

Description

Title of the invention: Sealed and thermally-insulating tank including a corrugation blocker

Technical field

5 [0001] The invention relates to the field of sealed and thermally-insulating membrane tanks.
The invention relates in particular to the field of sealed and thermally-insulating tanks for the storage and/or the transportation of liquefied gas at low temperature, such as tanks for the transportation of liquefied petroleum gas (LPG) at for example a temperature between
10 -50°C and 0°C inclusive or for the transportation of liquefied natural gas (LNG) at around -162°C at atmospheric pressure. These tanks may be installed on land or on a floating structure. In the case of a floating structure the tank may be intended to transport liquefied gas or to receive liquefied gas serving as fuel for the propulsion of the floating structure.

Technological background

15 [0002] In the prior art there are known sealed and thermally-insulating tanks for the storage of liquefied natural gas integrated into a supporting structure such as the double hull of a ship intended to transport liquefied natural gas. Such tanks generally have a multilayer structure including successively in the direction of thickness from the exterior to the interior of the tank a secondary thermally-insulating barrier retained on the supporting structure, a secondary sealing membrane resting against the secondary thermally-insulating barrier, a
20 primary thermally-insulating barrier resting against the secondary sealing membrane and a primary sealing membrane resting against the primary thermally-insulating barrier and intended to be in contact with the liquefied natural gas contained in the tank.

[0003] The document WO2019102163 describes a secondary thermally-insulating barrier and a primary thermally-insulating barrier formed of juxtaposed insulating panels. In that
25 document WO2019102163 the secondary sealing membrane consists of a plurality of metal plates including corrugations projecting toward the exterior of the tank and therefore allowing the secondary sealing membrane to be deformed by the effect of thermal and mechanical loads generated by the fluid stored in the tank. An internal face of the insulating panels of the secondary thermally-insulating barrier includes grooves receiving the
30 corrugations of the corrugated metal plates of the secondary sealed membrane. These corrugations and these grooves form a grid of channels extending along the walls of the tank.

[0004] In order to block said channels the document WO2019102163 describes further that the thermally-insulating barrier includes a housing intersecting the groove and having a width greater than the width of the groove. The tank therefore includes a blocker arranged in the housing in such a manner that the blocker blocks a portion of the groove situated on the projecting side of the sealing membrane and creates a head loss for a flow circulating in the groove. The blocker can therefore be moved in the housing to adapt to the position of the corrugation in the groove.

Summary

[0005] One idea behind the invention is to render the corrugation blockers more adaptable whilst simplifying mounting in the tank.

[0006] Another idea behind the invention is to limit the presence of continuous circulation channels in the thermally insulating barriers in order to limit natural convection phenomena in said thermally insulating barriers.

[0007] In accordance with one embodiment the invention provides a sealed and thermally-insulating tank for storing a fluid fixed to a supporting structure, in which a tank wall includes at least one thermally-insulating barrier and at least one sealing membrane, the sealing membrane including a series of parallel corrugations having a longitudinal direction and plane portions situated between said corrugations, said corrugations projecting from the plane portions, said thermally-insulating barrier being situated against the sealing membrane, the thermally-insulating barrier including insulating panels, the insulating panels being juxtaposed to one another,

in which the tank includes at least one corrugation blocker situated in line with a corrugation of the series of corrugations between a corrugation of the series of corrugations and one of the insulating panels, the corrugation blocker being configured to block a space left free between said corrugation and said groove in which said corrugation is housed,

in which the corrugation blocker includes a compressible material core and a flexible envelope covering said core completely so as to form a container for the compressible material core, the corrugation blocker being compressed between the sealing membrane and the thermally-insulating barrier.

[0008] Thanks to these features, a tank of this kind offers the possibility of flexible blocking of the grooves receiving the corrugations of the membrane despite a tolerance in respect of the position of the corrugations in the grooves. A tolerance of this kind may in particular arise from the fabrication and the mounting of the corrugations in the grooves. Moreover,

thanks to these features the space between the convex side of the corrugation and the bottom of the groove, formed by the thermally-insulating barrier, can be blocked by the corrugation blocker for different positions of the corrugation in the groove. Indeed, the compressible material core when compressed enables simple filling of this space by adapting to the position of the corrugation and being compressed more in line with the corrugation.

[0009] The corrugation blocker therefore makes it possible to limit the formation of flows in the channels of the thermally-insulating barrier, in particular the formation of thermosiphons between these channels and any flow channel situated closer to the hull, for example a space with mastic applied to it between the thermally-insulating barrier and the supporting structure.

[0010] In embodiments of the invention a tank of the above kind may have one or more of the following features.

[0011] In accordance with one embodiment the thermally-insulating barrier is situated between the sealing membrane and the supporting structure, the corrugations projecting toward the interior of the tank, each insulating panel including a plane rigid plate forming the face in contact with the sealing membrane, the corrugation blocker being situated between a corrugation of the series of corrugations and a rigid plate of an insulating panel.

[0012] In accordance with one embodiment said corrugations project from the plane portions on a projecting side of the sealing membrane, said thermally-insulating barrier being situated on the projecting side of the sealing membrane, the thermally-insulating barrier including a series of parallel grooves receiving the series of corrugations, said corrugation blocker being situated in line with a corrugation of the series of corrugations between a corrugation of the series of corrugations and a bottom of a groove of the series of grooves.

[0013] In accordance with one embodiment the corrugation blocker is compressed by the sealing membrane so that the dimension in a thickness direction decreases locally by at least 20%, preferably at least 30%, more preferably at least 40% and for example of the order of 50% between the thickness before compression and the thickness after compression.

[0014] In accordance with one embodiment the envelope includes a first layer and a second layer, the first layer being situated in contact with the sealing membrane, the first layer and the second layer being fixed to one another over at least a part of a perimeter of the first layer and of the second layer so as to form the container for the compressible material core.

[0015] In accordance with one embodiment the first layer and the second layer are fixed to one another all around the perimeter of the first layer and the second layer so as to form a closed container for the compressible material core.

5 [0016] In accordance with one embodiment the first layer is made of a material more flexible than the material of the second layer.

[0017] In accordance with one embodiment the envelope includes only one layer including an internal surface situated in contact with the sealing membrane, the single layer being produced in the form of a flexible cylinder so as to form the container for the compressible material core.

10 [0018] In accordance with one embodiment the single layer, the first layer and/or the second layer include(s) at least one perforation so as to favor the exit of air upon compression of the blocker. In the case of a single layer, the latter may include at least one perforation on an external surface and/or on the internal surface of the single layer.

15 [0019] In accordance with one embodiment the core represents at least 50% by volume, preferably at least 90% by volume, of the corrugation blocker in the compressed state or in the state before compression.

[0020] In accordance with one embodiment the core is made of a foam, powder or non-woven fibrous material.

20 [0021] In accordance with one embodiment the core is made of a material chosen from: mineral wool, melamine foam, polyester wadding, polyethylene wadding, synthetic plastic foam, polyamide fibers, acrylic fibers or combinations thereof.

[0022] For example, polyester wadding may be produced in the form of fiber matting, beads, balls or tufts.

25 [0023] In accordance with one embodiment the envelope is preferably made from a material that is not gastight and liable to create a high head loss.

30 [0024] In accordance with one embodiment the envelope includes a woven or non-woven textile layer consisting of mineral and/or synthetic fibers, for example glass fibers or polyester, polyamide or acrylic type polymer fibers. A layer of this kind may be combined with aluminum foil or a plastic film, this foil or this film preferably being perforated to avoid a complete seal. A layer of this kind may equally be coated in order to improve the sealing property of the layer.

[0025] In accordance with one embodiment the tank includes a plurality of corrugation blockers, each corrugation blocker being situated between a corrugation and a groove in which said corrugation is housed.

5 [0026] In accordance with one embodiment the tank includes a plurality of corrugation blockers, each corrugation blocker being situated between a corrugation and an insulating panel.

10 [0027] In accordance with one embodiment the tank includes a plurality of corrugation blockers situated in line with a corrugation of the series of corrugations between a corrugation of the series of corrugations and a groove of the series of grooves, each corrugation blocker being configured to block a space left free between said corrugation and said groove in which said corrugation is housed, the corrugation blockers being regularly spaced from one another in the longitudinal direction of a series of corrugations.

15 [0028] In accordance with one embodiment the tank includes a plurality of corrugation blockers situated in line with a corrugation of a series of corrugations between the corrugation of the series of corrugations and an insulating panel formed in line with the corrugation, each corrugation blocker being configured to block a space left free between said corrugation and said insulating panel, the corrugation blockers being spaced regularly from one another in the longitudinal direction of the series of corrugations.

20 [0029] In accordance with one embodiment the tank includes a plurality of corrugation blockers situated in line with a corrugation of the series of corrugations between a corrugation of the series of corrugations and a groove of the series of grooves, each corrugation blocker being configured to block a space left free between said corrugation and said groove in which said corrugation is housed, the corrugation blockers for said corrugations being regularly spaced from one another in the longitudinal direction.

25 [0030] In accordance with one embodiment the thermally-insulating barrier is a first thermally-insulating barrier and the tank includes a second thermally-insulating barrier situated opposite the projecting side of the sealing membrane and the tank includes at least one complementary corrugation blocker situated facing the at least one corrugation blocker so as to sandwich a corrugation of the sealing membrane between the corrugation blocker and the complementary corrugation blocker, the complementary corrugation blocker being
30 configured to block a space left free between said corrugation and the second thermally-insulating barrier.

[0031] In accordance with one embodiment the thermally-insulating barrier includes an internal surface, the series of grooves being produced on the internal surface and the corrugations projecting toward the exterior of the tank.

5 [0032] In accordance with one embodiment the sealing membrane is a secondary sealing membrane, the thermally-insulating barrier is a primary thermally-insulating barrier, the corrugations projecting toward the interior of the tank, and the tank includes a secondary thermally-insulating barrier retained on the supporting structure and carrying the secondary sealing membrane, the primary thermally-insulating barrier being carried by the secondary sealing membrane, the tank including a primary sealing membrane carried by
10 the primary thermally-insulating barrier and intended to be in contact with the fluid in the tank, the series of grooves being formed on an external surface of the primary thermally-insulating barrier.

[0033] In accordance with one embodiment the thermally-insulating barrier includes insulating panels, the insulating panels being juxtaposed to one another, the insulating panels being
15 provided with grooves forming the series of grooves so that the grooves of two adjacent insulating panels are aligned in the longitudinal direction, the at least one corrugation blocker being housed in the groove of one of the insulating panels.

[0034] In accordance with one embodiment an interpanel space is delimited between two adjacent insulating panels, the at least one corrugation blocker being housed in the groove
20 of one of the two insulating panels and able to project into the interpanel space.

[0035] In accordance with one embodiment the thermally-insulating barrier includes at least one insulating seal housed in the interpanel space and extending in a longitudinal direction of the interpanel space and at least one bridging element disposed above the insulating seal,
25 and the bridging element includes a bridging plate, the bridging plate straddling two adjacent insulating panels and being fixed to an internal face of the two insulating panels in such a manner as to oppose movement apart of the two insulating panels, the internal faces of the insulating panels forming the internal surface of the thermally-insulating barrier.

[0036] In accordance with one embodiment the thermally-insulating barrier includes at least
30 one insulating seal housed in the interpanel space and extending in a longitudinal direction of the interpanel space and at least one bridging element that is part of a chain of bridging elements and disposed above the insulating seal, and a first bridging element of the chain of bridging elements extends between two successive corrugations of the series of corrugations, the corrugation blocker being situated between said first bridging element
35 and a second bridging element of the chain of bridging elements.

- [0037] In accordance with one embodiment the bridging element includes an insulating strip assembled onto the bridging plate, the insulating strip having a dimension less than the bridging plate in the longitudinal direction in such a manner as to be housed in the interpanel space and being compressed between the bridging plate and the insulating seal in a thickness direction of the thermally-insulating barrier.
- [0038] In accordance with one embodiment the thermally-insulating barrier includes a chain of bridging elements extending in the longitudinal direction of the interpanel space and including a plurality of bridging elements straddling two adjacent insulating panels and fixed to one another.
- [0039] In accordance with one embodiment a first bridging element of the chain of bridging elements extends between two successive corrugations of the series of corrugations, the corrugation blocker being situated between said first bridging element and a second bridging element of the chain of bridging elements in line with a corrugation of the series of corrugations between the sealing membrane and the thermally-insulating barrier.
- [0040] In accordance with one embodiment the first bridging element is fixed to the second bridging element by the corrugation blocker.
- [0041] In accordance with one embodiment the corrugation blocker is fixed to a flexible layer and two adjacent bridging elements of said chain are fixed to one another by means of the flexible layer.
- [0042] In accordance with one embodiment each insulating panel includes a layer of insulating polymer foam and a rigid plate forming the face in contact with the sealing membrane, the groove of the series of grooves being formed in the rigid plate.
- [0043] In accordance with one embodiment the series of corrugations is a first series of corrugations and the corrugated metal plates comprise a second series of parallel corrugations extending parallel to the transverse direction and plane portions situated between said corrugations.
- [0044] A tank of this kind may form part of a terrestrial storage installation, for example for storing LNG, or be installed in a coastal or deep water floating structure, in particular a methane tanker ship, a floating storage and regasification unit (FSRU), a floating production storage and offloading (FPSO) unit, etc. A tank of this kind may also serve as a fuel tank in any type of ship.
- [0045] In accordance with one embodiment the invention also provides a ship for transporting a cold liquid product, the ship including a double hull and an aforementioned tank disposed in the double hull.

[0046] In accordance with one embodiment the invention also provides a transfer system for a cold liquid product, the system including the aforementioned ship, insulated pipes arranged in such a manner as to connect the tank installed in the hull of the ship to a floating or terrestrial storage installation and a pump for driving a flow of cold liquid product through the insulated pipes from or to the floating or terrestrial storage installation to or from the tank of the ship.

[0047] In accordance with one embodiment the invention also provides a method of loading or offloading such a ship in which a cold liquid product is routed through insulated pipes from or to a floating or terrestrial storage installation to or from the tank of the ship.

10 **Brief description of the figures**

[0048] The invention will be better understood and other aims, details, features and advantages thereof will become more clearly apparent the course of the following description of particular embodiments of the invention given by way of non-limiting illustration only with reference to the appended drawings.

15 [0049] [Fig. 1] Figure 1 represents a cutaway perspective view of a tank wall.

[0050] [Fig. 2] Figure 2 is a partial view in section of a thermally-insulating barrier on which rests a corrugated sealing membrane including a corrugation housed in a groove of the thermally-insulating barrier and depicts different possible positions of the corrugation in the groove.

20 [0051] [Fig. 3] Figure 3 is a perspective view of a thermally-insulating barrier including a plurality of corrugation blockers in accordance with a first embodiment.

[0052] [Fig. 4] Figure 4 is a view in section taken along the line IV-IV in figure 3 depicting a corrugation blocker housed in a groove before disposition of the sealing membrane.

25 [0053] [Fig. 5] Figure 5 is a view in section taken along the line IV-IV in figure 3 depicting a corrugation blocker housed in a groove and depicting a first position of the corrugation in the groove.

[0054] [Fig. 6] Figure 6 is a view in section taken along the line IV-IV in figure 3 depicting a corrugation blocker housed in a groove and depicting a second position of the corrugation in the groove.

30 [0055] [Fig. 7] Figure 7 is an exploded perspective view of insulating panels of a thermally-insulating barrier and of a chain of bridging elements in accordance with one embodiment intended to straddle two adjacent rows of insulating panels.

[0056] [Fig. 8] Figure 8 is a partial view in perspective of the thermally-insulating barrier provided with a chain of bridging elements.

[0057] [Fig. 9] Figure 9 is a view in section taken along the line IX-IX in figure 8 depicting the sealing membrane positioned on the thermally-insulating barrier.

5 [0058] [Fig. 10] Figure 10 is a view in section taken along the line X-X in figure 8.

[0059] [Fig. 11] Figure 11 is a schematic view in section of a blocker in accordance with a second embodiment housed in a corrugation before compression.

[0060] [Fig. 12] Figure 12 is a schematic view in section of a blocker in accordance with the second embodiment housed in a corrugation after compression against an insulating panel.

10 [0061] [Fig. 13] Figure 13 is a schematic cutaway representation of a methane tanker ship tank and a terminal for loading/offloading that tank.

Description of embodiments

[0062] By convention the terms “external” and “internal” are used to define the relative position of one element with respect to another with reference to the interior and to the exterior of
15 the tank.

[0063] In figure 1 there has been represented the multilayer structure of one embodiment of a sealed and thermally-insulating tank for storing a fluid.

[0064] Each wall of the tank includes, from the exterior to the interior of the tank, a secondary thermally-insulating barrier 1 including juxtaposed insulating panels 2 anchored to a supporting structure 3 by secondary retaining members, a secondary sealing membrane
20 4 carried by the insulating panels 2 of the secondary thermally-insulating barrier 1, a primary thermally-insulating barrier 5 including juxtaposed insulating panels 6 anchored to the insulating panels 2 of the secondary thermally-insulating barrier 1 by primary retaining members 19, and a primary sealing membrane 7 carried by the insulating panels 6 of the
25 primary thermally-insulating panel 5 and intended to be in contact with the cryogenic fluid contained in the tank.

[0065] The supporting structure 3 may in particular be a self-supporting metal plate or more generally any type of rigid partition having appropriate mechanical properties. The supporting structure 3 may in particular be formed by the hull or the double hull of a ship.
30 The supporting structure 3 includes a plurality of walls defining the general shape of the tank, usually a polyhedral shape.

[0066] The secondary thermally-insulating barrier 1 includes a plurality of insulating panels 2 anchored to the supporting structure 3 by means of beads of resin, not depicted, and/or

studs welded to the supporting structure 3. The beads of resin must be sufficiently adhesive if they alone anchor the insulating panels 2 but are not necessarily adhesive if the insulating panels 2 are anchored by means of studs. The insulating panels 2 have a substantially rectangular parallelepiped shape.

5 [0067] As depicted in figures 3 to 10 in particular, the insulating panels 2, 6 each include a layer of insulating polymer foam 9 provided on its internal face with an internal rigid plate 10 and possibly on its external face with an external rigid plate (not depicted). The internal rigid plates 10 and external rigid plates are for example plywood boards glued to said layer of insulating polymer foam 9. The insulating polymer foam may in particular be a
10 polyurethane-based foam. The polymer foam is advantageously reinforced by glass fibers contributing to reducing its thermal contraction.

[0068] The insulating panels 2, 6 are juxtaposed in parallel rows and separated from one another by interpanel spaces 12 guaranteeing a functional assembly clearance. The interpanel spaces 12 are filled with an insulating seal 13 represented in figures 5 and 6 in
15 particular, such as glass wool, rock wool or open-cell flexible synthetic foam, for example, possibly wrapped in kraft paper. The insulating seal 13 is advantageously made of a porous material so as to form gas flow spaces in the interpanel spaces 12 between the insulating panels 2. Gas flow spaces of this kind are advantageously used in order to enable circulation of inert gas, such as nitrogen, in the secondary thermally-insulating
20 barrier 1 so as to maintain it under an inert atmosphere and therefore to prevent combustible gas being found in an explosive concentration range and/or to reduce the pressure in the secondary thermally-insulating barrier 1 in order to increase its insulating power. This circulation of gas is also important for facilitating detection of any combustible gas leaks. The interpanel spaces 12 have for example a width of the order of 30 mm.
25 Insulating seals 13 are therefore placed in a longitudinal direction corresponding to the greater length of the insulating panels 2, 6 and insulating seals 13 are placed in a transverse direction perpendicular to the longitudinal direction. The insulating seals 13 are sized so that their internal face directed toward the secondary sealing membrane 4 is aligned with the limit of the insulating polymer foam layer 9, as can be seen in figure 6.

30 [0069] An internal plate 10 in accordance with one embodiment is represented in detail in figures 3, 7 and 8. The internal plate 10 includes two series of grooves 14, 15 perpendicular to one another so as to form a grid of grooves. Each of the series of grooves 14, 15 is parallel to two opposite sides of the insulating panels 2. The grooves 14, 15 are intended to receive corrugations projecting toward the exterior of the tank formed on the metal plates
35 of the secondary sealing barrier 4. In the embodiment represented the internal plate 10

includes three grooves 14 extending in the longitudinal direction of the insulating panel 2 and nine grooves 15 extending in the transverse direction of the insulating panel 2.

[0070] The grooves 14, 15 pass completely through the thickness of the internal plate 10 and therefore open at the level of the insulating polymer foam layer 9. Moreover, the insulating panels 2 include in the crossover zones between the grooves 14, 15 clearance holes 16 formed in the layer of insulating polymer foam 9. The clearance holes 16 enable housing of the node zones formed at the intersections between the corrugations of the metal plates of the secondary sealing barrier 4. These node zones have a top projecting toward the exterior of the tank.

[0071] Moreover, the internal plate 10 is equipped with metal plates 17, 18 for anchoring the edge of the corrugated metal plates of the secondary sealing membrane 4 to the insulating panels 2. The metal plates 17, 18 extend in two perpendicular directions each of which is parallel to two opposite sides of the insulating panels 2. The metal plates 17, 18 are fixed to the internal plate 10 of the insulating panel 2 by screws, rivets or staples for example. The metal plates 17, 18 are placed in recesses formed in the internal plate 10 so that the internal surface of the metal plates 17, 18 is flush with the internal surface of the internal plate 10.

[0072] The internal plate 10 is also equipped with studs 19 projecting toward the interior of the tank and intended to fix the primary thermally-insulating barrier 5 to the insulating panels 2 of the secondary thermally-insulating barrier 1. The metal studs 19 pass through holes formed in the metal plates 17.

[0073] Moreover, the internal plate 10 has along its edges, in each interval between two successive grooves 14, 15, a step 21 intended to receive a bridging element 20 described in more detail hereinafter.

[0074] As can be seen in figures 1 and 9 the secondary sealing membrane 4 includes a plurality of corrugated metal plates 24 each having a substantially rectangular shape. The corrugated metal plates 24 are disposed in a manner offset relative to the insulating panels 2 of the secondary thermally-insulating barrier 1 so that each of said corrugated metal plates 24 extends conjointly over four adjacent insulating panels 2.

[0075] Each corrugated metal plate 24 includes a first series of parallel corrugations 25 extending in the transverse direction and a second series of parallel corrugations 26 extending in the longitudinal direction. Each of the series of corrugations 25, 26 is parallel to two opposite edges of the corrugated metal plate 24. The corrugations 25, 26 project toward the exterior of the tank, that is to say in the direction of the supporting structure 3.

The corrugated metal plate 24 includes between the corrugations 25, 26 a plurality of plane surfaces. At the level of each crossover between two corrugations 25, 26 the metal plate includes a node zone. In the embodiment represented the corrugations 25, 26 of the first series and of the second series have identical heights. It is nevertheless possible for the corrugations 25 of the first series to have a greater height than the corrugations 26 of the second series or vice versa.

[0076] As represented in figure 9 the corrugations 25, 26 of the corrugated metal plates 24 are housed in the grooves 14, 15 formed in the internal plate 10 of the insulating panels 2. The adjacent corrugated metal plates 24 are welded together with an overlap. The corrugated metal plates 24 are anchored to the metal plates 17, 18 by spot welds.

[0077] The corrugated metal plates 24 are for example made of Invar®: that is to say an alloy of iron and of nickel the coefficient of expansion of which is typically between 1.2×10^{-6} and $2 \times 10^{-6} \text{ K}^{-1}$, or an iron alloy with a high content of manganese, the coefficient of expansion of which is typically of the order of $7 \times 10^{-6} \text{ K}^{-1}$. Alternatively, the corrugated metal plates 24 may equally well be made of stainless steel or of aluminum.

[0078] The primary thermally-insulating barrier 5 includes a plurality of insulating panels 6 of substantially rectangular parallelepiped shape. Here the insulating panels 6 are offset relative to the insulating panels 2 of the secondary thermally-insulating barrier 1 so that each insulating panel 6 extends over four insulating panels 2 of the secondary thermally-insulating barrier 1. An insulating panel 6 has a structure analogous to that of an insulating panel 2 of the secondary thermally-insulating barrier 1.

[0079] The primary sealing membrane 7, visible in figure 1, is obtained by assembling a plurality of corrugated metal plates 27. Each corrugated metal plate 27 includes a first series of parallel, so-called high corrugations 28 extending in the longitudinal direction and a second series of parallel, so-called low corrugations 29 extending in the transverse direction. The node zones have a structure close to that of the node zones of the corrugated metal plates 24 of the secondary sealing membrane 4. The corrugations 28, 29 project toward the interior of the tank. The corrugated metal plates 27 are for example made of stainless steel or of aluminum.

[0080] The grooves 14, 15 are sized to constitute an adjustment zone for the arrangement of the corrugations 25, 26 in the tank during fabrication of the tank. In particular, these grooves 14, 15 must be sized to allow for variations of the dimensions of the corrugations 25, 26 linked to the fabrication tolerances of said corrugations 25, 26 in the corrugated metal plates 24. Moreover, this sizing must take account of the tolerances for positioning the insulating panels 2 and the corrugated metal plates 24 relative to one another.

[0081] Figure 2 depicts a central position 35 and extreme positions 36 defining a range of possible positions of a corrugation 25, 26 housed in a groove 14, 15. The groove 14, 15 is preferably sized so as to have a width 37 in a transverse direction perpendicular to a longitudinal direction of the corrugation 25, 26 and parallel to an internal face of the internal plate 10 that is greater than or equal to a width 38 of the corrugation 25, 26 in said direction plus a predetermined tolerance corresponding to twice the positioning tolerance of the corrugation 25, 26 in the groove 14, 15 on either side of the central position 35.

[0082] Because of these dimensions, there remains in the grooves 14, 25 a space between the insulating barrier 1 and the sealing membrane 4. These grooves 14, 15 could therefore constitute a grid of circulation channels. Such channels extending continuously between the sealing membrane and the thermally-insulating barrier in the whole of the tank wall would favor convection movements, in particular on tank walls having a large vertical component such as the transverse tank walls. This kind of grid of continuous channels could generate thermosiphon phenomena favoring transfer of heat by gaseous convection in the thermally-insulating barrier.

[0083] One aspect of the invention is based on the idea of preventing these convection movements in the walls of the tank. To this end one aspect of the invention is based on the idea of limiting the length of the channels formed by the grooves 14, 15 of the thermally-insulating barrier.

[0084] In accordance with one embodiment corrugation blockers 32 are inserted in one, some or all of the grooves 14, 15 of the thermally-insulating barrier. These corrugation blockers 32 are disposed in the grooves 14, 15 in order to be arranged between the sealing membrane 4 and the thermally-insulating barrier 1.

[0085] The corrugation blockers 32 are described hereinafter in connection with the secondary thermally-insulating barrier 1 and the secondary sealing membrane 4 described hereinabove. It is obvious that the corrugation blockers may equally well be used between the primary thermally-insulating barrier 5 and the primary sealing membrane 7 in the case of corrugations 25, 26 projecting toward the exterior of the tank or between the primary thermally-insulating barrier 5 and the secondary sealing membrane 4 in the case of corrugations 25, 26 projecting toward the interior of the tank. Finally, these corrugation blockers 32 could equally well be used for a tank with only one sealing membrane.

[0086] Figure 3 represents a first embodiment with a secondary thermally-insulating barrier 1 including a plurality of juxtaposed insulating panels 2 provided with series of grooves 14, 15. In this embodiment corrugation blockers 32 are housed in a plurality of grooves 14 of the series of grooves of the same insulating panel 2 at a distance from the interpanel space

12 so as to be supported by the insulating polymer foam layer 9 and to lie between two parts of the internal rigid plate 10.

[0087] In this illustration the blockers 32 are aligned in the transverse direction so as to form a blocking line on the insulating panel 2. In another embodiment the blockers 32 could be positioned in a quincunx or be housed in alternate grooves 14.

[0088] In the embodiment represented the grooves 14 of the same insulating panel 2 include a single blocker 32 so that the pitch between two blockers of a groove 14 of the secondary thermally-insulating barrier 1 is equal to the dimension of the insulating panel 2 in the longitudinal direction of the corrugations 25. It is obvious that in a different embodiment this pitch could be different, for example by virtue of housing two blockers 32 in a groove 14 of the same insulating panel 2.

[0089] As depicted in figures 4 to 6 in particular the corrugation blocker 32 is formed of a compressible material core 33 and an envelope 34 entirely covering the core 33. The core 33 is for example made of mineral wool, melamine foam, polyamide fibers, acrylic fibers, polyethylene wadding or polyester wadding, and enables a head loss to be created in the groove 14 whilst rendering the corrugation blocker 32 deformable in order to adapt to the space left free between the corrugation 25 and the groove 14. Indeed, with the uncertainty as to the placing of the corrugation in the groove 14 because in particular of fabrication and assembly tolerances it is advantageous to fit a larger, greatly deformable corrugation blocker 32 of globally complementary shape to the space remaining between the corrugation and the groove 14 so that it is therefore compressed so as to fill all of the space.

[0090] The envelope 34 is for its part made for example of woven glass fibers and serves as a container for the core 33 and produces an additional head loss for the flow of fluid passing through the channel formed between the corrugation and the groove 14. Indeed, the material of the envelope 34 may be chosen to have a greater or lesser filtering effect so as to fix the head loss of a flow through it. A corrugation blocker 32 with an envelope 34 of this kind can therefore produce for example a head loss of the order of 3 to 5 Pa under the normal operating conditions of the tank. In this embodiment the envelope 34 is formed of an internal layer 41 in contact with the secondary sealing membrane 4 and an external layer 39 in contact with the insulating panel 2. The two layers 39, 41 are for example fixed to one another all around their perimeter so as to form the closed container for the compressible material core 33. Moreover, it has been found that it could be more advantageous to produce an internal layer 41 more flexible than the external layer 39 so that the internal layer 41 can be deformed more easily in contact with the corrugation 25

and the external layer 39 continues to fulfill its role of support and retention in the groove 14. The external layer 39 of the corrugation blocker 32 is for example glued or stapled to the two parts of the internal rigid plates 10.

5 [0091] In an embodiment that is not represented an additional flexible layer may be situated under the external layer 39 so that the role of retention in the groove 14 is transferred to this additional flexible layer and not to the external layer 39 from the container forming the core 33.

10 [0092] Figures 4 to 6 represent a corrugation blocker 32 in a groove 14 of an insulating panel 2 at different stages in assembling the tank wall and with different placings of the corrugation 25 in the groove 14.

[0093] Indeed, figure 4 represents the corrugation blocker 32 before the secondary sealing membrane 4 is installed so that the corrugation blocker is in an uncompressed state. Figures 5 and 6 represent for their part the corrugation blocker 32 after positioning the secondary sealing membrane 4 and therefore a corrugation 25 in the groove 14 in which the corrugator blocker 32 is housed, the corrugation blocker 32 therefore being in a compressed state. With reference to the range of possible positions depicted in figure 2, figure 5 represents a first situation in which the corrugation 25 is in a central position 35 whereas figure 6 represents a second situation in which the corrugation 25 is in an extreme position 36.

20 [0094] In figure 4 the corrugation blocker 32 is fixed by the two ends of the external layer 39 to the internal rigid plate 10 of the insulating panel 2 and the central part of the external layer 39 rests on the foam layer 9. The corrugation blocker 30 is therefore fixed in the groove 14 and already blocks most of the groove 14 by forming a U-section corrugation blocker 30. Here the compressible material core 33 is in an uncompressed state and so the corrugation blocker 32 has a globally constant initial thickness.

30 [0095] In figure 5 the corrugation 25 has been placed in a central position 35 inside the groove 14. The corrugation 25 has therefore compressed more the central part 42 of the corrugation blocker 32 in line with the crest of the corrugation 25 so as locally and greatly to reduce the thickness of the corrugation blocker 32, for example by of the order of 50% relative to its initial value. With the aid of its compressible material core 33 compressed in this way, the blocker therefore comes to block the space left free between the insulating panel 2 and the sealing membrane 4 by adapting to the position of the corrugation 25.

[0096] In a similar manner, in figure 6 the corrugation 25 has been placed in an extreme position 36 inside the groove 14 (here on the right-hand side of the groove 14). The

corrugation 25 has therefore compressed more a first part 43 of the corrugation blocker 32 situated to the right of the corrugation while a second part 44 of the corrugation blocker 32 is for its part not compressed. The right-hand part 43 has therefore been reduced greatly in thickness compared to its initial value, for example by of the order of 50%. In the example represented the left-hand part 44 for its part has slightly increased in thickness because of creep in this part of the compressible material of the core 33. With the aid of its compressible material core 33 compressed in this way, the blocker then comes to block the space left free between the insulating panel 2 and the sealing membrane 4 by adapting to the position of the corrugation 25.

[0097] The bridging elements 20 are represented in particular in figures 7 to 10. In those figures the bridging elements 20 each include a bridging plate 22 that straddles two adjacent insulating panels 2, straddling the interpanel space 12 between the insulating panels 2. Each bridging plate 22 is fixed against each of the adjacent two insulating panels 2 in such a manner as to oppose them moving away from each other. The bridging plates 22 have a rectangular parallelepiped shape and consist for example of a plywood board.

[0098] The external face of the bridging plates 22 is fixed against the bottom of the steps 21. The depths of the steps 21 is substantially equal to the thickness of the bridging plates 22 and so the internal face of the bridging plates 22 arrives substantially at the level of the other plane zones of the internal plate 10 of the insulating panel 2. The bridging plates 22 are therefore in a position to assure continuity in the bridging of the secondary sealing membrane 4.

[0099] In such a manner as to ensure a good distribution of the connecting forces between the adjacent panels a plurality of bridging plates 22 extends along each edge of the internal plate 10 of the insulating panels 2, a bridging plate 22 being disposed in each gap between two adjacent grooves 14, 15 of a series of parallel grooves.

[0100] The bridging plates 22 advantageously extend over substantially all of the length of the gap between two adjacent grooves 14, 15. Moreover, the steps 21 on either side of the interpanel space 12 form a housing for the bridging plate 22, i.e. the gap formed between the edges of the steps 21 of two insulating panels 2. The housing has a transverse dimension that is slightly greater than the transverse dimension of the bridging plate 22 so that mounting and/or fabrication tolerances can be ignored when inserting the bridging plate 22 in the housing.

[0101] The bridging plates 22 may be fixed against the internal plate 10 of the insulating panels 2 by any appropriate means. For example and as represented in figure 3 applying a glue 40 in the step 21 between the external face of the bridging plates 22 and the internal

plate 10 of the insulating panels 2 enables satisfactory fixing of the bridging plates 22 to the insulating panels 2.

5 [0102] The bridging elements 20 each also include an insulating strip 23 fixed, for example glued, to the external face of the bridging plates 22. During assembly of the bridging elements 20 and the insulating panels 2 the insulating strip 23 is housed in the interpanel space 12 between the bridging plate 22 and the insulating seal 13 and comes to be compressed between those two elements. In order to be easily housed in the interpanel space 12 the insulating strip 23 has a dimension in the transverse direction of the interpanel space 12 that is equal to the dimension of the interpanel space 12 in the transverse direction of the interpanel space 12. The insulating strip 23 is for example made of a polymer foam such as polyurethane foam. The insulating strip 23 has for example a longitudinal dimension equal to that of the bridging plate 22.

15 [0103] Moreover, as represented in the embodiment depicted in figures 7 and 8 in particular, the bridging elements 20 straddling the same two adjacent insulating panels 2 are connected two by two so as to form a chain of bridging elements 30 extending in the longitudinal direction of the interpanel space 12. However, in another embodiment that is not represented the bridging elements 20 may all be independent of one another.

20 [0104] Two adjacent bridging elements 20 of the chain of bridging elements 30 are fixed to one another with the aid of a corrugation blocker 32, as can be seen in figures 7 and 8 in particular. The external layer 39 of the corrugation blocker 32 is more particularly fixed, for example stapled or glued, to the internal plates 10 of the two insulating panels 2. In this embodiment the corrugation blocker 32 is therefore placed at the level of the interpanel space and in line with the two grooves 14 so as to come to be positioned between a corrugation and the insulating seal 13.

25 [0105] In an embodiment that is not represented two adjacent bridging elements 20 of the chain of bridging elements 30 are fixed, for example stapled, to one another with the aid of a flexible layer 31. A corrugation blocker 32 is fixed, for example glued, to the flexible layer 31.

30 [0106] Moreover, in an embodiment depicted in figure 7 in particular the bridging plates 22 situated in line with the directions of the metal plates 17, 18 fixed to the insulating panels 2 are equipped with thermal protection strips 45 fixed against the internal wall of said bridging plates 22 and intended to protect the bridging plate 22 during welding of the plates forming the sealing membrane.

[0107] The chain of bridging elements 30 has been depicted in figure 7 during the step of gluing them to the insulating panels 2 with the glue 40 at the level of the steps 21 whereas in figure 8 the chain of bridging elements 30 has already been fixed to the insulating panels 2.

5 [0108] Figures 9 and 10 are depictions in section of figure 8 allowing better distinction of the relative arrangement of the various elements with respect to one another in two different section directions.

[0109] In figure 9 there have also been depicted the corrugated metal plates 24 of the secondary sealing membrane 4 the corrugations 25 and 26 of which are disposed in the
10 grooves 14, 15 of the insulating panels 2 of the secondary thermally-insulating barrier 1. Figure 9 is therefore a section taken in the longitudinal direction of the interpanel space 12 at the level of said interpanel space.

[0110] It is therefore possible to distinguish the bridging plates 22, the edges of which are beveled, the external layers 39 being stapled or stuck to these beveled surfaces. The
15 insulating strip 23 extends at its edges the beveled edge of the bridging plates 22 so as to obtain a V-section external layer 39 in which the base of the V rests on the insulating seal 13. The external layer 39 therefore connects the edges of two adjacent bridging plates 22. The corrugation blocker 32 is placed on the flexible layer 31 and comes to be compressed between the flexible layer 31 and the corrugation 25.

20 [0111] Figure 10 is a section taken in the transverse direction of the interpanel space 12. It is therefore possible in this figure to distinguish the insulating strip 23 that is compressed between the bridging plate 22 and the insulating seal 13 and fills all of the space left free by the insulating seal 13 in the thickness direction and in the transverse direction. The bridging plate 22 is housed on either side of the latter in two steps 21 of the two adjacent
25 insulating panels 2.

[0112] In the first embodiment from figures 2 to 10 the corrugation blocker 32 is housed in a groove 15 so as to be compressed between a corrugation and the bottom of a groove 15. The corrugation blocker 32 is moreover glued or stapled to the walls of the groove formed by the rigid plates 10. This embodiment corresponds in particular to the situation where
30 the corrugations of the sealing membrane project toward the exterior of the tank and are housed in a groove.

[0113] Figures 11 and 12 correspond to a second embodiment that differs from the first embodiment in that the blocker 32 is this time glued to the interior of the corrugation and is compressed between a corrugation and the plane rigid plate 10 of an insulating panel

2, 6. Moreover, this second embodiment corresponds in particular to the situation in which the corrugations of the sealing membrane project toward the interior of the tank 71.

[0114] Thus figure 11 schematically represents a corrugation blocker 32 housed in a corrugation before compression so that the corrugation blocker has a height greater than the crest height of the corrugation. Moreover, before compression the corrugation blocker 32 does not necessarily have a shape complementary to the corrugation.

[0115] Figure 12 also schematically represents a corrugation blocker 32 housed in a corrugation but this time after compression between the plane rigid plate 10 of an insulating panel 2, 6 and the corrugation of the sealing membrane 4, 7. The corrugation blocker 32 has therefore been compressed and deformed so as to fill all of the space left free between the corrugation of one of the series of corrugations 25, 26 and the rigid plate 10.

[0116] Referring to figure 13, a cutaway view of a methane tanker ship 70 shows a sealed and insulated tank 71 of prismatic general shape mounted in the double hull 72 of the ship. The wall of the tank 71 includes a primary sealed barrier intended to be in contact with the LNG contained in the tank, a secondary sealed barrier arranged between the primary sealed barrier and the double hull 72 of the ship, and two insulating barriers respectively arranged between the primary sealed barrier and the secondary sealed barrier and between the secondary sealed barrier and the double hull 72.

[0117] In a manner known in itself loading/offloading pipes 73 disposed on the top deck of the ship may be connected by means of appropriate connectors to a maritime or harbor terminal to transfer a cargo of LNG from or to the tank 71.

[0118] Figure 13 shows an example of a maritime terminal including a loading and offloading station 75, an underwater pipe 76 and a terrestrial installation 77. The loading and offloading station 75 is a fixed off-shore installation including a mobile arm 74 and a tower 78 that supports the mobile arm 74. The mobile arm 74 carries a bundle of insulated flexible tubes 79 that can be connected to the loading/offloading pipes 73. The orientable mobile arm 74 adapts to all methane tanker loading gauges. A connecting pipe that is not shown extends inside the tower 78. The loading and offloading station 75 enables loading and offloading of the methane tanker 70 from or to the terrestrial installation 77. The latter includes liquefied gas storage tanks 80 and connecting pipes 81 connected via the underwater pipe 76 to the loading or offloading station 75. The underwater pipe 76 enables transfer of the liquefied gas between the loading or offloading station 75 and the terrestrial installation 77 over a great distance, for example 5 km, which enables the methane tanker ship 70 to remain at a great distance from the coast during loading and offloading operations.

[0119] Pumps onboard the ship 70 and/or pumps equipping the terrestrial installation 77 and/or pumps equipping the loading and offloading station 75 are used to generate the pressure necessary to transfer the liquefied gas.

5 [0120] Although the invention has been described in connection with a plurality of particular embodiments, it is obvious that it is in no way limited to them and that it encompasses all technical equivalents and combinations of the means described if the latter fall within the scope of the invention.

[0121] The use of the verb "to include" or "to comprise" and conjugate forms thereof does not exclude the presence of elements or steps other than those stated in a claim.

10 [0122] In the claims, any reference sign between parentheses should not be interpreted as a limitation of the claim.

Claims

[Claim 1] A sealed and thermally-insulating tank for storing a fluid fixed to a supporting structure, in which a tank wall includes at least one thermally-insulating barrier (1, 5) and at least one sealing membrane (4, 7), the sealing membrane including a series of parallel corrugations (25, 26) having a longitudinal direction and plane portions situated between said corrugations (25, 26), said corrugations (25, 26) projecting from the plane portions, said thermally-insulating barrier (1, 5) being situated against the sealing membrane (4, 7), the thermally-insulating barrier (1, 5) including insulating panels (2, 6), the insulating panels (2, 6) being juxtaposed to one another,

in which the tank includes at least one corrugation blocker (32) situated in line with a corrugation of the series of corrugations (25, 26) between a corrugation of the series of corrugations (25, 26) and one of the insulating panels (2, 6), the corrugation blocker (32) being configured to block a space left free between said corrugation and said groove in which said corrugation is housed,

in which the corrugation blocker (32) includes a compressible material core and a flexible envelope covering said core completely so as to form a container for the compressible material core, the corrugation blocker (32) creeping or being compressed between the sealing membrane and the thermally-insulating barrier.

[Claim 2] The tank as claimed in claim 1 in which said corrugations (25, 26) project from the plane portions on a projecting side of the sealing membrane, said thermally-insulating barrier (1, 5) being situated on the projecting side of the sealing membrane, the thermally-insulating barrier (1, 5) including a series of parallel grooves (14, 15) receiving the series of corrugations (25, 26), said corrugation blocker (32) being situated in line with a corrugation of the series of corrugations (25, 26) between a corrugation of the series of corrugations (25, 26) and a bottom of a groove of the series of grooves (14, 15).

[Claim 3] The tank as claimed in claim 2 in which the insulating panels include grooves forming the series of grooves so that the grooves (14, 15) of two adjacent insulating panels (2, 6) are aligned in the longitudinal direction, the at least one corrugation blocker (32) being housed in the groove of one of the insulating panels.

[Claim 4] The tank as claimed in claim 2 or claim 3 in which the thermally-insulating barrier (1) is a first thermally-insulating barrier and the tank includes a second thermally-insulating barrier situated opposite the projecting side of the sealing membrane and in which the tank includes at least one complementary corrugation blocker situated facing the at least one corrugation blocker (32) so as

to sandwich a corrugation of the sealing membrane between the corrugation blocker and the complementary corrugation blocker, the complementary corrugation blocker being configured to block a space left free between said corrugation and the second thermally-insulating barrier.

5 [Claim 5] The tank as claimed in any one of claims 2 to 4 in which the thermally-insulating barrier includes an internal surface, the series of grooves (14, 15) being produced on the internal surface and the corrugations projecting toward the exterior of the tank.

10 [Claim 6] The tank as claimed in any one of claims 2 to 4 in which the sealing membrane is a secondary sealing membrane (4), the thermally-insulating barrier is a primary thermally-insulating barrier (5), the corrugations projecting toward the interior of the tank, and in which the tank includes a secondary thermally-insulating barrier (1) retained on the supporting structure and carrying the secondary sealing membrane (4), the primary thermally-insulating barrier (5) being carried by the
15 secondary sealing membrane (4), the tank including a primary sealing membrane (7) carried by the primary thermally-insulating barrier (5) and intended to be in contact with the fluid in the tank, the series of grooves (14, 15) being formed on an external surface of the primary thermally-insulating barrier (5).

20 [Claim 7] The tank as claimed in any one of claims 2 to 6 in which each insulating panel (2) includes a layer of insulating polymer foam (9) and a rigid plate (10) forming the face in contact with the sealing membrane, the groove of the series of grooves (14, 15) being formed in the rigid plate.

25 [Claim 8] The tank as claimed in claim 1 in which the thermally-insulating barrier (1, 5) is situated between the sealing membrane (4, 7) and the supporting structure, the corrugations projecting toward the interior of the tank, each insulating panel (2) including a plane rigid plate (10) forming the face in contact with the sealing membrane, the corrugation blocker (32) being situated between a corrugation of the series of corrugations (25, 26) and a rigid plate (10) of an insulating panel (2).

30 [Claim 9] The tank as claimed in any one of claims 1 to 8 in which the corrugation blocker (32) is compressed by the sealing membrane so that the dimension in a thickness direction decreases locally by at least 20% between the thickness before compression and the thickness after compression.

35 [Claim 10] The tank as claimed in any one of claims 1 to 9 in which the envelope (34) includes a first layer (41) and a second layer (39), the first layer being situated in contact with the sealing membrane, the first layer and the second layer being fixed to one another over at least a part of a perimeter of the first layer and the

second layer so as to form the container for the compressible material core, the first layer being made of a material more flexible than the material of the second layer.

[Claim 11] The tank as claimed in any one of claims 1 to 9 in which the envelope (34) comprises a single layer having an internal surface situated in contact with the sealing membrane, the single layer being produced in the form a flexible cylinder so as to form the container for the compressible material core.

[Claim 12] The tank as claimed in claim 10 or 11 in which the single layer, the first layer (41) and/or the second layer (39) include(s) at least one perforation.

[Claim 13] The tank as claimed in any one of claims 1 to 12 in which the core (33) represents at least 90% by volume of the corrugation blocker (32) in the compressed state or in the state before compression.

[Claim 14] The tank as claimed in any one of claims 1 to 13 in which the core (33) is made of a foam, powder or non-woven fibrous material preferably chosen from: mineral wool, melamine foam, polyester wadding, polyethylene wadding, synthetic plastic foam, polyamide fibers, acrylic fibers or combinations thereof.

[Claim 15] The tank as claimed in any one of claims 1 to 14 in which the envelope (34) includes a woven or non-woven textile layer consisting of mineral and/or synthetic fibers.

[Claim 16] The tank as claimed in any one of claims 1 to 15 in which the tank includes a plurality of corrugation blockers (32), each corrugation blocker (32) being situated between a corrugation and an insulating panel.

[Claim 17] The tank as claimed in any one of claims 1 to 16 in which the tank includes a plurality of corrugation blockers (32) situated in line with a corrugation of the series of corrugations (25, 26) between a corrugation of the series of corrugations (25, 26) and an insulating panel formed in line with the corrugation, each corrugation blocker (32) being configured to block a space left free between said corrugation and said insulating panel, the corrugation blockers (32) being regularly spaced from one another in the longitudinal direction of a series of corrugations.

[Claim 18] A ship (70) for transporting a cold liquid product, the ship including a double hull (72) and a tank (71) as claimed in any one of claims 1 to 17 disposed in the double hull.

[Claim 19] A transfer system for a cold liquid product, the system including a ship (70) as claimed in claim 18, insulated pipes (73, 79, 76, 81) arranged in such a manner as to connect the tank (71) installed in the hull of the ship to a floating or

terrestrial storage installation (77) and a pump for driving a flow of cold liquid product through the insulated pipes from or to the floating or terrestrial storage installation to or from the tank of the ship.

5 [Claim 20] A method of loading or offloading a ship (70) as claimed in claim 18 in which a cold liquid product is routed through insulated pipes (73, 79, 76, 81) from or to a floating or terrestrial storage installation (77) to or from the tank of the ship (71).