

Description

Title of the invention: Sealed and thermally insulating tank for storing a liquefied gas

Technical field

- 5 [0001] The invention relates to the field of sealed and thermally insulating tanks for storing and/or transporting liquefied gas, such as tanks for transporting liquefied petroleum gas (LPG) having for example a temperature of between -50°C and 0°C, or for transporting liquefied natural gas (LNG) at approximately -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 to transport liquefied gas or to receive liquefied gas that is used as fuel to propel the floating structure.
- 10 [0002] In the case of a floating structure, the tank may be intended to transport liquefied gas or to receive liquefied gas that is used as fuel to propel the floating structure.

Technological background

- 15 [0003] A sealed and thermally insulating tank for storing LNG, this tank being arranged in a load-bearing structure, has a multi-layer structure, specifically, from the outside to the inside of the tank: a secondary thermally insulating barrier anchored against the load-bearing structure, 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 natural gas stored in the tank.
- 20 [0004] During the manufacture of a tank for an LNG tanker, a side opening is closed once the tank has been manufactured, by attaching a portion of the load-bearing structure on which a tank portion is assembled. Publication KR 10 20110011155A describes such a side opening. This side opening is sometimes referred to as a side breach. Before the side breach is closed, it is necessary to check the tightness of the sealing membranes of the tank wall which has already been manufactured around the side breach.
- 25 [0005] Publication WO2020260572 provides a method for testing tightness, according to a first example, for checking the tightness of the sealing membrane of an unfinished tank
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portion, i.e. a tank portion intended to be joined to one or more other tank portions in order to finish the manufacture of said tank.

[0006] There is a need to check the tightness of a sealing membrane comprising undulations. In particular, there is a need to check the tightness of a metal sealing membrane comprising undulations.

Summary of the invention

[0007] An idea on which the invention is based is to provide a means for forming a closed and sealed space within a tank wall comprising a metal sealing membrane comprising undulations.

10 [0008] According to one embodiment, the invention provides a sealed and thermally insulating tank for storing a liquefied gas, the tank comprising a tank wall resting against a load-bearing wall, the tank wall comprising at least one sealing membrane and at least one thermally insulating barrier arranged between the sealing membrane and the load-bearing wall,

15 the thermally insulating barrier comprising a row of end blocks extending in a transverse direction;

the tank wall also comprising a sealing structure extending between the sealing membrane and the load-bearing wall in a thickness direction of the tank wall in order to sealingly enclose at least one space between the sealing membrane and the load-

20 bearing wall, the sealing structure extending along the end blocks and terminating the tank wall in a longitudinal direction perpendicular to the transverse direction, the sealing structure being sealingly fixed on one side to the load-bearing wall and on the other side to the sealing membrane; the sealing structure comprising a first metal structure and a second metal structure; the first metal structure having a first height and a first base; the first base being sealingly fixed to the load-bearing wall; the first

25 height extending in the thickness direction of the tank wall;

the second metal structure having a second height extending in the thickness direction of the tank wall and a second base, the second base covering and being fixed to an upper wall of the end blocks;

30 the sealing membrane comprising a plurality of undulations extending in the longitudinal direction and flat parts located between the undulations, the flat parts of the sealing membrane being sealingly fixed to the second base; the sealing membrane also comprising a plurality of caps sealingly fixed to the

longitudinal ends of the longitudinal undulations and to the second base to close said longitudinal ends.

[0009] By virtue of these features, the sealing membrane, the caps, the sealing structure and the load-bearing wall sealingly enclose at least one space in the tank wall.

5 [0010] It is then possible to check the tightness of the sealing membrane of this closed and sealed space that is formed.

[0011] To test the tightness of the tank wall being tested, the closed and sealed space is connected to a pressure increasing or reducing means. Such pressure reducing means are for example a vacuum pump connected to the closed and sealed space or
10 any other pressure reducing means capable of reducing the pressure in the closed and sealed space.

[0012] Activating the pressure reducing means reduces the pressure in the closed and sealed space with respect to the environment outside said closed and sealed space. This reduction in pressure is for example around -500 to -800 mbar, preferably -800 mbar.
15 The test is performed for 24 to 48 hours and the pressure variation is recorded to determine if there are any leaks.

[0013] In addition, the first metal structure and the second metal structure make it easier to install the sealing structure at one end of the tank wall. The presence of two component parts - the first metal structure and the second metal structure - makes it possible to
20 compensate for any defect in flatness along the row of end blocks.

[0014] According to some embodiments, such a tank may include one or more of the following features.

[0015] According to one embodiment, at least one said cap has a cap foot and a cap body, the cap foot being sealingly fixed to the second base, the cap body being sealingly
25 fixed to the longitudinal end of a said longitudinal undulation.

[0016] The cap foot makes it easier for an operator to position the cap and thus to weld the cap to the second base and also to weld the cap to the undulation. In addition, the cap foot reduces the risk of burning or damaging the material positioned underneath the cap foot.

30 [0017] For example, a ratio of a width ℓ of the cap foot to a height h of the cap body is comprised between 1 and $1/6$.

- [0018] The cap foot makes it easier to weld the cap to the second base. In addition, it limits the amount of welding energy fed into the prefabricated blocks by making the weld bead longer, and thus prevents burns or fires starting on the prefabricated blocks during the welding operations.
- 5 [0019] According to one embodiment, the cap foot has a flat overall shape and the cap body has a flat overall shape, the cap foot and the cap body forming an angle of between 30° and 150° , for example 135° , in particular between 80° and 100° , for example 90° , with one another.
- 10 [0020] For example, the cap foot has a rectangular overall shape. For example, the angle formed by the cap foot and the cap body is 90° . In other words, an angle of 90° is formed between the cap foot and the cap body.
- [0021] According to one embodiment, the cap foot has truncated corners on a face away from the cap body.
- 15 [0022] According to one embodiment, the second metal structure is located above the first metal structure in the thickness direction of the tank wall.
- [0023] The first metal structure is sealingly fixed to the load-bearing wall. The first metal structure extends along the row of end blocks in the transverse direction and in the thickness direction of the tank wall.
- 20 [0024] In one embodiment, the first metal structure has a first height and a first base. The first base is sealingly fixed to the load-bearing wall. The first height extends in the thickness direction of the tank wall.
- [0025] The first height and the first base are sealingly interconnected at a lower end, in the thickness direction of the tank wall, of an end block of the row of end blocks.
- 25 [0026] For example, the first height and the first base are directly fixed to one another and form a right angle at the lower end of said end block of the row of end blocks. Thus, in the direction of the row of end blocks, the first height and the first base form a straight L.
- [0027] The second metal structure covers and is fixed to an upper wall of the end blocks and, sealingly, to the flat parts of the sealing membrane.
- 30 [0028] The second metal structure extends along the row of end blocks in the transverse direction and in the thickness direction of the tank wall.

- [0029] In one embodiment, the second metal structure has a second height and a second base. The second height extends in the thickness direction of the tank wall. The second base covers and is fixed to an upper wall of the insulating end blocks. In addition, the second base is sealingly fixed to the flat parts of the sealing membrane.
- 5 [0030] The second height and the second base are sealingly interconnected at an upper end, in the thickness direction of the tank wall, of an end block of the row of end blocks.
- [0031] For example, the second height and the second base are directly fixed to one another and form a right angle at the upper end of said end block of the row of end blocks. Thus, in the direction of the row of end blocks, the second height and the second base
- 10 form an L inverted by 180°.
- [0032] According to one embodiment, the cap foot is fixed to the second base by a fillet weld.
- [0033] According to one embodiment, the first base is sealingly fixed to the load-bearing wall by continuous welding.
- [0034] According to one embodiment, a said end block comprises a plurality of lateral
- 15 anchoring strips, the lateral anchoring strips being fixed on a side wall of said end block; the first height being fixed to the lateral anchoring strips.
- [0035] According to one embodiment, the first height is fixed to the lateral anchoring strips by spot welding. Such welding makes it easier to remove the first metal structure once the tightness has been checked.
- 20 [0036] According to one embodiment, a said end block comprises a plurality of anchoring strips; the anchoring strips being fixed on an upper wall of said end block; the second base being sealingly fixed to the anchoring strips.
- [0037] According to one embodiment, a first thermal-protection sheet is positioned on one of the side walls of an end block; the first thermal-protection sheet being covered by the
- 25 first height.
- [0038] According to one embodiment, the secondary sealing membrane is made of composite material.
- [0039] According to one embodiment, the undulations extend periodically along the transverse direction of the tank wall.
- 30 [0040] According to another aspect, the invention provides a method for testing the tightness of the sealing membrane in a tank according to the invention; the method comprising:

[0041] - reducing the pressure in the insulating barrier with respect to an environment outside the tank wall; and

[0042] - measuring a parameter indicative of the variation in pressure inside the insulating barrier after the pressure in the tank wall has been reduced.

5 [0043] For example, the reduction in pressure is around -500 to -800 mbar. For example, the test is performed for 24 to 48 hours and the pressure variation is recorded to determine if there are any leaks.

[0044] According to one embodiment, prefabricated elements are anchored in the space inside the load-bearing structure in order to form the tank wall. Each prefabricated
10 element comprises a portion of the thermally insulating barrier and a portion of the sealing membrane. These prefabricated elements can be anchored in a regular network on the load-bearing structure.

[0045] According to one embodiment, the thermally insulating barrier has a plurality of standard insulating blocks distributed in a regular network inside it. The standard
15 insulating blocks may be rectangular slabs.

[0046] At one end of the tank wall, i.e. at the end of the thermally insulating barrier, the tank wall comprises end blocks.

[0047] According to one embodiment, the end blocks are rectangular slabs and are arranged in a row. An end block may comprise a lower wall (also referred to as bottom wall) and
20 an upper wall (also referred to as top wall).

[0048] The lower and upper walls may be interconnected by four side walls. In this case, the side walls support the upper wall. The end blocks then form boxes.

[0049] Conversely, an insert may rest against the lower wall and support the upper wall.

[0050] The thermally insulating barrier thus comprises a row of end blocks terminating the
25 tank wall. The row of end blocks extends in a transverse direction of the tank wall.

[0051] The end blocks may be thermally insulating. For example, the end blocks may comprise a thermally insulating material similar or even identical to the thermally insulating material of the standard insulating blocks of the thermally insulating barrier.

[0052] If the end blocks are boxes, they may be filled with an insulating material, for example
30 glass wool or rock wool, or with synthetic foam having a density of less than 60 kg/m³. If the end blocks comprise solely a lower wall and an upper wall resting against an

insert, this mechanically load-bearing insert can be thermally insulating, for example polyurethane foam, possibly reinforced with fibres.

- 5 [0053] The sealing structure extends along the end blocks and terminates the tank wall in a longitudinal direction of the tank wall, the longitudinal direction being perpendicular to the transverse direction.
- [0054] In addition, in order to sealingly enclose at least one space between the sealing membrane and the load-bearing wall, the sealing structure is sealingly fixed on one side to the load-bearing wall and on the other side to the sealing membrane.
- 10 [0055] The sealing structure comprises a first metal structure and a second metal structure. The sealing structure thus comprises at least two component parts and is therefore not made in one piece. The first metal structure and the second metal structure make it easier to install the sealing structure at the end of the tank wall. The presence of two component parts - the first metal structure and the second metal structure - makes it possible to compensate for any defect in flatness along the row of end blocks and any variation in thickness of the thermally insulating barrier.
- 15 [0056] The first metal structure and the second metal structure form part of the sealing structure and are sealingly interconnected inside it.
- [0057] It is possible to sealingly connect the first metal structure and the second metal structure in multiple possible ways.
- 20 [0058] A first possible way is to fix the first metal structure to the second metal structure without an intermediate component part in between. In other words, the first metal structure and the second metal structure are directly fixed to one another. In this case, the second metal structure can overlap the first metal structure, or vice versa.
- 25 [0059] A second possible way is to provide one or more intermediate component parts sealingly connecting the first metal structure to the second metal structure. These intermediate component parts can be made of metal, for example be a third metal structure, or not made of metal. For example, it is possible to position a seal between the first metal structure and the second metal structure in order to ensure the tightness of the sealing structure.
- 30 [0060] According to one embodiment, the sealing membrane is a primary sealing membrane, the thermally insulating barrier is a primary thermally insulating barrier and the row of end blocks is a row of primary end blocks; the tank wall also comprising a secondary

sealing membrane arranged between the primary thermally insulating barrier and the load-bearing wall and a secondary thermally insulating barrier arranged between the load-bearing wall and the secondary sealing membrane, the secondary thermally insulating barrier comprising a row of secondary end blocks; the sealing structure also
 5 comprises a third metal structure arranged between the first metal structure and the second metal structure, the third metal structure having a third height and a third base, the third base being fixed to an upper wall of the secondary end blocks, the third height being sealingly fixed to the first height, the second height being sealingly fixed to the third height.

10 [0061] In this embodiment, the sealing structure comprises a third metal structure sealingly connecting the first metal structure to the second metal structure.

[0062] According to one embodiment, the third height is sealingly fixed to the first height by a continuous weld.

15 [0063] According to one embodiment, the second height is sealingly fixed to the third height by continuous welding.

[0064] According to one embodiment, a said secondary end block comprises a plurality of upper secondary anchoring strips; the upper secondary anchoring strips being fixed on an upper wall of said end block; the second base being fixed to the upper secondary anchoring strips.

20 [0065] According to one embodiment, the second base is fixed to the upper secondary anchoring strips by spot welding. Such welding makes it easier to remove the second metal structure once the tightness has been checked.

25 [0066] According to one embodiment, a second thermal-protection sheet is positioned both on an upper wall of a said secondary end block and on a side wall of said secondary end block; the second thermal-protection sheet being covered by the third height and the third base.

[0067] According to another aspect, the invention provides a ship for transporting a cold liquid product, the ship having a double hull and a sealed and thermally insulating tank according to the invention arranged in the double hull.

30 [0068] According to another aspect, the invention provides a system for transferring a cold liquid product, the system comprising a ship according to the invention, insulated pipelines arranged such that they connect the tank of the ship to a floating or onshore

storage facility, and a pump for driving a stream of cold liquid product through the insulated pipelines to or from the floating or onshore storage facility from or to the tank of the ship.

5 [0069] According to another aspect, the invention provides a method for loading or offloading a ship according to the invention, wherein a cold liquid product is conveyed through insulated pipelines to or from a floating or onshore storage facility from or to the tank of the ship.

Brief description of the figures

10 [0070] The invention will be better understood, and further aims, details, features and advantages thereof will become more clearly apparent, in the course of the following description of several particular embodiments of the invention, which are given solely by way of non-limiting illustration, with reference to the appended drawings.

[0071] Figure 1 is an exploded perspective view which schematically shows a first step of manufacturing a portion of a tank wall according to a first embodiment.

15 [0072] Figure 2 is a view which is similar to Figure 1 and schematically shows a second step of manufacturing the tank wall according to the first embodiment.

[0073] Figure 3 is an enlarged view of the zone III in Figure 2, which schematically shows the tank wall according to the first embodiment when the second step is complete.

20 [0074] Figure 4 is a perspective view, which schematically shows a third step of manufacturing the tank wall according to the first embodiment.

[0075] Figure 5 is a view which is similar to Figure 4 and schematically shows a fourth step of manufacturing the tank wall according to the first embodiment.

[0076] Figure 6 is a view which is similar to Figure 4 and schematically shows a fifth step of manufacturing the tank wall according to the first embodiment.

25 [0077] Figure 7 is a view which is similar to Figure 4 and schematically shows a sixth step of manufacturing the tank wall according to the first embodiment.

[0078] Figure 8 schematically shows an enlarged view of the zone VIII in Figure 7.

[0079] Figure 9 schematically shows a cap according to a second embodiment.

30 [0080] Figure 10 is a partial view, in perspective, which is similar to Figure 8 and illustrates the primary membrane.

[0081] Figure 11 is a cut-away schematic view of a tank of an LNG tanker and of a loading/offloading terminal for this tank.

Description of the embodiments

5 [0082] By convention, the terms “lower” and “upper” are used to define the relative position of one element with respect to another, respectively towards the outside and the inside of the tank, as in the horizontal wall shown in Figure 1. Nevertheless, the following description is applicable to any wall regardless of its orientation in the Earth’s gravitational field.

10 [0083] One particular embodiment, which is given solely by way of non-limiting illustration, will now be described with reference to the appended Figures 1 to 9. The figures focus on an end portion of the tank wall close to a side breach 90, given that the rest of the tank wall can be manufactured by methods known from elsewhere, for example as described in document FR2903165.

15 [0084] The sealed and thermally insulating tank for storing liquefied natural gas, this tank being arranged in a load-bearing structure 1000, has a multi-layer structure, specifically, from the outside toward the inside of the tank: a secondary thermally insulating barrier 3 anchored against the load-bearing structure 1000, a secondary sealing membrane 2 resting on the secondary thermally insulating barrier 3, a primary thermally insulating barrier 5 resting on the secondary sealing membrane 2 and a
20 primary sealing membrane 4 resting on the primary thermally insulating barrier 5 and intended to be in contact with the liquefied natural gas stored in the tank.

[0085] Known prefabricated elements, which are shown in part, can be anchored on a large part of the load-bearing structure 1000 in order to form the two insulating barriers and the secondary sealing membrane 2 of the tank. Each prefabricated element comprises
25 a portion of the secondary thermally insulating barrier 3, a portion of the secondary sealing membrane 2 and a portion of the primary thermally insulating barrier 5. These prefabricated elements are anchored in a regular network on the load-bearing structure 1000.

30 [0086] The secondary sealing membrane 2 of a prefabricated block is a rigid sealing film 317 bonded to the secondary thermally insulating barrier.

[0087] The portion of the primary thermally insulating barrier of a prefabricated block only partially covers the secondary sealing membrane 2, without covering a peripheral

portion of the secondary sealing membrane. A flexible sealing film 11 is fixed on said peripheral portion of the secondary sealing membrane of two adjacent prefabricated elements in order to ensure that the secondary sealing membrane 2 is continuous.

5 [0088] More particularly, each prefabricated block comprises, from the outside of the tank to the inside of the tank: a bottom plate 311, a secondary insulating insert, the rigid sealing film 317, a primary insulating insert and a top plate 512.

[0089] The bottom plate 311 and the secondary insulating insert form a first substantially parallelepipedal block 31 covered by the rigid sealing film 317.

10 [0090] The primary insulating insert and the top plate 512 form a second substantially parallelepipedal block 51 resting on the rigid sealing film.

[0091] The bottom plate 311 and the top plate 512 are for example manufactured from plywood. The secondary insulating insert and the primary insulating insert are for example manufactured from polyurethane foam, possibly reinforced with fibres. The rigid sealing film 317 is for example a composite material, i.e. a material made up of an aluminium sheet inserted between two layers of glass fibres and resin.

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[0092] In such a prefabricated block, the bottom plate 311, the secondary insulating insert and the rigid sealing film 317 have dimensions in a plane perpendicular to the thickness direction of the tank that are greater than the dimensions of the primary insulating insert and of the top plate 512 such that a peripheral edge of the rigid sealing film 317 is not covered by the primary insulating insert.

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[0093] During the manufacture of the tank, such prefabricated blocks are anchored side-by-side on the load-bearing structure 1000, for example the inner wall of a double hull of a ship. A flexible sealing film 11 is applied to the peripheral edge (not visible) of the rigid sealing film 317 of two side-by-side prefabricated blocks in such a way as to ensure continuous sealing between the rigid sealing films 317 of two adjacent prefabricated blocks. This flexible sealing film 11 is for example made of triplex®, i.e. comprising a sheet of aluminium between two layers of glass fibres joined to one another by a flexible resin such as rubber.

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[0094] The secondary sealing membrane 2 is formed by the rigid sealing films 317 of the prefabricated blocks and the flexible sealing films 11 connecting the prefabricated blocks. This affords a continuous secondary sealing membrane 2.

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[0095] Further details regarding such prefabricated blocks, their arrangement, or further elements making up the tank are for example described in document FR2903165.

[0096] Figures 1 and 2 illustrate a truncated view of the tank wall 100 resting against the load-bearing wall 1000. As illustrated in Figures 1 and 2, the tank wall 100 is interrupted in the longitudinal direction L and transverse direction T close to the side breach 90, which is a rectangular window extending in these two directions.

[0097] The following text describes the tank wall interrupted in the longitudinal direction L.

[0098] The secondary thermally insulating barrier 3 comprises the aforementioned prefabricated blocks and, at the longitudinal end L of the tank wall 100, a row of secondary end blocks 32. The row of secondary end blocks 32 extends in the transverse direction T of the tank wall and terminates the secondary thermally insulating barrier 3 of the tank wall 100.

[0099] The secondary end blocks 32 are boxes comprising a lower wall (or bottom wall) and an upper wall 322 (or top wall) interconnected by side walls 321 and 323. The side walls 323 extend in the longitudinal direction L and the side walls 321 extend in the transverse direction T. A first side wall 321 (not visible) is positioned facing the adjacent prefabricated block in the longitudinal direction L and a second side wall 321 terminates the tank wall 100.

[0100] In addition, the secondary end walls 32 comprise lateral anchoring strips 101 and upper secondary anchoring strips 102. The upper secondary anchoring strips 102 are fixed on the upper wall 322 and the lateral anchoring strips 101 are fixed on the second side wall 321 terminating the tank wall 100. The upper secondary anchoring strips 102 form a row of anchoring strips extending in the transverse direction T. Similarly, the lateral anchoring strips 101 form a row of anchoring strips extending in the transverse direction T.

[0101] The lateral anchoring strips 101 and the upper secondary anchoring strips 102 are fixed by riveting or screwing.

[0102] The lateral anchoring strips 101 and the upper secondary anchoring strips 102 are made of metal, for example stainless steel.

[0103] As illustrated in Figure 1, during the manufacture of the tank, a first metal structure 6 is fixed to the load-bearing wall 1000 and to the lateral anchoring strips 101. Figure 2

illustrates the state of the tank when the first metal structure 6 is fixed to the load-bearing wall 1000 and to the lateral anchoring strips 101.

[0104] The first metal structure 6 is made of stainless steel.

[0105] The first metal structure 6 has a first base 62 and a first height.

5 [0106] The first base 62 and the first height 61 form a right angle with one another. The first base 62 is sealingly fixed to the load-bearing wall 100 by a continuous weld. The first height 61 is welded to the lateral anchoring strips 101. Thus, the right angle of the first metal structure 6 closely follows a right angle formed by the load-bearing wall 1000 and the second side wall 321. In the transverse direction, the first height and the first
10 base form a straight L.

[0107] In addition, a first thermal-protection sheet 601 is positioned on the second side wall 321. During the fixing of the first metal structure 6, the first height 61 covers the first thermal-protection sheet 601. The first thermal-protection sheet 601 protects the second side wall 321 against the heat of welding during the joining of multiple
15 segments of the first metal structure 6. A weld seam 88 between two aligned segments is shown in an exploded view in Figure 1, with the understanding that these segments can be mounted one after another in practice, in which case the weld seam 88 is produced in line with the first thermal-protection sheet 601. It is possible to distribute multiple thermal-protection sheets 601 along the second side wall 321.

20 [0108] In addition, as illustrated in Figures 2 and 3, the tank wall 100 comprises a third metal structure 8.

[0109] The third metal structure 8 has a third base 82 and a third height 81. The third base 82 and the third height 81 form a right angle with one another at the upper end of the secondary end blocks 32 of the row of secondary end blocks 32. Thus, in the
25 transverse direction, the third height 81 and the third base 82 form an L inverted by 180°.

[0110] The third base 82 is fixed to the upper secondary anchoring strips 102 by spot welding. The third height 81 is sealingly fixed to the first height 61 by a continuous weld (figure 3).

30 [0111] Thus, the first height 61 and the third height 81 terminate the secondary layer of the tank wall 100.

[0112] A second thermal-protection sheet 801 is positioned in a straddling manner on the upper wall 322 and the second side wall 321. In other words, the second thermal-protection sheet 801 is positioned on either side of the upper edge corner of the secondary end block 32. The second thermal-protection sheet 801 is covered by the third metal structure 8.

[0113] As illustrated in Figures 1, 2, 4 and 5, the primary thermally insulating barrier 5 comprises, at the longitudinal end L of the tank wall 100, a row of primary end blocks 52. The row of primary end blocks 52 extends in the transverse direction T of the tank wall and terminates the primary layer of the tank wall 100.

[0114] Moreover, primary insulating slabs 87 fill the spaces between the second blocks 51 and cover the flexible sealing film 11, according to the known technique.

[0115] In addition, primary anchoring strips 202 are fixed on the top plates 512 of the second blocks 51 and of the primary insulating slabs 87. The primary anchoring strips 202 form a row of anchoring strips extending in the transverse direction T. The primary anchoring strips 202 are fixed by riveting or screwing. The primary anchoring strips 202 are made of metal, for example stainless steel.

[0116] The primary end blocks 52 have a larger dimension than the secondary end blocks 32 in the longitudinal direction L. As illustrated in Figure 5, the primary end blocks 52 cover a longitudinal end of the prefabricated blocks, the secondary end blocks 32 and the third base 82.

[0117] The primary end blocks 52 are fixed to the secondary sealing membrane 2 by means of an adhesive strip 55. The adhesive strip 55 is positioned on either side of the row of secondary end blocks 32 and the adjacent prefabricated blocks. The adhesive strip 55 thus covers the upper secondary anchoring strips 102 and the secondary sealing membrane 2.

[0118] The primary end blocks 52 have an upper wall 522 (or top wall) and a side wall 521. The side wall 521 is aligned with the first height 61 and the third height 81 in the thickness direction of the tank wall 100. Thus, the primary end blocks 52 terminate the tank wall 100 at the primary layer.

[0119] As illustrated in Figure 6, the second metal structure 9 covers the primary end blocks 52 and a part of the third height 81.

[0120] The second metal structure 9 has a second base 92 and a second height 91. The second base 92 and the second height 91 form a right angle with one another at the upper end of the primary end blocks 52 of the row of primary end blocks 52. Thus, in the transverse direction, the second height 91 and the second base 92 form an L inverted by 180°.

[0121] On one side, the second base 92 is fixed to the primary anchoring strips 202. On the other side, the second height 91 is sealingly fixed to the third height 81 by continuous welding.

[0122] As illustrated in Figure 7, the primary sealing membrane 4 has a plurality of undulations 43 extending in the longitudinal direction L and flat parts 44 located between the undulations 43.

[0123] The flat parts 44 are sealingly fixed to the second base 92.

[0124] The undulations 43 and the second base 92 delimit orifices 45 at the longitudinal ends of the undulations 43.

[0125] In addition, the primary sealing membrane 4 comprises a plurality of caps 40 at the longitudinal ends of the undulations 43. The caps 40 comprise solely a cap body 41 (Figure 8) having a flat overall shape. The contour of the cap body 41 closely follows the contour of the undulation 43. Thus, the cap 40 can be manufactured by cutting out from a flat metal sheet.

[0126] The caps 40 sealingly close the orifices 45. As a result, the primary sealing membrane 4 and the second metal structure 9 snugly sealingly enclose the primary insulating barrier 5 of the tank wall 100.

[0127] As illustrated in Figure 8, the caps 40 are fixed by welding to the longitudinal ends of the undulations 43 and to the second base 92: the cap body 41 is sealingly fixed to the longitudinal end of a longitudinal undulation and to the second base 92 by a weld established around the entire contour of the cap body 41.

[0128] Alternatively, the caps 40 have a cap body 41 and a cap foot 42 (Figure 9), which both have a flat overall shape. The cap foot 41 has an overall shape of rectangular contour and extends from the cap body 41 such that the cap body 41 and the cap foot 42 form a right angle or another angle, for example 135°. Thus, the cap 40 can be manufactured by cutting out and folding from a flat metal sheet.

[0129] In addition, the width ℓ of the cap foot 42 corresponds to $1/5$ of the height h of the cap body 41. However, a ratio of the width ℓ of the cap foot 42 to the height h of the cap body 41 can vary between 1 and $1/6$.

5 [0130] In this case, the cap foot 42 is welded to the second base 92 by a fillet weld. The cap foot 42 makes it easier for an operator to position the cap and thus to weld the cap 40 to the second base 92 and also to weld the cap to the undulation 43.

10 [0131] Thus, in this embodiment, the sealing structure comprises the primary metal structure 6, the second metal structure 9 and the third metal structure 8. The third metal structure 8 sealingly connects the primary metal structure 6 and the second metal structure 9.

[0132] As illustrated in Figures 6 and 7, in the thickness direction of the tank wall 100, the sealing structure has the first height 61, the second height 91 and the third height 81.

15 [0133] The load-bearing wall 1000, the first metal structure 6, the third metal structure 8 and the secondary sealing membrane 2 delimit a first closed and sealed space enclosing the secondary insulating barrier. It is then possible to check the tightness of this closed and sealed space.

20 [0134] Similarly, the secondary sealing membrane 2, the third metal structure 8, the second metal structure 9, the primary sealing membrane and the caps 40 delimit a second closed and sealed space enclosing the primary insulating barrier. It is then possible to check the tightness of this closed and sealed space.

[0135] A description has just been given of the tank wall interrupted in the longitudinal direction L. The tank wall interrupted in the transverse direction T has the same features, mutatis mutandis.

25 [0136] According to one embodiment, there is an undulation 43 at the join between two component parts making up the second metal structure 9, and more specifically at a gap between two second bases 92 side-by-side in the transverse direction T. This situation is possible if, by contrast to what Figures 6 and 7 show, the two second bases 92 do not touch and do not sealingly close the second metal structure 9. In this case, it is possible to increase the width ℓ of the cap foot 42 that closes this undulation 43, such that the cap foot 42 completely covers the gap between the two second bases 92 and sealingly closes the second metal structure 9.

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[0137] In another embodiment, shown in Figure 10, the longitudinal end edge 20 of the primary sealing membrane 4 is spaced apart from the second base 92 in the longitudinal direction L, by contrast to what Figure 7 shows. In this case, the second metal structure 9 may have an intermediate structure arranged between the longitudinal end edge 20 of the primary sealing membrane 4 and the second base 92. The intermediate structure consists of at least two metal intermediate parts 21 side-by-side in the transverse direction T with a gap 22 located facing an orifice 45. In order to seal the second metal structure 9, it is possible to increase the width l of the cap foot 42 to simultaneously cover the gap 22 between the two metal intermediate parts 21 and the second base 92. A sealing weld is established around the entire contour of the cap 40 as in the other embodiments. Each metal intermediate part 21 may have two wings forming an angle with one another, for example an angle of 135° . For example, the two wings are separated by the edge corner 23. This embodiment makes it possible to close the second metal structure 9 close to an edge corner of a polyhedral tank.

[0138] In a variant, the metal intermediate parts 21 may be flat, in which case the primary sealing membrane 4 remains substantially coplanar with the second base 92.

[0139] Manufacturing method

[0140] Figures 1 to 9 illustrate the successive manufacturing steps for obtaining a sealed tank as described above.

[0141] As illustrated in Figure 1, the prefabricated blocks are firstly anchored in the load-bearing wall 1000.

[0142] The secondary end boxes 32 are then anchored in the load-bearing wall 1000 and the lateral anchoring strips 101 and the upper secondary anchoring strips 102 are fixed on the secondary end boxes 32.

[0143] As illustrated in Figure 1, a first thermal-protection sheet 601 is positioned on the second side wall 321 and then the first metal structure 6 is fixed to the load-bearing wall 1000 and to the lateral anchoring strips 101 of the row of secondary end boxes 32.

[0144] Then, as illustrated in Figure 2, a thermal-protection sheet 801 is positioned on the upper edge corner of the secondary end boxes 32 and the third metal structure 8 is fixed to the upper secondary anchoring strips 102 and to the first height 61.

[0145] Then, as illustrated in Figure 4, an adhesive strip 55 is fixed on either side of the row of secondary end blocks 32 and the adjacent prefabricated blocks.

[0146] Then, as illustrated in Figure 5, the primary end boxes 52 are fixed to the tank wall by means of the adhesive strip 55.

5 [0147] Then, as illustrated in Figure 6, the second structure 9 is fixed to the primary anchoring strips 202 and to the third height 82.

[0148] Then, as illustrated in Figures 7 and 8, the sealing membrane 4 is fixed to the second structure 9 and the caps 40 are fixed to the longitudinal ends of the undulations 43 to close the orifices 45.

10 [0149] The technique described above for producing a tank having two sealing membranes can be used in various types of tank, for example to form a double-membrane tank for liquefied natural gas (LNG) in an onshore facility or in a floating structure such as an LNG tanker or the like. It can also be used to produce a tank wall having a single
15 sealing membrane. Within this context, it can be considered that the secondary sealing membrane 2, the secondary thermally insulating barrier 3 and the third metal structure 8 illustrated in the above-mentioned figures are not present and that the second height 91 is sealingly welded to the first height 61. Thus, the load-bearing wall 1000, the first metal structure 6, the second metal structure 9, the single sealing membrane and the
20 caps 40 delimit a closed and sealed space which encloses a single insulating barrier and the tightness of which can be checked.

[0150] In this way, this technique can also be applied to tanks having one or more thermally insulating barriers and one or more sealing membranes side-by-side.

[0151] With reference to Figure 11, a cut-away view of an LNG tanker 70 shows a sealed and insulated tank 71 having a prismatic overall shape assembled in the double hull 72 of
25 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
30 hull 72.

[0152] As is known per se, loading/offloading pipelines 73 arranged on the upper deck of the ship can be connected, by means of appropriate connectors, to a maritime or harbour

terminal or to an LNG bunkering ship to transfer a cargo of LNG to or from the tank 71.

[0153] Figure 11 shows an example of a maritime terminal including a loading/offloading station 75, an subsea line 76 and an onshore facility 77. The loading/offloading station 75 is a fixed offshore facility including a mobile arm 74 and a tower 78 which supports the mobile arm 74. The mobile arm 74 carries a bundle of flexible insulated hoses 79 that can be connected to the loading/offloading pipelines 73. The orientable mobile arm 74 can be adapted to all sizes of LNG tankers. A connecting line (not shown) extends inside the tower 78. The loading/offloading station 75 is used to load and offload the LNG tanker 70 from or to the onshore facility 77. This facility includes liquefied gas storage tanks 80 and connecting lines 810 connected via the subsea line 76 to the loading/offloading station 75. The subsea line 76 is used to transfer the liquefied gas between the loading/offloading station 75 and the onshore facility 77 over a long distance, for example 5 km, allowing the LNG carrier 70 to be kept a long way from the coast during the loading and offloading operations.

[0154] Pumps carried on board the ship 70 and/or pumps in the onshore facility 77 and/or pumps in the loading/offloading station 75 are used to generate the pressure required to transfer the liquefied gas.

[0155] Although the invention has been described in connection with several particular embodiments, it is evident that it is in no way limited thereto and that it comprises all the technical equivalents of the means described and the combinations thereof where these fall within the scope of the invention.

[0156] Use of the verb "have" or "comprise" or "include" and their conjugated forms does not exclude the presence of elements or steps other than those set out in a claim.

[0157] In the claims, any reference sign between parentheses should not be interpreted as a limitation of the claim.

CLAIMS

- [Claim 1] Sealed and thermally insulating tank for storing a liquefied gas, the tank comprising a tank wall (100) resting against a load-bearing wall (1000), the tank wall comprising at least one sealing membrane and at least one thermally insulating barrier arranged between the sealing membrane and the load-bearing wall,
- 5 the thermally insulating barrier comprising a row of end blocks (32) extending in a transverse direction (T);
- the tank wall also comprising a sealing structure extending between the sealing membrane (4) and the load-bearing wall in a thickness direction of the tank wall in order to sealingly
- 10 enclose at least one space between the sealing membrane and the load-bearing wall, the sealing structure extending along the end blocks (32) and terminating the tank wall in a longitudinal direction (L) perpendicular to the transverse direction, the sealing structure being sealingly fixed on one side to the load-bearing wall and on the other side to the sealing membrane; the sealing structure comprising a first metal structure (6) and a second metal
- 15 structure (9); the first metal structure having a first height (61) and a first base (62); the first base (62) being sealingly fixed to the load-bearing wall; the first height (61) extending in the thickness direction of the tank wall;
- the second metal structure having a second height (91) extending in the thickness direction of the tank wall and a second base (92), the second base (92) covering and being fixed to
- 20 an upper wall of the end blocks;
- the sealing membrane comprising a plurality of undulations (43) extending in the longitudinal direction (L) and flat parts (44) located between the undulations, the sealing membrane also comprising a plurality of caps (40) sealingly fixed to longitudinal ends of the longitudinal undulations to close said longitudinal ends,
- 25 characterized by the fact that the flat parts (44) of the sealing membrane are sealingly fixed to the second base (92) and that the caps (40) are sealingly fixed to the second base (92), wherein a said end block comprises a plurality of lateral anchoring strips (101), the lateral anchoring strips being fixed to a side wall of said end block, the first height (61) being fixed to the lateral anchoring strips.
- 30 [Claim 2] Sealed and thermally insulating tank according to Claim 1, wherein at least one said cap has a cap foot (42) and a cap body (41), the cap foot being sealingly fixed to the second base, the cap body being sealingly fixed to the longitudinal end of a said longitudinal undulation.

[Claim 3] Sealed and thermally insulating tank according to Claim 2, wherein the cap foot has a flat overall shape and the cap body has a flat overall shape, the cap foot and the cap body forming an angle of between 30° and 150°, for example 90° or 135°, with one another.

5 [Claim 4] Sealed and thermally insulating tank according to any one of Claims 2 to 3, wherein the cap foot is fixed to the second base by a fillet weld.

[Claim 5] Sealed and thermally insulating tank according to any one of the preceding claims, wherein the first height (61) is fixed to the lateral anchoring strips by spot welding.

10 [Claim 6] Sealed and thermally insulating tank according to any one of the preceding claims, wherein a said end block comprises a plurality of anchoring strips (202); the anchoring strips (202) being fixed on an upper wall (512) of said end block; the second base being sealingly fixed to the anchoring strips.

[Claim 7] Sealed and thermally insulating tank according to any one of the preceding claims, wherein a first thermal-protection sheet (601) is positioned on one of the side walls (321) of an end block;
15 the first thermal-protection sheet being covered by the first height (61).

[Claim 8] Sealed and thermally insulating tank according to any one of the preceding claims, wherein the sealing membrane is a primary sealing membrane (4), the thermally insulating barrier is a primary thermally insulating barrier (5) and the row of end blocks is a
20 row of primary end blocks (52);

the tank wall also comprising a secondary sealing membrane (2) arranged between the primary thermally insulating barrier and the load-bearing wall and a secondary thermally insulating barrier (3) arranged between the load-bearing wall and the secondary sealing membrane,

25 the secondary thermally insulating barrier comprising a row of secondary end blocks (32); the sealing structure also comprising a third metal structure (8) arranged between the first metal structure (6) and the second metal structure (9), the third metal structure having a third height (81) and a third base (82),

30 the third base (82) being fixed to an upper wall of the secondary end blocks, the third height (81) being sealingly fixed to the first height (61), the second height (91) being sealingly fixed to the third height (81).

[Claim 9] Sealed and thermally insulating tank according to Claim 8, wherein the second height (91) is sealingly fixed to the third height (81) by continuous welding.

35 [Claim 10] Sealed and thermally insulating tank according to Claim 8 or 9, wherein the third height (81) is sealingly fixed to the first height (61) by a continuous weld.

[Claim 11] Sealed and thermally insulating tank according to any one of Claims 8 to 10, wherein a said secondary end block (32) comprises a plurality of upper secondary anchoring strips (102);

the upper secondary anchoring strips being fixed on an upper wall (322) of said secondary end block;

the second base (82) being fixed to the upper secondary anchoring strips.

[Claim 12] Sealed and thermally insulating tank according to Claim 11, wherein the second base (82) is fixed to the upper secondary anchoring strips by spot welding.

[Claim 13] Sealed and thermally insulating tank according to any one of Claims 8 to 12, wherein a second thermal-protection sheet (801) is positioned both on an upper wall (322) of a said secondary end block and on a side wall (321) of said secondary end block; the second thermal-protection sheet being covered by the third height (81) and the third base (82).

[Claim 14] Sealed and thermally insulating tank according to any one of Claims 8 to 13, wherein the secondary sealing membrane is made of composite material.

[Claim 15] Sealed and thermally insulating tank according to any one of the preceding claims, wherein the undulations extend periodically along the transverse direction of the tank wall.

[Claim 16] Sealed and thermally insulating tank according to any one of the preceding claims, wherein the load-bearing wall has an opening, the tank wall being terminated by the sealing structure close to the opening.

[Claim 17] Method for testing the tightness of the sealing membrane in a sealed and thermally insulated tank according to one of Claims 1 to 16; the method comprising:

- reducing the pressure in the insulating barrier with respect to an environment outside the tank wall; and

- measuring a parameter indicative of the variation in pressure inside the insulating barrier after the pressure in the tank wall has been reduced.

[Claim 18] Ship (70) for transporting a cold liquid product, the ship having a double hull (72) and a sealed and thermally insulating tank according to one of Claims 1 to 17 arranged in the double hull.

[Claim 19] System for transferring a cold liquid product, the system comprising a ship (70) according to Claim 18, insulated pipelines (73, 79, 76, 810) arranged so as to connect the tank (71) of the ship to a floating or onshore storage facility (77), and a pump for driving a stream of cold liquid product through the insulated pipelines to or from the floating or onshore storage facility from or to the tank of the ship.

[Claim 20] Method for loading or offloading a ship (70) according to Claim 18, wherein a cold liquid product is conveyed through insulated pipelines (73, 79, 76, 810) to or from a floating or onshore storage facility (77) from or to the tank of the ship.