

Description

Title of the invention: Sealing membrane for a sealed fluid storage tank

Technical field

5 [0001] The invention relates to the field of sealing membranes for sealed tanks with membranes. In particular, the invention relates to the field of sealing membranes for sealed and thermally insulating tanks for the storage and/or transport of liquefied gas at low temperature, such as tanks for the transport of Liquefied Petroleum Gas (also known as LPG) with a temperature of, for example, between -50°C and 0°C, or for the transport of
10 Liquefied Natural Gas (LNG) at around -162°C, at atmospheric pressure. These tanks may be installed onshore or on a floating structure. In the case of a floating structure, the tank may be intended for the transport of liquefied gas or to receive liquefied gas serving as fuel for the propulsion of the floating structure.

Prior art

15 [0002] FR2691520 discloses a sealed and thermally insulating tank for storing LNG, comprising a secondary thermally insulating barrier, a secondary sealing membrane resting on the secondary thermally insulating barrier, a primary thermally insulating barrier resting on the secondary sealing membrane, and a primary sealing membrane resting on the primary thermally insulating barrier and intended to be in contact with the liquefied gas.

20 [0003] The primary sealing membrane of this document is composed of corrugated metal plates having a first series of parallel corrugations referred to as "high" corrugations and a second series of parallel corrugations referred to as "low" corrugations, the second series of corrugations being perpendicular to the first series of corrugations. These corrugated metal plates are made of stainless steel with a thickness of approximately 1.2 mm.
25 Furthermore, the low corrugations have a height of approximately 35 mm while the high corrugations have a height of approximately 55 mm. In particular, the corrugations of the primary sealing membrane give the primary sealing membrane a degree of flexibility allowing it to contract or expand under the effect of changes in temperature without risking damage to its structure.

30 [0004] When such a tank is integrated in a carrier, the liquefied gas contained in the tank undergoes various movements. In particular, the movements of a carrier at sea, for example under the effect of climatic conditions such as sea conditions or wind, causes agitation of the liquid in the tank. The agitation of the liquid, generally referred to as

“sloshing”, generates stresses on the walls of the tank which can adversely affect the integrity of the tank, in particular by bending the corrugations of the primary sealing membrane. When it sustains such damage, the primary sealing membrane loses flexibility and may no longer be able to perform its role.

5 [0005] FR1323237 also describes a sealing membrane for a tank for storing liquefied gas. In this document, the sealing membrane comprises two series of embossments. As in the previous document, these embossments give the sealing membrane a degree of flexibility so that it can contract or expand under the effect of changes in temperature.

10 [0006] However, due to their shape and dimensional ratios, the embossments in this document are also subjected to sloshing of the fluid, and the sealing membrane may therefore lose flexibility or be damaged.

Summary

15 [0007] An idea forming the basis of the invention is to reduce the risk of damage from sloshing to the sealing membrane of a sealed tank, while preserving the flexibility of the sealing membrane allowing it to thermally expand and contract.

[0008] According to one embodiment, the invention provides a sealing membrane for a sealed fluid storage tank, in which the sealing membrane comprises at least one metal plate, the metal plate comprising a flat portion defining a plane of the plate and a plurality of reliefs protruding from the flat portion in a thickness direction perpendicular to the plane of the plate, the reliefs being spaced apart from one another, the metal plate comprising, in all directions of the plane, at least one relief, each relief comprising a base constituting the connection between the relief and the flat portion, and comprising at least one vertex, the base comprising, in the plane formed by the flat portion, a first dimension equal to the diameter of the smallest circle circumscribed around the base and a second dimension equal to the diameter of the largest circle inscribed in the base, and the distance between the vertex and the base in the thickness direction forming a height of the relief, in which the height of the relief is less than 20 mm, in which each relief is spaced apart from an adjacent relief in all directions of the plane by a distance less than or equal to 2 times the first dimension of the base, and the ratio of the first dimension of the base to the height of each relief is less than or equal to 2.

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[0009] By virtue of these features, the reliefs, owing to their height and their dimensional ratios, are not subjected as much to the sloshing of the fluid, allowing the sealing membrane to avoid being damaged and losing its seal. Moreover, such a maximum distance between adjacent patterns linked to the dimensions of the reliefs makes it possible to have a

sufficient distribution of the reliefs over the entire sealing membrane in order to allow regular contraction or expansion in all directions and thus maintain flexibility during use of the tank.

- 5 [0010] The term “adjacent patterns” means patterns which are separated from one another by at least one straight line in the plane of the plate formed only by the flat portion.
- [0011] The diameter of the smallest circle circumscribed around the base means the diameter of the smallest circle located around and outside the base, and having at least two points of intersection with the base such that the circle surrounds the base without cutting the latter. For example, in the case of a triangular base, this circle has as its center the point
10 of intersection of the perpendicular bisectors of the sides of the base.
- [0012] The diameter of the largest circle inscribed in the base means the diameter of the largest circle located inside the base and having at least two points of intersection with the base such that the circle is located entirely within the base without cutting the latter. For example, in the case of a triangular base, this circle has as its center the point of
15 intersection of the bisectors of the base.
- [0013] According to embodiments, such a sealing membrane may have one or more of the following features.
- [0014] According to one embodiment, the ratio of the second dimension of the base to the height of the relief is less than or equal to 0.6.
- 20 [0015] According to one embodiment, the sealing membrane comprises a plurality of metal plates welded to one another edge to edge in a sealed manner.
- [0016] The expression “welded in a sealed manner” means a weld made using a continuous weld bead to form a continuous surface between the two elements welded to one another.
- [0017] According to one embodiment, all the reliefs of the plate are identical.
- 25 [0018] According to one embodiment, the reliefs are regularly or irregularly distributed over the metal plate.
- [0019] According to one embodiment, the metal plate comprises at least a first series of reliefs and a second series of reliefs, the reliefs of the first series having dimensions and/or shapes different to the reliefs of the second series.
- 30 [0020] According to one embodiment, each relief is spaced apart from an adjacent relief in all directions of the plane by a distance less than or equal to 1.5 times, preferably less than or equal to once, the first dimension of the base.

- [0021] According to one embodiment, each metal plate measures at least 1 m in the longitudinal direction and at least 0.5 m in the transverse direction, for example 3 m in the longitudinal direction and 1 m in the transverse direction.
- 5 [0022] According to one embodiment, the height of the relief is between 8 mm and 20 mm, preferably between 10 mm and 14 mm.
- [0023] According to one embodiment, the ratio of the first dimension of the base to the height of the relief is less than or equal to 1.5, for example 1.4 for a relief of ellipsoidal shape.
- [0024] According to one embodiment, the ratio of the second dimension of the base to the height of the relief is greater than or equal to 0.7.
- 10 [0025] According to one embodiment, the ratio of the second dimension of the base to the height of the relief is between 1 and 2.5.
- [0026] According to one embodiment, the reliefs are produced by forming, preferably drawing, or by stamping or die-stamping, or by magnetofforming.
- [0027] According to one embodiment, the thickness of the metal plate e_{plaque} , expressed in
15 mm in the flat portion, is greater than or equal to $\frac{115}{E}$, where E is the Young's modulus of the material from which the metal plate is made, expressed in GPa.
- [0028] According to one embodiment, the metal plate is made of stainless steel or of high manganese steel.
- 20 [0029] Thus, for a stainless steel having a Young's modulus of 200 GPa, the minimum thickness of the plate is therefore approximately equal to 0.58 mm. For a high manganese steel with a Young's modulus of 170 GPa, the minimum thickness of the plate is therefore approximately equal to 0.68 mm.
- [0030] According to one embodiment, the metal plates have a thickness of between 0.5 mm and 2 mm.
- 25 [0031] According to one embodiment, the metal plates are made of a metal with a Young's modulus of between 130 GPa and 230 GPa.
- [0032] According to one embodiment, the metal plates are made of a metal with a yield strength of greater than 170 MPa at room temperature.
- 30 [0033] According to one embodiment, the metal plates are made of a metal with a yield strength between 170 MPa and 500 MPa.

[0034] According to one embodiment, the number of reliefs per linear meter of metal plate N_{relief} falls within the following range:

$$\frac{\alpha \times \Delta T \times 10^6}{11 \times h} \leq N_{\text{relief}} \leq \frac{\alpha \times \Delta T \times 10^7}{35 \times h}$$

where α is the coefficient of thermal expansion of the metal plate in K^{-1} , ΔT is the temperature difference between ambient temperature and the temperature of the fluid stored in the tank in K, and h is the height of the relief in mm.

[0035] According to one embodiment, the base has the shape of an ellipse, for example a circle, or of a polygon.

[0036] According to one embodiment, the base has the shape of an ellipse and the ratio of the first dimension of the base to the height of the relief is less than or equal to 1.4.

[0037] According to one embodiment, the ratio of the first dimension to the second dimension is less than or equal to 1.4, preferably between 1 and 1.4.

[0038] According to one embodiment, the first dimension of the base is equal to the second dimension of the base.

[0039] According to one embodiment, each relief has a pyramidal or semi-ellipsoidal shape, for example a hemisphere or a pyramid with a square base.

[0040] According to one embodiment, each relief has a shape that widens towards the base.

[0041] According to one embodiment, the orthogonal projection of the at least one vertex of the relief in the plane of the plate is located within the perimeter of the base.

[0042] According to one embodiment, at least 90%, preferably all, of the areas of the metal plate protruding from the flat portion are reliefs.

[0043] According to one embodiment, the invention provides a sealed and thermally insulating tank for storing liquefied gas, integrated in a supporting structure, the tank comprising a plurality of tank walls forming an internal space for receiving the liquefied gas, at least one of the tank walls comprising a thermally insulating barrier secured to the supporting structure and an aforementioned sealing membrane resting on the thermally insulating barrier and intended to be in contact with the liquefied gas in the tank.

[0044] According to one embodiment, the reliefs protrude from the flat portion in the direction of the internal space of the tank.

[0045] According to one embodiment, the reliefs protrude from the flat portion in the direction of the supporting structure.

[0046] According to one embodiment, the thermally insulating barrier comprises a plurality of insulating panels juxtaposed to one another.

[0047] According to one embodiment, the sealing membrane is a primary sealing membrane, the thermally insulating barrier is a primary thermally insulating barrier, and the tank wall comprises, in a thickness direction from the outside to the inside of the tank, a secondary thermally insulating barrier secured to the supporting structure, a secondary sealing membrane resting on the secondary thermally insulating barrier, the primary thermally insulating barrier resting on the secondary sealing membrane and the primary sealing membrane resting on the primary thermally insulating barrier.

[0048] Such a tank may form part of an onshore storage facility, for example for storing LNG, or be installed in a floating structure, coastal or deep-water, in particular a liquefied gas carrier, a floating storage and regasification unit (FSRU), a remote floating production and storage unit (FPSO), and the like. Such a tank may also be used as a fuel tank in any type of carrier.

[0049] According to one embodiment, a carrier for the transport of a cold liquid product comprises a double hull and a tank as described above arranged in the double hull, the double hull forming the supporting structure of the tank.

[0050] According to one embodiment, the invention also provides a transfer system for transferring a cold liquid product, the system comprising the abovementioned carrier, insulated pipelines arranged so as to connect the tank installed in the hull of the carrier to a floating or onshore storage facility, and a pump for pumping a flow of cold liquid product through the insulated pipelines from or to the floating or onshore storage facility, to or from the tank of the carrier.

[0051] According to one embodiment, the invention also provides a method for loading or unloading such a carrier, in which a cold liquid product is conveyed through insulated pipelines from or to a floating or onshore storage facility, to or from the tank of the carrier.

Brief description of the figures

[0052] The invention will be better understood, and other objects, details, features and advantages thereof will appear more clearly during the following description of several particular embodiments of the invention, provided solely by way of non-limiting illustration, with reference to the attached drawings.

[0053] [Fig. 1] Figure 1 shows a schematic top view of a portion of a sealing membrane comprising reliefs according to a first embodiment.

[0054] [Fig. 2] Figure 2 shows a schematic view in section along the line II-II of figure 1, showing one of the reliefs of the sealing membrane.

[0055] [Fig. 3] Figure 3 shows a perspective view of a portion of a sealing membrane comprising a relief according to a second embodiment.

5 [0056] [Fig. 4] Figure 4 shows a schematic view in section along the line IV-IV of figure 3, showing one of the reliefs of the sealing membrane.

[0057] [Fig. 5] Figure 5 shows a schematic top view of a portion of a sealing membrane comprising reliefs according to a third embodiment.

10 [0058] [Fig. 6] Figure 6 shows a schematic end-on view of a tank wall according to a first variant comprising a sealing membrane according to the first embodiment and a thermally insulating barrier.

[0059] [Fig. 7] Figure 7 shows a schematic end-on view of a tank wall according to a second variant comprising a sealing membrane according to the first embodiment and a thermally insulating barrier.

15 [0060] [Fig. 8] Figure 8 shows a schematic end-on view of a tank wall according to a third variant comprising a primary sealing membrane according to the first embodiment, a primary thermally insulating barrier, a secondary sealing membrane and a secondary thermally insulating barrier.

20 [0061] [Fig. 9] Figure 9 schematically depicts, with part cut away, a tank of a liquefied gas carrier comprising a sealing membrane and a terminal for loading/unloading this tank.

Description of the embodiments

[0062] By convention, “on” or “above” or “upper” refers to a position closer to the interior of the tank, while “under” or “below” or “lower” refers to a position closer to the supporting structure, regardless of the orientation of the tank wall relative to the earth's field of gravity.

25 [0063] A sealing membrane 1 for a sealed fluid storage tank will be described below.

[0064] Figure 1 shows a sealing membrane 1 according to a first embodiment. The sealing membrane 1 comprises a plurality of metal plates 2 welded to one another edge to edge in a sealed manner. The metal plates 2 comprise a flat portion 3 defining a plane of the plate and a plurality of reliefs 4 protruding from the flat portion 3 in a thickness direction
30 perpendicular to the plane of the plate.

[0065] The reliefs 4 are spaced apart from one another and distributed over the whole of the metal plate 2 so that it is not possible to draw a straight line in the plane of the plate without passing through a relief 4. To be specific, in order to ensure the flexibility of the metal plate

2 vis-à-vis thermal contraction/expansion, the sealing membrane 2 has reliefs in all directions of the plane of the plate. The flat portion 3 thus separates the reliefs 4 from one another. Each relief 4 has a base 5 and at least one vertex 6. The thickness 11 of the metal plates 2 of the sealing membrane 1 is relatively small compared to the other dimensions of the metal plates 2, to ensure the flexibility of the sealing membrane vis-à-vis thermal contraction/expansion

[0066] In the first embodiment shown in figures 1 and 2, the reliefs 4 have a circular base 5 and a single vertex 6 so as to form hemispheres or semi-ellipsoids. The reliefs 4 are in this case regularly distributed on the metal plate 2 but could be, in another embodiment not shown, irregularly distributed on the metal plate 2.

[0067] Figure 2 depicts, in section, one of the reliefs of figure 1 so as to show the different dimensions of the relief 4. To be specific, the base 5 comprises, in the plane of the plate, a first dimension 7 and a second dimension 8 which, in the case of the first embodiment, are equal. The first dimension 7 is equal to the diameter of the smallest circle circumscribed around the base 5 while the second dimension 8 is equal to the diameter of the largest circle inscribed in the base 5. In addition, the distance between the vertex 6 and the base 5 in the thickness direction of the metal plate 2 defines the height 9 of the relief 4.

[0068] In the embodiment of figure 2, each relief 4 is spaced apart from an adjacent relief 4 by a distance less than or equal to once the first dimension 7 of the base 5. The ratio of the second dimension 8 of the base 5 to the height 9 of the relief 4 is approximately equal to 3.33. Thus, the ratio of the first dimension 7 of the base 5 to the height 9 of the relief 4 is approximately equal to 0.3.

[0069] Figures 3 and 4 show a second embodiment of the reliefs 4 of the sealing membrane 1. In this embodiment, the shape of the base 5 of the reliefs 4 is different to the first embodiment. To be specific, the base 5 is in this case a quadrilateral having a larger dimension 7 formed by the diagonal of the quadrilateral and a smaller dimension 8 formed by the smaller side of the quadrilateral. The ratio between the first dimension 7 of the base 5 and the second dimension 8 of the base 5 is in this case equal to approximately 1.4 while the ratio between the second dimension 8 of the base 4 and the height 9 of the relief 4 is approximately equal to 2.5. Thus, the ratio of the first dimension 7 of the base 5 to the height 9 of the relief 4 is approximately equal to 0.56.

[0070] In the first two embodiments, the metal plates 2 include reliefs of identical shape and size from one metal plate to the other.

[0071] Figure 5 shows a third embodiment of the reliefs 4 of the sealing membrane 1 where, unlike the previous embodiments, the metal plate 2 comprises a first series of reliefs 22 and a second series of reliefs 23 having different dimensions and shapes. To be specific, the reliefs 4 of the first series 22 take the form of the reliefs of the first embodiment of figures 1 and 2 while the reliefs 4 of the second series 23 take the form of the reliefs 4 of the second embodiment. As shown, the series alternate with one another on the dimensions of the metal plate 2

[0072] In other embodiments not shown, the reliefs 4 may have different shapes and sizes with respect to what has been described above, and the metal plate 2 may also include more than two different series of reliefs.

[0073] The technique described above for producing a sealing membrane may be used in different types of storage tanks, for example to constitute the primary sealing membrane of an LNG storage tank in an onshore facility or in a floating structure such as a liquefied gas carrier or the like.

[0074] Figure 6 shows the multilayer structure of a tank wall according to a first variant for a sealed and thermally insulating tank 71 for storing, for example, liquefied gas. In this variant as shown, the tank wall comprises successively, in the thickness direction from the outside to the inside of the tank 71, a thermally insulating barrier 12 retained on a supporting structure 15, and a sealing membrane as described in the first embodiment shown in figures 1 and 2, resting against the thermally insulating barrier 12 and intended to be in contact with the fluid contained in the tank.

[0075] The supporting structure 3 may in particular be formed by the hull or the double hull of a carrier. The supporting structure 3 comprises a plurality of walls defining the general shape of the tank, usually a polyhedral shape.

[0076] The thermally insulating barrier 12 comprises a plurality of insulating panels 16 which are anchored to the supporting structure 15 by means of anchoring devices (not shown). The insulating panels 16 have a general parallelepiped shape and are arranged in parallel rows.

[0077] Figure 7 shows the multilayer structure of a tank wall according to a second variant. This variant differs from the first variant only by the shape of the thermally insulating barrier 12. To be specific, in this variant, the insulating panels 16 have on their upper surface complementary shapes 18 which are complementary to the reliefs 4 so as to optimally match the shape of the sealing membrane 1. Specifically, in the case shown, the reliefs 4 protrude towards the interior of the tank and the complementary shapes 18 thus fill the

space under the reliefs 4. In an embodiment not shown, the reliefs 4 protrude towards the outside of the tank and the complementary shapes 18 are in this case hollows in the thermally insulating barrier 12 to receive the reliefs 4.

[0078] Figure 8 shows the multilayer structure of a tank wall according to a third variant. Each tank wall successively comprises, in the thickness direction, from the outside to the inside of the tank 71, a secondary thermally insulating barrier 14 retained on a supporting structure 15, a secondary sealing membrane 13 resting against the secondary thermally insulating barrier 12, a primary thermally insulating barrier 12 resting against the secondary sealing membrane 13 and a primary sealing membrane 6 as described in the first embodiment shown in figures 1 and 2, resting on the primary thermally insulating barrier 12 and intended to be in contact with the fluid contained in the tank.

[0079] The primary thermally insulating barrier 12 comprises a plurality of primary insulating panels 16 which are anchored to the supporting structure 15 by means of anchoring devices (not shown). The secondary thermally insulating barrier 14 comprises a plurality of secondary insulating panels 17 which are anchored to the supporting structure 15 by means of anchoring devices (not shown). The primary 16 and secondary 17 insulating panels have a general parallelepiped shape and are arranged in parallel rows.

[0080] The secondary insulating panels 17 and the primary insulating panels 16 comprise a bottom plate, a cover plate and optionally an intermediate plate, for example made of plywood. The insulating panels 16, 17 also include one or more layers of insulating polymer foam sandwiched between the bottom plate, the cover plate and the optional intermediate plate and adhesively bonded to said plates. The insulating polymer foam may in particular be a polyurethane-based foam, optionally reinforced with fibers. In another embodiment, the insulating panels 16, 17 may be made entirely of insulating polymer foam. The insulating panels 16, 17 may also be produced in the form of a box filled with an insulating lining.

[0081] The secondary sealing membrane 13 may be produced in the same way as the primary sealing membrane 1. The secondary sealing membrane 13 may also be produced by a continuous sheet of metal strakes with raised edges or by strips of laminated composite materials adhesively bonded to one another.

[0082] With reference to figure 9, a view of a liquefied gas carrier 70 with part cut away shows a sealed and insulated tank 71 of generally prismatic shape mounted in the double hull 72 of the carrier. The wall of the tank 71 comprises 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 carrier, and two insulating barriers

arranged respectively between the primary sealed barrier and the secondary sealed barrier and between the secondary sealed barrier and the double hull 72.

5 [0083] In a manner known per se, loading/unloading pipelines 73 arranged on the upper deck of the carrier may be connected, by means of appropriate connectors, to a maritime or port terminal for transferring a cargo of LNG from or to the tank 71.

10 [0084] Figure 9 shows an example of a maritime terminal comprising a loading and unloading station 75, an underwater pipe 76 and an onshore facility 77. The loading and unloading station 75 is a fixed offshore facility comprising a movable arm 74 and a tower 78 which supports the movable arm 74. The movable arm 74 carries a bundle of insulated flexible
15 pipes 79 which may be connected to the loading/unloading pipelines 73. The orientable movable arm 74 may be adjusted to suit all sizes of liquefied gas carrier. A connecting pipe (not shown) extends inside the tower 78. The loading and unloading station 75 allows loading and unloading of the liquefied gas carrier 70 from or to the onshore facility 77. This facility comprises tanks 80 for storing liquefied gas and connection pipes 81 connected by
20 the underwater pipe 76 to the loading or unloading station 75. The underwater pipe 76 allows the transfer of the liquefied gas between the loading or unloading station 75 and the onshore facility 77 over a long distance, for example 5 km, which makes it possible to keep the liquefied gas carrier 70 at a long distance from the shore during loading and unloading operations.

20 [0085] To generate the pressure necessary to transfer the liquefied gas, use is made of pumps on board the carrier 70 and/or pumps fitted to the onshore facility 77 and/or pumps fitted to the loading and unloading station 75.

25 [0086] Although the invention has been described in connection with several particular embodiments, it is obvious that it is in no way limited thereto and that it includes all technical equivalents of the means described as well as combinations thereof, if these fall within the scope of the invention.

[0087] The use of the verb “comprise” or “include” and conjugated forms thereof does not rule out the presence of other elements or other stages in addition to those stated in a claim.

30 [0088] In the claims, any reference sign in parentheses should not be interpreted as a limitation of the claim.

Claims

- [Claim 1] A sealing membrane (1) for a sealed fluid storage tank, in which the sealing membrane (1) comprises at least one metal plate (2), the metal plate (2) comprising a flat portion (3) defining a plane of the plate and a plurality of reliefs (4) protruding from the flat portion (3) in a thickness direction perpendicular to the plane of the plate, the reliefs (4) being spaced apart from one another, the metal plate (2) comprising, in all directions of the plane, at least one relief (4), each relief (4) comprising a base (5) constituting the connection between the relief (4) and the flat portion (3), and comprising at least one vertex (6), the base (5) comprising, in the plane formed by the flat portion (3), a first dimension (7) equal to the diameter of the smallest circle circumscribed around the base (5) and a second dimension (8) equal to the diameter of the largest circle inscribed in the base (5), and the distance between the vertex (6) and the base (5) in the thickness direction forming a height (9) of the relief, in which the height (9) of the relief (4) is less than 20 mm,
- in which each relief (4) is spaced apart from an adjacent relief (4) in all directions of the plane by a distance less than or equal to 2 times the first dimension (7) of the base (5), and the ratio of the first dimension (7) of the base (5) to the height (9) of each relief (4) is less than or equal to 2.
- [Claim 2] The sealing membrane (1) as claimed in claim 1, wherein the ratio of the second dimension (8) of the base (5) to the height (9) of the relief (4) is less than or equal to 0.6.
- [Claim 3] The sealing membrane (1) as claimed in claim 1 or claim 2, wherein the reliefs (4) are produced by forming, preferably drawing, or by stamping or die-stamping, or by magnetofforming.
- [Claim 4] The sealing membrane (1) as claimed in one of claims 1 to 3, wherein the thickness (11) of the metal plate (2) e_{plaque} , expressed in mm in the flat portion (3), is greater than or equal to $\frac{115}{E}$, where E is the Young's modulus of the material from which the metal plate (2) is made, expressed in GPa.
- [Claim 5] The sealing membrane (1) as claimed in one of claims 1 to 4, wherein the metal plates (2) have a thickness (11) of between 0.5 mm and 2 mm.
- [Claim 6] The sealing membrane (1) as claimed in one of claims 1 to 5, wherein the metal plates (2) are made of a metal with a Young's modulus of between 130 GPa and 230 GPa.

[Claim 7] The sealing membrane (1) as claimed in one of claims 1 to 6, wherein the metal plates (2) are made of a metal with a yield strength which is greater than 170 MPa at ambient temperature.

5 [Claim 8] The sealing membrane (1) as claimed in one of claims 1 to 7, wherein the number of reliefs (4) per linear meter of metal plate N_{relief} falls within the following range:

$$\frac{\alpha \times \Delta T \times 10^6}{11 \times h} \leq N_{relief} \leq \frac{\alpha \times \Delta T \times 10^7}{35 \times h}$$

where α is the coefficient of thermal expansion of the metal plate (2) in K^{-1} , ΔT is the temperature difference between ambient temperature and the temperature of the fluid stored in the tank in K, and h is the height (9) of the relief (4) in mm.

10 [Claim 9] The sealing membrane (1) as claimed in one of claims 1 to 8, wherein the base (5) has the shape of an ellipse or of a polygon.

[Claim 10] The sealing membrane (1) as claimed in one of claims 1 to 8, wherein the base (5) has the shape of an ellipse and the ratio of the first dimension (7) of the base (5) to the height (9) of the relief (4) is less than or equal to 1.4.

15 [Claim 11] The sealing membrane (1) as claimed in one of claims 1 to 10, wherein the ratio of the first dimension to the second dimension is less than or equal to 1.4.

[Claim 12] A sealed and thermally insulating tank (71) for storing liquefied gas, integrated in a supporting structure (15), the tank comprising a plurality of tank walls forming an internal space for receiving the liquefied gas, at least one of the tank walls comprising
20 a thermally insulating barrier (12) secured to the supporting structure (15) and a sealing membrane (1) as claimed in one of claims 1 to 11 resting on the thermally insulating barrier (12) and intended to be in contact with the liquefied gas in the tank.

[Claim 13] The tank as claimed in claim 12, wherein the reliefs (4) protrude from the flat portion (3) in the direction of the internal space of the tank.

25 [Claim 14] The tank as claimed in claim 12, wherein the reliefs (4) protrude from the flat portion (3) in the direction of the supporting structure (15).

[Claim 15] The tank as claimed in one of claims 12 to 14, wherein the sealing membrane is a primary sealing membrane (1), the thermally insulating barrier is a primary thermally insulating barrier (12), and the tank wall (1) comprises, in a thickness
30 direction from the outside to the inside of the tank, a secondary thermally insulating barrier (14) secured to the supporting structure (15), a secondary sealing membrane (13) resting on the secondary thermally insulating barrier (14), the primary thermally insulating barrier (12) resting on the secondary sealing membrane (13) and the primary sealing membrane (1) resting on the primary thermally insulating barrier (12).

[Claim 16] A carrier (70) for the transport of a cold liquid product, the carrier comprising a double hull (72) and a tank (71) as claimed in one of claims 12 to 15 arranged in the double hull, the double hull forming the supporting structure of the tank (71).

5 [Claim 17] A transfer system for transferring a cold liquid product, the system comprising a carrier (70) as claimed in claim 16, insulated pipelines (73, 79, 76, 81) arranged so as to connect the tank (71) installed in the hull of the carrier to a floating or onshore storage facility (77) and a pump for pumping a flow of cold liquid product through the insulated pipelines from or to the floating or onshore storage facility, to or from the tank of the carrier.

10 [Claim 18] A method for loading or unloading a carrier (70) as claimed in claim 16, in which a cold liquid product is conveyed through insulated pipelines (73, 79, 76, 81) from or to a floating or onshore storage facility (77), to or from the tank of the carrier (71).