the first direction. If there is an interstice between two primary or secondary insulating panels, the dimension of the repeating pattern is equal to the sum of the dimension of the primary or secondary insulating panel and the dimension of the interstice.
- 10 [47] According to one embodiment, the dimension of a strake in the second direction is an integer multiple of said first regular spacing or pitch. These features make it possible to select the orientation of the strakes as a function of local requirements in the desired application.
- [48] According to one embodiment, the primary sealed membrane also has second
15 corrugations parallel to the second direction and arranged in a repeating pattern in the first direction, the flat portions being positioned between the first corrugations and between the second corrugations.
- [49] The repeating pattern of the second corrugations can be a repeating pattern including one corrugation or several corrugations. A repeating pattern comprising a single
20 corrugation means that the second corrugations are spaced apart by a second regular spacing in the first direction. In this case, the second regular spacing can be the same as or different from the first regular spacing. A repeating pattern comprising several corrugations means that the spacing between the corrugations is not necessarily regular, but that all of the spacings repeat at a regular interval, referred to as the dimension of the
25 repeating pattern of the corrugations.
- [50] According to the embodiments, the first and second corrugations can be continuous or discontinuous at the intersections between first and second corrugations. Continuous corrugations make it possible to form continuous channels, for example to enable an inert gas to flow between the primary sealed membrane and the primary insulating barrier.
30 Discontinuous corrugations make it easier to form the sheet by stamping.
- [51] According to one embodiment, the dimension of the repeating pattern of the primary insulating panels is an integer multiple of the dimension of the repeating pattern of the second corrugations, for example an integer multiple of said second regular spacing.

- [52] According to one embodiment, a rectangular sheet of the primary sealed membrane has a dimension in the first direction that is substantially equal to an integer multiple of the dimension of the repeating pattern of the second corrugations or an integer multiple of the second regular spacing. There may be a slight discrepancy between these two quantities, that is less than the dimension of the overlap between two adjacent sheets.
- [53] The primary sealed membrane is held on the primary insulating barrier by anchoring means that can be made of different materials.
- [54] According to one embodiment, the anchoring means have metal anchoring strips fastened to the primary insulating panels at positions corresponding to the contours of the rectangular sheets, onto which the edge zones of the rectangular sheets can be welded. A primary insulating panel can notably have an anchoring strip to fasten a straight edge of one or more rectangular sheets or two intersecting anchoring strips to fasten a corner zone of one or more rectangular sheets.
- [55] According to one embodiment, the anchoring means have metal inserts, for example in the form of disks, fastened to the primary insulating panels at positions corresponding to the edge zones of the primary insulating panels away from the contours of the rectangular sheets, onto which the central zones of the rectangular sheets can be welded.
- [56] According to one embodiment, a primary insulating panel has crossed stress-relief slots in a thickness direction of the primary insulating panel leading to a cover plate of the primary insulating panel. According to the embodiments, one or each metal anchoring strip can have several aligned segments that are fastened to the cover plate and separated by the stress-relief slots and/or metal inserts can be fastened to the cover plate between the stress-relief slots.
- [57] According to one embodiment, at least one of the insulating panels has a bottom plate resting on the load-bearing structure or the secondary sealed membrane, an intermediate plate arranged between the bottom plate and the cover plate, a first layer of insulating polymer foam sandwiched between the bottom plate and the intermediate plate and a second layer of insulating polymer foam sandwiched between the intermediate plate and the cover plate. Such a structure is advantageous in that it helps to limit the bending stresses caused by the differential contraction of the materials in the insulating panel.
- [58] According to one embodiment, recesses are formed in the second layer of insulating polymer foam so that the intermediate plate projects beyond the second layer of insulating polymer foam to form one of the bearing zones for the secondary retaining members.

- [59] According to one embodiment, the first layer of insulating polymer foam has, at each of the corner zones of the insulating panel, a cutout receiving a pillar that extends between the bottom plate and the intermediate plate. This helps to limit crushing and creeping of the foam.
- 5 [60] According to another embodiment, at least one of the insulating panels has a bottom plate, a cover plate and load-bearing partitions extending in the thickness direction of the tank wall between the bottom plate and the cover plate and delimiting a plurality of compartments filled with an insulating packing such as perlite.
- [61] According to one embodiment, the fluid is a liquefied gas such as liquefied natural gas.
- 10 [62] Such a tank may be part of an onshore storage facility, for example for storing LNG, or be installed on a coastal or deep-water floating structure, notably a liquefied natural gas carrier, a floating storage and regasification unit (FSRU), a floating production, storage and unloading (FPSO) unit, inter alia.
- [63] According to one embodiment, a ship used to transport a cryogenic fluid has a double
15 hull and the aforementioned tank arranged in the double hull.
- [64] According to one embodiment, the double hull has an inner hull forming the load-bearing structure of the tank.
- [65] According to one embodiment, the invention also provides a method for loading onto or unloading from such a ship, in which a fluid is channeled through insulated pipes to or
20 from an onshore or floating storage facility to or from the tank on the ship.
- [66] According to one embodiment, the invention also provides a transfer system for a fluid, the system including the aforementioned ship, insulated pipes arranged to connect the tank installed in the hull of the ship to an onshore or floating storage facility and a pump for driving a fluid through the insulated pipes to or from the onshore or floating storage
25 facility to or from the tank on the ship.

Short description of the figures

- [67] The invention can be better understood, and additional objectives, details, features and advantages thereof are set out more clearly, in the detailed description below of several specific embodiments of the invention given solely as non-limiting examples, with
30 reference to the drawings attached.
- [68] Figure 1 is a perspective cut-away view of a tank wall.
- [69] Figure 2 is a perspective view of a secondary insulating panel that can be used in the tank wall.

- [70] Figure 3 is a perspective view of a primary insulating panel that can be used in the tank wall.
- [71] Figure 4 is a perspective view of a retaining device that can cooperate with primary insulating panels and secondary insulating panels to hold said panels on the load-bearing structure.
- [72] Figure 5 is an exploded view of the retaining device in figure 4.
- [73] Figure 6 is a magnified view of the zone VI in figure 1, also showing the anchoring means of the primary membrane according to a first embodiment.
- [74] Figure 7 is a magnified cross-section view along the line VII-VII in figure 6.
- [75] Figure 8 is a view similar to the view in figure 6, also showing the bridging elements of the primary insulating barrier.
- [76] Figure 9 is a magnified cross-section view along the line IX-IX in figure 8.
- [77] Figure 10 is a view similar to the view in figure 6, showing the anchoring means of the primary membrane according to a second embodiment.
- [78] Figure 11 is a cut-away schematic view of a tank in a liquefied natural gas carrier ship and of a loading/unloading terminal for this tank.
- [79] Figure 12 is a perspective cut-away view of a tank wall according to another embodiment.
- [80] Figure 13 is a magnified view of the zone XIII in figure 12, also showing a primary anchoring member according to one embodiment.
- [81] Figure 14 is a perspective view of a tank wall according to another embodiment.
- [82] Figure 15 is a perspective view of a cross section of a polyhedral tank.
- [83] Figure 16 is a partial projection view of the zone XVI in figure 15 according to a first embodiment.
- [84] Figure 17 is a cross-section view along the line XVII-XVII of the end wall in figure 16 according to the first embodiment.
- [85] Figure 18 is a cross-section view along the line XVIII-XVIII of the bevel wall in figure 16 according to a first embodiment.
- [86] Figure 19 is a cross-section view along the line XVII-XVII of the end wall in figure 16 according to a second embodiment of the tank.

[87] Figure 20 is a cross-section view along the line XVIII-XVIII of the bevel wall in figure 16 according to the second embodiment.

[88] Figure 21 is a perspective view of a bevel wall according to a third embodiment.

Description of the embodiments

5 [89] Figure 1 shows a multi-layer structure of a wall 1 of a sealed thermally insulating tank for storing a liquefied fluid, such as liquefied natural gas (LNG). Each wall 1 of the tank has, arranged successively in the thickness direction from the outside towards the inside of the tank, a secondary thermally insulating barrier 2 held on a load-bearing wall 3, a secondary sealed membrane 4 bearing against the secondary thermally insulating barrier 2, a primary thermally insulating barrier 5 bearing against the secondary sealed membrane 4 and a primary sealed membrane 6 designed to be in contact with the liquefied natural gas contained in the tank.

[90] The load-bearing structure may notably be formed by the hull or the double hull of a ship. The load-bearing structure comprises a plurality of load-bearing walls 3 defining the general shape of the tank, which is usually polyhedral.

[91] The secondary thermally insulating barrier 2 has a plurality of secondary insulating panels 7 that are anchored to the load-bearing wall 3 using retaining devices 98 that are described in detail below. The secondary insulating panels 7 have an overall parallelepipedic shape and are arranged in parallel rows. Three rows are indicated using the letters A, B and C. Mastic beads 99 are interposed between the secondary insulating panels 7 and the load-bearing wall 3 to fill the gaps between the load-bearing wall 3 and a flat reference surface. Kraft paper is inserted between the mastic beads 99 and the load-bearing wall 3 to prevent the mastic beads 99 from sticking to the load-bearing wall 3.

[92] Figure 2 shows the structure of a secondary insulating panel 7 according to one embodiment. In this case, the secondary insulating panel 7 has three plates, specifically a bottom plate 8, an intermediate plate 9 and a cover plate 10. The bottom plate 8, intermediate plate 9 and cover plate 10 are for example made of plywood. The secondary insulating panel 7 also has a first layer of insulating polymer foam 11 sandwiched between the bottom plate 8 and the intermediate plate 9 and a second layer of insulating polymer foam 12 sandwiched between the intermediate plate 9 and the cover plate 10. The first and second layers of insulating polymer foam 11, 12 are respectively glued to the bottom plate 8 and the intermediate plate 9 and to the intermediate plate 9 and the cover plate 10. The insulating polymer foam may notably be a polyurethane-based foam, optionally reinforced with fibers.

[93] The first layer of insulating polymer foam 11 has cutouts in the corner zones to accommodate corner pillars 13. The corner pillars 13 extend, in the four corner zones of the secondary insulating panel 7, between the bottom plate 8 and the intermediate plate 9. The corner pillars 13 are fastened, for example using staples or screws or glue, to the bottom plate 8 and the intermediate plate 9. The corner pillars 13 are for example made of plywood or plastic. The corner pillars 13 absorb some of the compression load when in use and help to limit the crushing and creeping of the foam. The thermal contraction coefficient of such corner pillars 13 is different from the thermal contraction coefficient of the first layer of insulating polymer foam 11. Furthermore, when the tank is being cooled, the distortion of the secondary insulating panel 7 can be lesser at the corner pillars 13 than in other zones.

[94] Furthermore, the secondary insulating panel 7 has recesses 14, 54 in the corner zones thereof to receive retaining devices 98, which are detailed below. The secondary insulating panel 7 has a first recess 14 from the bottom plate 8 to the intermediate plate 9 designed to enable a rod 15 of the retaining device 98 to pass through. Above the intermediate plate 9, the secondary insulating panel 7 has a second recess 54. The dimensions of the second recess 54 are greater than the dimensions of the first recess 14 such that the intermediate plate 9 projects beyond the second layer of insulating polymer foam 12 and the cover plate 10. Thus, the intermediate plate 9 forms a bearing zone 16 in the corner zones of the secondary insulating panel 7 that is designed to cooperate with a secondary bearing plate 17 of the retaining device 98.

[95] Furthermore, the cover plate 10 has a counterbore 18 at these four corner zones. Each counterbore 18 is designed to receive a force distribution plate 19 of the retaining device 98. The thickness of the counterbores 18 is substantially similar to the thickness of the force distribution plate 19 such that the force distribution plate 19 is flush with the upper surface of the cover plate 10. The cover plate 10 also has slots 20 designed to receive welding supports.

[96] The structure of the secondary insulating panel 7 is described above by way of example. Furthermore, in another embodiment, the secondary insulating panels 7 can have a different overall structure, for example the structure described in document WO2012/127141. The secondary insulating panels 7 are then formed into boxes with a bottom plate, a cover plate and load-bearing partitions extending in the thickness direction of the tank wall 1 between the bottom plate and the cover plate and delimiting a plurality of compartments filled with an insulating packing such as perlite, glass wool or rock wool.

[97] Figure 1 also shows that the secondary sealed membrane 4 has a continuous layer of metal strakes 21 with raised edges. The strakes 21 are welded via the raised edges 32 thereof to parallel welding supports that are fastened in the slots 20 formed in the cover plates 10 of the secondary insulating panels 7. The strakes 21 are for example made of Invar®, i.e. an alloy of iron and nickel with a coefficient of expansion typically between $1.2 \cdot 10^{-6}$ and $2 \cdot 10^{-6} \text{ K}^{-1}$. It is also possible to use alloys of iron and manganese with a typical coefficient of expansion of around $7 \cdot 10^{-6} \text{ K}^{-1}$.

[98] The primary thermally insulating barrier 5 has a plurality of primary insulating panels 22 that are anchored to the load-bearing wall 3 by the aforementioned retaining devices 98. The primary insulating panels 22 are generally parallelepipedic. Furthermore, the dimensions of the primary insulating panels are identical to the dimensions of the primary insulating panels 22, with the exception of the thickness thereof in the thickness direction of the tank wall 1, which can be different, and notably smaller. Each of the primary insulating panels 22 is aligned with one of the secondary insulating panels 7 in the thickness direction of the tank wall 1.

[99] Figure 3 shows the structure of a primary insulating panel 22 according to one embodiment. The primary insulating panel 22 has a multi-layer structure similar to the multi-layer structure of the secondary insulating panel 7 in figure 2. Furthermore, the primary insulating panel 22 comprises successively a bottom plate 23, a first layer of insulating polymer foam 24, an intermediate plate 25, a second layer of insulating polymer foam 26 and a cover plate 27. The insulating polymer foam may notably be a polyurethane-based foam, optionally reinforced with fibers.

[100] The primary insulating panel 22 has recesses 28 in the corner zones thereof such that the bottom plate 23 projects beyond the first layer of insulating polymer foam 24, the intermediate plate 25, the second layer of insulating polymer foam 26 and the cover plate 27. Thus, the bottom plate 23 forms a bearing zone 29 in the corner zones of the primary insulating panel 22 that is designed to cooperate with a primary bearing plate 30 of the retaining device 98. A wedge (not shown) can be added to the bottom plate 23, the shape of said wedge being similar to the shape of the bearing zone 29 and being designed to cooperate with the primary bearing plate 30 of the retaining device 98.

[101] The bottom plate 23 has slots 31 that are designed to receive the raised edges 32 of the strakes 21 of the secondary sealed membrane 4. The cover plate 27 can also have anchoring means (not shown in figures 1 and 3) to anchor the primary sealed membrane 6.

[102] The structure of the primary insulating panel 22 is described above by way of example. Furthermore, in another embodiment, the primary insulating panels 22 can have a different overall structure, for example as described in document WO2012/127141.

[103] In another embodiment, the primary thermally insulating barrier 5 has primary insulating panels 22 with at least two different types of structure, for example the two aforementioned structures, as a function of the installation zone thereof in the tank.

[104] Figure 1 also shows that the primary sealed membrane 6 has a continuous layer of rectangular sheets 33 that have two mutually perpendicular series of corrugations. The first series of corrugations 55 extends perpendicular to the rows of insulating panels A, B, C, and therefore perpendicular to the raised edges 32 of the strakes 21, and has regular spacings 57. The second series of corrugations 56 extends parallel to the rows of insulating panels A, B, C, and therefore parallel to the raised edges 32 of the strakes 21, and has regular spacings 58. Preferably, the first series of corrugations 55 is taller than the second series of corrugations 56.

[105] The rectangular sheets 33 are welded together to form small overlap zones 59 along the edges thereof, using a known technique.

[106] A rectangular sheet 33 preferably has width and length dimensions that are integer multiples of the spacings between the corresponding corrugations and also integer multiples of the dimensions of the primary insulating panels 22. Figure 1 shows a rectangular sheet 33 that measures 4 times the spacing 57 by 12 times the spacing 58. The spacings 57 and 58 are preferably equal. Thus, the orientation of the corrugations 55 and 56 in the tank can be easily adapted to the requirements of the application without entailing significant modifications in the manufacture of the insulating barriers.

[107] For example, in a variant embodiment, the primary sealed membrane 6 is turned through 90° such that the first series of corrugations 55 extends parallel to the rows of insulating panels A, B, C and therefore parallel to the raised edges 32 of the strakes 21.

[108] The primary insulating panels 22 and the secondary insulating panels 7 have the same dimension in the widthwise direction of the rows A, B, C. By convention, this dimension shall be referred to as the length of the insulating panels. This row width is an integer multiple of the spacing between corrugations in the same direction, in this case the spacing 58, and an integer multiple of the width of the strakes 21, to facilitate the modular manufacture of the tank wall by forming repeating patterns many times over substantially all of the load-bearing wall 3.

[109] Preferably, the width of a strake 21 is an integer multiple of the spacing between corrugations in the same direction, for example double.

[110] In the lengthwise direction of the rows A, B, C, a primary insulating panel 22 can have the same dimension as a secondary insulating panel 7 or an integer multiple of this dimension. This dimension is an integer multiple of the spacing between corrugations in the same direction, in this case the spacing 57, to facilitate the modular manufacture of the tank wall by forming repeating patterns many times over all of the load-bearing wall 3.

[111] Preferably, the primary insulating panels 22 and the secondary insulating panels 7 are square. This makes it easier to adapt the relative orientation of the strakes and the corrugations in the tank without requiring significant modifications to the design of the insulating panels.

[112] Preferred dimensional example

Spacing between corrugations 57, 58: PO

Width of the primary insulating panel 22 and the secondary insulating panel 7: 4PO

Length of the primary insulating panel 22 and the secondary insulating panel 7: 4PO (square)

Width of a strake 21: 2PO

Length of a sheet 33: 12PO (figure 1) or 8PO (not shown)

Width of a sheet 33: 4PO

PO = 300 mm.

With these dimensions, a good compromise is achieved between the ease of holding the parts that make up the tank wall and the number of parts that have to be assembled. This arrangement also simplifies the connection of the corrugations between two walls of a tank.

[113] Dimensional example 2

Spacing between corrugations 58: PO

Spacing between corrugations 57: GO

Width of the primary insulating panel 22 and the secondary insulating panel 7: 3GO

Length of the primary insulating panel 22 and the secondary insulating panel 7: 4PO (rectangular)

Width of a strake 21: 2PO

Length of a sheet 33: 12PO

Width of a sheet 33: 3GO

PO = 300 mm

GO = 340 mm

[114] Example 3

- 5 The corrugations 55 are not equidistant, but arranged in a repeating pattern of four corrugations 55, with the following successive spacings:

340, 340, 340, 180 mm

Preferably, the 180 mm gap is split into two 90 mm portions located on two opposite edges of the rectangular sheet 33.

- 10 The dimension of the repeating pattern is therefore 1200 mm. For the remainder, the dimensions of the first example are retained.

[115] Example 4

The corrugations 55 are not equidistant, but arranged in a repeating pattern of four corrugations 55, with the following successive spacings:

- 15 300, 400, 300, 200 mm

Preferably, the 200 mm gap is split into two 100 mm portions located on two opposite edges of the rectangular sheet 33.

The dimension of the repeating pattern is therefore 1200 mm. For the remainder, the dimensions of the first example are retained.

- 20 [116] As shown in figure 1, the retaining devices 98 are positioned in the four corners of the primary insulating panels 22 and the secondary insulating panels 7. Thus, each stack of one secondary insulating panel 7 and one primary insulating panel 22 is anchored to the load-bearing wall 3 using for retaining devices 98. Thus, the retaining device 98 in this case comprises a primary retaining member superposed on a secondary retaining member.
- 25 Furthermore, each retaining device 98 cooperates with the corners of four adjacent secondary insulating panels 7 and with the corners of four adjacent primary insulating panels 22.

[117] Figures 4 and 5 more specifically show the structure of a retaining device 98 according to one embodiment.

- 30 [118] The retaining device 98 has a socket 34, the base of which is welded to the load-bearing wall 3 in a position that corresponds to a clearance in the corner zones of four adjacent secondary insulating panels 7. The lower end of a rod 15 is screwed into a nut

35, shown in figure 5, seated in the socket 34. The rod 15 passes between the adjacent secondary insulating panels 7.

[119] The rod 15 passes through a bore formed in an insulating plug 36 designed to ensure continuous secondary thermal insulation in the retaining device 98. The insulating plug 36 has a cross-shaped section that is defined by four branches in a plane orthogonal to the thickness direction of the tank wall 1. Each of the four branches is inserted into an interstice formed between two of the four adjacent secondary insulating panels 7.

[120] The retaining device 98 also has a secondary bearing plate 17 that bears towards the load-bearing wall 3 against the bearing zone 16 formed in each of the four adjacent secondary insulating panels 7 in order to hold said panels against the load-bearing wall 3. In the embodiment shown, the secondary bearing plate 17 is seated in the second recess 54 formed in the second layer of insulating polymer foam 12 of each of the secondary insulating panels 7 and bears against a zone of the intermediate plate 9 that forms the bearing zone 16.

[121] A nut 37 cooperates with a thread formed at the upper end of the rod 15 to hold the secondary bearing plate 17 on the rod 15.

[122] In the embodiment shown, the retaining device 98 also has one or more Belleville spring washers 38. The spring washers 38 are threaded onto the rod 15 between the nut 37 and the secondary bearing plate 17, which helps to ensure the elastic anchoring of the secondary insulating panels 7 on the load-bearing wall 3. Furthermore and advantageously, a locking member 39 is welded locally onto the upper end of the rod 15 to fasten the nut 37 in position on the rod 15.

[123] The retaining device 98 also has a force distribution plate 19, an upper plate 40 and a spacer 41 that are fastened to the secondary bearing plate 17.

[124] The force distribution plate 19 is seated in each of the counterbores 18 formed in the cover plates 10 of the four adjacent secondary insulating panels 7. The force distribution plate 19 is therefore positioned between the cover plates 10 and each of the four secondary insulating panels and the secondary sealed membrane 4. The force distribution plate 19 is intended to mitigate the occurrence of height differences between the corners of the adjacent secondary insulating panels 7. Furthermore, the force distribution plate 19 helps to distribute the stresses liable to be exerted on the secondary sealed membrane 4 and the primary insulating panels 22 in the corner zones of the secondary insulating panels 7. Consequently, the force distribution plate 19 helps to limit the pinching of the bottom plates 23 of the primary insulating panels 22 and pinching and compressing of the layers

of insulating polymer foam 24, 26 of the primary insulating panels 22 in the corner zones of the secondary insulating panels 7.

[125] The force distribution plate 19 is advantageously made of a metal selected from stainless steel, alloys of iron and nickel, such as Invar, which has a coefficient of expansion typically between $1.2 \cdot 10^{-6}$ and $2 \cdot 10^{-6} \text{ K}^{-1}$ and alloys of iron and manganese, which have a coefficient of expansion of less than $2 \cdot 10^{-5} \text{ K}^{-1}$, typically $7 \cdot 10^{-6} \text{ K}^{-1}$. The thickness of the force distribution plate 19 is between 1 mm and 7 mm, preferably between 2 mm and 4 mm, for example approximately 3 mm. The force distribution plate 19 is advantageously square and the side length is between 100 mm and 250 mm, for example approximately 150 mm.

[126] The upper plate 40 is arranged beneath the force distribution plate 19 and has dimensions less than the dimensions of the force distribution plate 19, such that the force distribution plate 19 entirely covers the upper plate 40. The upper plate 40 is seated in the recesses 15 formed in the corner zones of the secondary insulating panels 7 level with the bearing zones 16, i.e. in the embodiment shown in figure 5, in the recesses 54 formed in the second layer of insulating polymer foam 12 of the secondary insulating panels 7.

[127] The upper plate 40 has a threaded bore 42 in which a threaded base of a pin 43 designed to anchor the primary insulating panels 22 is mounted. To enable the pin 43 to be fastened to the upper plate 40, the force distribution plate 19 also has a bore formed opposite the threaded bore of the upper plate 40, thereby enabling the pin 43 to pass through the force distribution plate 19.

[128] The upper plate 40 has an overall parallelepipedic rectangular shape with two opposing large faces that are parallel to the load-bearing wall 3 and four faces that link the two large faces and that extend parallel to the thickness direction of the tank wall 1. In the embodiment illustrated in figures 4 and 5, the four faces that extend parallel to the thickness direction of the tank wall 1 are linked by fillets 44. This eliminates any acute angles and helps to further limit the pinching of the bottom plates 23 of the primary insulating panels 22 by limiting the concentration of stresses.

[129] In one embodiment (not shown), the upper plate 40 and the force distribution plate 19 can be formed from a single one-piece part.

[130] The spacer 41 is arranged between the secondary bearing plate 17 and the upper plate, thereby helping to keep a gap between the secondary bearing plate 17 and the upper plate 40. In the embodiment illustrated in figures 4 and 5, the spacer 41 has bevels

45 to fit inside the footprint of the upper plate 40, as seen in the thickness direction of the tank wall 1. In other words, the upper plate 40 entirely covers the spacer 41.

[131] The spacer 41 is advantageously made of wood, which helps to limit the heat bridge to the load-bearing wall 3 at the retaining device 98. The shape of the spacer 41 is an inverted "U", thereby forming a central seat 46 between the branches of the "U". The central seat 46 receives the upper end of the rod 15, the locking member 39, the nut 37 and the spring washers 38. The spacer 41 is also seated in the recess 15 formed level with the bearing surface 16.

[132] The locking member 39 is a square or rectangle in which the diagonal is longer than the dimension of the central seat 46 between the two branches of the "U", thereby blocking rotation of the rod 15 in relation to the spacer 39 and preventing the rod 15 from disengaging from the nut 35.

[133] In order to fasten the force distribution plate 19, the upper plate 40, the spacer 41 and the secondary bearing plate 17 together, each of the aforementioned elements is provided with two bores, each of which is traversed by a screw 47, 48. Each of the bores formed in the secondary bearing plate 17 has a thread cooperating with one of the screws 47, 48 to fasten the aforementioned elements together.

[134] Furthermore, the pin 43 passes through a hole formed through a strake 21 of the secondary sealed membrane 4. The pin 43 has a flange 49 that is welded to the periphery thereof, about the hole, to ensure the seal of the secondary sealed membrane 4. The secondary sealed membrane is therefore sandwiched between the flange 49 of the pin 43 and the force distribution plate 19.

[135] The retaining device 98 also has a primary bearing plate 30 that bears towards the load-bearing wall 3 against the bearing zone 29 formed in each of the four adjacent primary insulating panels 22 in order to hold said panels against the load-bearing wall 3. In the embodiment shown, each bearing zone 29 is formed by a projecting portion of the bottom plate 23 of one of the primary insulating panels 22. The primary bearing plate 30 is seated in the recesses 28 formed in the corner zones of the primary insulating panels 22 level with the bearing zones 29.

[136] A nut 50 cooperates with a thread formed at the upper end of the pin 43 to fasten the primary bearing plate 30 to the pin 43. In the embodiment shown, the retaining device 98 also has one or more Belleville spring washers 51 that are threaded onto the pin 43 between the nut 50 and the primary bearing plate 30 to ensure the elastic anchoring of the primary insulating panels 22 to the load-bearing wall 3.

[137] Furthermore, an insulating plug 52, shown in figure 5, is inserted above the retaining device 98 in the recesses 28 formed in the corner zones of four adjacent primary insulating panels 22 such as to ensure the continuity of the primary thermally insulating barrier 5 at the retaining device 98. Furthermore, a wooden closing plate 53, shown in figure 5, insures the flatness of the bearing surface of the primary sealed membrane 6. The closing plate 53 is received in the counterbores formed in the corner zones of the primary insulating panels 22.

[138] The fastening of the primary sealed membrane 6 to the primary insulating panels 22 is described below using several examples with reference to figures 6 to 14.

10 [139] In the embodiment shown in figure 6, metal anchoring strips 60 are fastened to the cover plates 27 of the primary insulating panels 22 along the contours of the rectangular sheets 33. The edges of the rectangular sheets 33 can then be fastened by welding along the anchoring strips 60. The anchoring strip 60 is fastened in a counterbore to the cover plate 27 by any suitable means, such as screws or rivets.

15 [140] Figures 6 and 7 also show metal plates 61 that can be fastened to the cover plates 27 of the primary insulating panels 22 in other locations, for example along the edges of the primary insulating panels 22 away from the contours of the rectangular sheets 33, to provide additional fastening points. A metal plate 61 is fastened in a counterbore to the cover plate 27 by any suitable means, such as screws or rivets.

20 [141] As shown more clearly in figure 7, which is a cross section at an interface 62 between two primary insulating panels 22, flat zones of a rectangular sheet 33 can be welded transparently to the metal plates 61.

[142] Figures 8 and 9 show another embodiment of the primary insulating panels 22, the edges of which have counterbores 63 to receive the bridging plates 64, which are for example made of plywood. The bridging plates 64 are fastened to the cover plates 27 of two primary insulating panels 22 to prevent any gaps between the two primary insulating panels 22 at the interface 62, thereby improving the uniformity of the bearing surface against which the primary sealed membrane 6 bears.

30 [143] In figures 6 and 8, the cover plates 27 and the layers of insulating polymer foam 26 are provided with stress-relief slots 65 that segment the cover plates 27 and the layers of insulating polymer foam 26 into several portions, thereby preventing fissuring during cooling.

[144] Figure 10 shows another embodiment of the primary insulating panels 22 in which the stress-relief slots 65 are limited to a neighboring zone of the anchoring strips 60, as described in published document FR-A-3001945.

5 [145] Thermal protection strips 66, for example made of composite material, are aligned with the anchoring strips 60 at given portions of the contours of the rectangular sheets 33 to prevent damage being caused to the cover plate 27 during welding.

[146] The tank wall 101 shown in figure 12 shows an embodiment in which a row of primary insulating panels 22 does not overlap just one row of secondary insulating panels 7, but straddles two rows of secondary insulating panels 7. Elements that are identical or similar to the elements in figures 1 to 10 are indicated using the same reference signs, and only the differences therebetween are described.

10

[147] Figure 12 essentially shows two modifications.

[148] Firstly, the primary retaining members 97 have been separated and offset from the secondary retaining members. The secondary retaining member (not shown) can be made in various different ways, for example as the retaining device 98 with all of the elements arranged above the distribution plate 19 removed. In this case, the force distribution plate 19 and the counterbore 18 designed to receive said plate can also be removed. There can be a variable number of secondary retaining members (not shown), for example between 2 and 5 per secondary insulating panel 7, for example arranged in the corners of the secondary panels and/or in the interstice between two secondary panels, either in the first direction or in the second direction. Other embodiments of the secondary retaining member are described in WO-A-2013093262.

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[149] The primary retaining member 97 can be made in various different ways, for example as illustrated in the magnified view in figure 13 or as described in the published document FR-A-2887010.

25

[150] In figure 13, the primary retaining member 97 has a plate 119, for example with a square or circular contour, that is fastened in a counterbore formed in the surface of the cover plate 10 and turned towards the layer of insulating polymer foam 11, for example by gluing. The plate 119 has a threaded hole opening out in the upper surface of the cover plate 10, into which a pin 143 identical to the pin 43 described above can be screwed.

30

[151] Furthermore, the entire first stage of the tank wall, specifically the primary thermally insulating barrier 5 and the primary sealed membrane 6 carried thereby, has been offset in both directions of the plane by half of the length of a secondary insulating panel 7. Thus,

instead of being directly above a secondary retaining member, the primary retaining member 97 is at the center of the cover plate of a secondary insulating panel 7.

[152] Despite this offsetting, a secondary retaining member still cooperates with the corners of four adjacent secondary insulating panels 7 and a primary retaining member 97 still cooperates with the corners of four adjacent primary insulating panels 22. The amplitude of this offsetting could be different and the primary retaining member 97 could be elsewhere on the cover plate of a secondary insulating panel 7, but preferably away from the raised edges 32 so as not to interfere therewith. The amplitude of the offsetting can be different in the two directions of the plane.

[153] The tank wall 201 shown schematically in figure 14 shows an embodiment in which a row of primary insulating panels 22 is superposed on a row of secondary insulating panels 7, but offset in the first direction by a fraction of the length of one insulating panel, in this case half of said length. Thus, a primary insulating panel 22 in the first row straddles two secondary insulating panels 7 in the underlying secondary row. Elements that are identical or similar to the elements in figures 1 to 13 are indicated using the same reference signs, and only the differences therebetween are described.

[154] In the embodiment shown schematically in figure 14, the primary insulating panels 22 are held on the secondary sealed membrane (not shown) by retaining members arranged in the middle of the sides of the primary insulating panels 22. Thus, the primary retaining member 97 arranged in the middle of the cover plate of the secondary insulating panel 7 cooperates with two primary insulating panels 22 of the first row and is positioned halfway along the width of the first row. Furthermore, secondary retaining members 92 are positioned in the corners of the secondary insulating panels 7, as in the preceding embodiments. The secondary retaining member 92 bears a primary retaining member 91. The secondary retaining member 92 and the primary retaining member 91 carried thereby can be made similarly to or differently from the retaining device 98. Unlike in figure 1, the primary retaining member 91 in this case cooperates exclusively with two primary insulating panels 22 at the middle of one side of these primary insulating panels 22.

[155] To facilitate access to the primary retaining member 91, the shape of the primary insulating panels 22 can be designed to form an access shaft 93. In this case, the shaft 93 is blocked after installation of the primary retaining member 91, for example with a polyurethane foam plug covered with a rigid plate, for example made of plywood (not shown).

[156] Figure 15 is a partial perspective cutaway view of a polyhedral tank 100. The tank 100 has a polyhedral load-bearing structure 103. The tank 100 has an end wall 102 transverse

to the load-bearing structure 101 and a plurality of longitudinal walls 104, 106 and 108. The walls 104 are respectively horizontal bottom and ceiling walls of the tank. The wall 106 is a vertical wall and the walls 108 are bevel walls respectively linking the horizontal walls 104 to the vertical wall 106.

5 [157] The structures described above with reference to figures 1 to 14 to make a tank wall can be applied to one, all or some of the walls of the polyhedral tank 100. A connection zone between a bevel wall 108 and an end wall 102 is described below in greater detail.

[158] Figure 16 is a flat partial projection view of the zone XVI in figure 15 according to one embodiment. The end wall 102 is linked firstly to the bevel wall 108 at a first edge 110 and
10 secondly to the horizontal wall 104 at a second edge 112.

[159] Each of the tank walls can have a multi-layer structure similar to the structure shown in figure 1 or figure 12. Figure 16 only shows the corrugations of the primary membrane 6 (shown using a dot-and-dash line) and the contours of some square primary insulating panels 22. These panels form primary rows 116 in the end wall 102, primary rows 117 in
15 the horizontal wall 104, primary rows 119 in the vertical wall 106, and primary rows 121 in the bevel wall 108.

[160] An associated secondary barrier is shown in the cross-section views in figures 17 and 18 in an example embodiment.

[161] On the end wall 102, the primary sealed membrane 6 has a first series of corrugations
20 118 that are spaced apart by a pitch y and parallel to the horizontal wall 104, and a second series of corrugations 120 that are spaced apart by the first pitch y and perpendicular to the horizontal wall 104.

[162] On the horizontal wall 104, the primary membrane 6 has a first series of longitudinal corrugations 122, each corrugation being connected continuously to one of the
25 corrugations of the second series 120 at the edge 112.

[163] The primary membrane in the bevel wall 108 has a series of longitudinal corrugations including corrugations 126 that are spaced apart by a second pitch z and connected continuously to the corrugations of the first series 118 at the edge 110, and a corrugation 127 arranged along the longitudinal upper edge of the wall 108 and that is connected
30 continuously to a corrugation of the second series 120 of the end wall 102.

[164] The additional corrugation 127 is optional depending on the width of the bevel wall 108. This corrugation 127 is added if the distance between the last corrugation 126 and the edge of the wall is greater than a certain distance. As a result, the maximum distance between two continuous corrugations remains below a given threshold, including at the

interface between two adjacent longitudinal walls. Thus, adding the additional corrugation 127 enables adjustment of the width of the bevel wall 108, providing greater tolerance in the dimensions of the tanks during construction.

[165] A longitudinal corrugation 126 is linked to one of the corrugations of the first series 118 by a deviation corrugation 128 forming an elbow between a first end linked to the corrugation of the first series 118 and a second end linked to the longitudinal corrugation 126.

[166] The repeating pattern of the primary rows 116 of the end wall 102 and of the primary rows 121 of the bevel wall 108 share a predetermined dimension L. This can be the same dimension as the repeating pattern of the primary rows 117 of the horizontal wall 104 and of the primary rows 119 of the vertical wall 106. For example, this dimension can be between 1000 mm and 1500 mm. Thus, the primary insulating panels 22 can be of identical width on all of these walls. Although not shown in the figures, the repeating pattern can also include an interstice between the primary insulating panels 22, the width of which is preferably equal to or less than 50 mm. In this case, the interstice between panels is covered by an insulant, for example glass wool, low-density polyurethane foam or any other insulating material.

[167] In figure 16, an angle 130 is defined between a plane of the bevel wall 108 and a plane of the horizontal wall 104, and an angle 132 is defined between a plane of the vertical wall 106 and the plane of the bevel wall 108. The angles 130 and 132 are complementary. The angle between two planes is between 0° and 90°.

[168] The angle 130 is selected such that the dimension L is firstly a first integer multiple n_1 of the first pitch y and secondly a second integer multiple n_2 , which is less than the first multiple n_1 , of the second pitch z , so $L = n_1 \cdot y = n_2 \cdot z$. For this purpose, the angle 130 is the arc cosine of the ratio n_2/n_1 .

[169] In the example shown, $n_1 = 3$ and $n_2 = 2$. The angle 130 is therefore $\arccos(2/3) = 48.19^\circ$. The angle 131 is therefore the complementary angle, or $\arcsin(2/3) = 41.81^\circ$.

[170] The primary membrane 6 has a series of longitudinal corrugations 124 on the vertical wall 106. Each corrugation 124 is connected continuously to one of the corrugations of the first series 118 at the edge 114.

[171] In a variant embodiment, the primary rows 116 can be oriented parallel to the vertical wall 106.

[172] Figures 17 and 18 show, respectively, cross sections of the end wall 102 along the line XVII-XVII and of the bevel wall 108 along the line XVIII- XVIII, according to a first example

embodiment. In this example embodiment, the end wall 102 has a plurality of secondary rows 216 parallel to the primary rows 116 and a secondary membrane including a plurality of strakes 218 parallel to the corrugations 118 of the first series. The first wall 108 also has a plurality of secondary rows 221 parallel to the primary rows 121 and a secondary membrane including a plurality of strakes 226 parallel to the longitudinal corrugations 126. In this embodiment, all of the primary insulating panels 22 and all of the secondary insulating panels 7 can be of the same width, at least on the end wall 102 and the bevel wall 108, but also potentially on all the other walls.

[173] Dimensional example

10 In an example embodiment:

- the dimension of the repeating pattern of the primary rows 116 of the end wall 102 is 1200 mm and is a first integer multiple n_1 , specifically 3, of the first pitch y , which is therefore equal to 400 mm,
- the dimension of the repeating pattern of the primary rows 121 of the bevel wall 108 is also 1200 mm and is a second integer multiple n_2 , specifically 2, of the second pitch z , which is therefore equal to 600 mm,
- the dimension of the repeating pattern of the secondary rows 216 of the end wall 102, and respectively of the repeating pattern of the secondary rows 221 of the first wall 108, is also 1200 mm,
- the width of the strakes 218 of the end wall 102 and of the strakes 226 of the bevel wall 108 is a whole fraction of this dimension, in this case 600 mm.

[174] Thus, in this example, the width of the strakes 226 is equal to the pitch z of the bevel wall 108.

[175] Figures 19 and 20 are views similar to the views in figures 17 and 18, according to a second embodiment in which the angle 130 does not satisfy the condition set out above. In this case, the angle 130 is for example set to 45° . The ratio between the pitches is therefore $y/z = \cos(45^\circ) = 0.707$

[176] In this second example embodiment, the dimension of the primary insulating panels 22 cannot be the same on the end wall 102 and the bevel wall 108. Indeed, the dimension of the repeating pattern of the primary rows 116 of the end wall 102 is an integer multiple n_1 of the pitch y (in this case $n_1=3$), while the dimension of the repeating pattern of the primary rows 121 of the bevel wall 108 is an integer multiple n_2 of the pitch z (in this case $n_2=2$). It is not possible to select two whole numbers that are both small enough to ensure

that the primary insulating panels 22 are easy to handle and that satisfy $n_2/n_1 \sim \cos(45^\circ)$. In this case, construction of the tank therefore uses insulating panels of different dimensions, at least on the bevel walls. The multiples n_1 and n_2 can be selected such that this difference is limited, for example less than 10%.

5 [177] Dimensional example 1

[178] The dimension of the repeating pattern of the primary rows 116 of the end wall 102 is 1200 mm and is a first integer multiple n_1 , specifically 3, of the first pitch y , which is therefore equal to 400 mm,

10 [179] The second pitch z is selected as a function of the cosine of the angle 130 such as to ensure the continuity of the longitudinal corrugations 126 of the bevel wall 108 and the corrugations 118 of the first series of the end wall 102. The second pitch z is 566 mm. The dimension of the repeating pattern of the primary rows 121 of the bevel wall 108 is a second integer multiple n_2 , specifically 2, which is selected to obtain a different dimension that is nonetheless relatively close to the dimension of the repeating pattern of the primary
15 rows 116 of the end wall 102. The dimension of the repeating pattern of the primary rows 121 of the first wall 108 is 1132 mm.

[180] Furthermore, in the end wall 102, the dimension of the repeating pattern of the secondary rows 216 is equal to the dimension of the repeating pattern of the primary rows 116. In the first wall 108, the dimension of the repeating pattern of the secondary rows 221
20 is equal to the dimension of the repeating pattern of the primary rows 121. Furthermore, the dimension of a stroke 226 of the first wall 108 is equal to the second pitch z .

[181] Dimensional example 2

- the dimension of the repeating pattern of the primary rows 116 of the end wall 102 is 1020 mm and is a first integer multiple n_1 , specifically 3, of the first pitch y , which is
25 therefore equal to 340 mm,

- The second pitch z is 480.8 mm. The dimension of the repeating pattern of the primary rows 121 of the bevel wall 108 is 961.6 mm and is a second integer multiple n_2 , specifically 2, of the pitch z .

[182] Figure 21 is a perspective view of the bevel wall 108 according to one embodiment.
30 Unlike in figure 16, the contours of a rectangular sheet 33 are in this case shown.

[183] A primary sealed membrane in which the corrugations are continuous at the intersections between the two series of corrugations is described above. The primary sealed membrane can also have two mutually perpendicular series of corrugations with

discontinuities of some corrugations at the intersections between the two series. In this case, the interruptions are distributed alternately in the first series of corrugations and the second series of corrugations and, within a given series of corrugations, the interruptions of a corrugation are offset in relation to the interruptions of an adjacent parallel corrugation.

5 This offsetting can be equal to the spacing between two parallel corrugations.

[184] With reference to figure 11, a cut-away view of a liquefied natural gas carrier ship 70 shows a sealed and insulated tank 71 having an overall prismatic shape mounted in the double hull 72 of the ship. The wall of the tank 71 has a primary sealed barrier designed to be in contact with the LNG contained in the tank, a secondary sealed barrier arranged
10 between the first sealed barrier and the double hull 72 of the ship, and two insulated barriers arranged respectively between the first sealed barrier and the second sealed barrier, and between the second sealed barrier and the double hull 72.

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

[186] Figure 11 shows an example sea terminal comprising a loading/unloading point 75, an undersea line 76 and an onshore facility 77. The loading/unloading point 75 is a static offshore installation comprising a moveable arm 74 and a column 78 holding the moveable arm 74. The moveable arm 74 carries a bundle of insulated hoses 79 that can connect to
20 the loading/unloading pipes 73. The orientable moveable arm 74 can be adapted to all sizes of liquefied natural gas carrier ships. A connecting line (not shown) extends inside the column 78. The loading/unloading point 75 makes loading and unloading of the liquefied natural gas carrier ship 70 possible to or from the onshore facility 77. This facility has liquefied gas storage tanks 80 and connection lines 81 connected via the undersea
25 line 76 to the loading/unloading point 75. The undersea line 76 enables liquefied gas to be transferred between the loading/unloading point 75 and the onshore facility 77 over a large distance, for example 5 km, which makes it possible to keep the liquefied natural gas carrier ship 70 a long way away from the coast during loading and unloading operations.

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

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

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

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

Claims

[Claim 1] 1. A sealed thermally insulating tank (100) built into a polyhedral load-bearing structure, said tank comprising tank walls fastened to the load-bearing walls of the load-bearing structure, the tank walls including a transverse end wall (102) and a plurality of longitudinal walls (104, 106, 108) linked to the end wall, the plurality of longitudinal walls including a first wall (108) linked to the end wall at a first edge (110) and a second wall (104, 106) adjacent to the first wall and linked to the end wall at a second edge (112, 114),

each of the longitudinal walls and the end wall having a sealed membrane (6) that is designed to be in contact with a product contained in the tank and an insulating barrier (5) arranged between the sealed membrane and the load-bearing structure,

in which the insulating barrier of the longitudinal walls includes rows of insulating panels (117, 119, 121) oriented longitudinally and juxtaposed according to a repeating pattern and the insulating barrier of the end wall has rows of insulating panels (116) oriented in a direction parallel or perpendicular to the second wall (104, 106) and juxtaposed according to a repeating pattern,

the sealed membrane of the end wall having a first series of corrugations (118, 120) parallel to the second wall and spaced apart by a first pitch y and a second series of corrugations (118, 120) perpendicular to the second wall and spaced apart by the first pitch y,

the sealed membrane of each longitudinal wall having a plurality of longitudinal corrugations, the longitudinal corrugations (122, 124) of the second wall being spaced apart by said first pitch y and connected continuously to the second series of corrugations (118, 120) of the end wall at the second edge, the longitudinal corrugations (126) of the first wall (108) being spaced apart by a second pitch z that is greater than the first pitch y and connected continuously to one of the first and second series of corrugations (120, 118) of the end wall by an angular arrangement at the first edge (110) and including a plurality of deviation corrugations (128),

in which the angle (130, 132) between a plane of the first wall and a plane of the second wall and a ratio between the first pitch y and the second pitch z are defined in relation to one another.

[Claim 2] The tank as claimed in claim 1, in which the repeating pattern of the rows of insulating panels of the end wall (102) and the repeating pattern of the rows of insulating panels of the first wall (108) share a predetermined dimension,

and in which the angle (130, 132) between the plane of the first wall (108) and the plane of the second wall (104, 106) is selected such that said dimension of the

repeating pattern is firstly a first integer multiple n_1 of the first pitch y and secondly a second integer multiple n_2 , which is less than the first multiple n_1 , of the second pitch z ,

said angle (130, 132) being a function of the arc cosine or the arc sine of the ratio between the second integer multiple n_2 and the first integer multiple n_1 .

[Claim 3] The tank as claimed in claim 2, in which the rows of panels of the end wall are perpendicular to the second wall and the longitudinal corrugations of the first wall are connected continuously to the first series of corrugations of the end wall, and in which the angle (130, 132) between the plane of the first wall and the plane of the second wall is equal to the arc cosine of the ratio between the second multiple n_2 and the first multiple n_1 .

[Claim 4] The tank as claimed in claim 2, in which the rows of panels of the end wall are parallel to the second wall and the longitudinal corrugations of the first wall are connected continuously to the second series of corrugations of the end wall, and in which the angle (130, 132) between the plane of the first wall and the plane of the second wall is equal to the arc sine of the ratio between the second multiple n_2 and the first multiple n_1 .

[Claim 5] The tank as claimed in claims 1 to 4, in which the ratio between the second pitch z and the first pitch y is equal to the cosine of the angle between the plane of the first wall (108) and the plane of the second wall (104, 106).

[Claim 6] The tank as claimed in claim 1 or 5, in which the dimension of the repeating pattern of the rows of insulating panels of the end wall (102) is different from, and in particular greater than, the dimension of the repeating pattern of rows of insulating panels of the first wall (108).

[Claim 7] The tank as claimed in claim 6, in which the dimension of the repeating pattern of the rows of insulating panels of the end wall (102) is an integer multiple of the first pitch y .

[Claim 8] The tank as claimed in claim 6 or 7, in which the dimension of the repeating pattern of the rows of insulating panels of the first wall (108) is an integer multiple of the second pitch z .

[Claim 9] The tank as claimed in any one of claims 1 to 8, in which the second wall (104) is horizontal and the longitudinal corrugations (126) of the first wall are connected continuously to the first series (118) of corrugations of the end wall.

[Claim 10] The tank as claimed in claim 9, in which, in the first wall (108), the sealed membrane also includes at least one additional longitudinal corrugation (127) adjacent

to an edge of the first wall connected continuously to a corrugation of the second series of corrugations (120) of the end wall (102).

[Claim 11] The tank as claimed in any one of claims 1 to 8, in which the second wall (106) is vertical and the longitudinal corrugations of the first wall are connected continuously to the second series of corrugations (118) of the end wall.

[Claim 12] The tank (100) as claimed in any one of claims 1 to 11, in which the sealed membrane is a primary membrane (6) and the insulating barrier is a primary insulating barrier (5),

and in which each of the longitudinal walls and the end wall also include a secondary sealed membrane (4) that is arranged between the primary sealed membrane and the load-bearing structure, and a secondary insulating barrier (2) that is arranged between the secondary membrane and the load-bearing structure, said secondary insulating barrier having secondary rows (216, 221) of insulating panels oriented in the same direction as the primary rows of said wall and juxtaposed in a repeating pattern,

the secondary membrane including a plurality of strakes (218, 226) that are parallel to one another, each of the strakes having a flat central portion bearing on an upper surface of the secondary panels and two raised edges projecting towards the inside of the tank, the distance between the two edges being the dimension of the strake, in which the strakes (218) and the secondary rows (216) of the end wall (102) are horizontal and the strakes (226) and the secondary rows (221) of the longitudinal walls are oriented longitudinally, and in which the dimension of the repeating pattern of the primary rows and the dimension of the repeating pattern of the secondary rows are the same on each of the longitudinal walls and the end wall.

[Claim 13] The tank as claimed in claim 12, in which, in the first wall and/or the end wall and/or the second wall, the dimension of the repeating pattern of the secondary panels is an integer multiple of the dimension of the strakes.

[Claim 14] The tank as claimed in any one of claims 12 to 13, in which, in the first wall and/or the end wall and/or the second wall, the second pitch and the dimension of the strakes are the same.

[Claim 15] A ship (70) used to transport a fluid, the ship having a double hull (72) and a tank (71, 100) as claimed in any one of claims 1 to 14, placed inside the double hull (72).

[Claim 16] A transfer system for a fluid, the system including a ship (70) as claimed in claim 15, insulated pipes (73, 79, 76, 81) arranged to connect the tank (71, 100) installed in the hull of the ship to an onshore or floating storage facility (77) and a pump

for driving a fluid through the insulated pipes to or from the onshore or floating storage facility to or from the tank on the ship.

[Claim 17] A method for loading or unloading a ship (70) as claimed in claim 15, in which a fluid is channeled through insulated pipes (73, 79, 76, 81) to or from an onshore or floating storage facility (77) to or from the tank on the ship (71).