

METHOD FOR PRODUCING A THERMAL INSULATION BARRIER FOR A WALL OF A VESSEL AND THERMAL INSULATION BARRIER PRODUCED THEREBY

Technical field

The invention relates to the field of membrane type fluid-tight and thermally
5 insulative tanks for the storage and/or the transportation of a fluid such as a cryogenic fluid.

Membrane type fluid-TIGHT and thermally insulative tanks are employed in particular for the storage of liquefied natural gas (LNG), which is stored at atmospheric pressure at approximately -162°C.

10 Technological background

The document WO2016046487 discloses a membrane type fluid-tight and thermally insulative tank. Each wall of the tank includes a multilayer structure featuring successively, in the direction of the thickness, from the exterior toward the interior of the tank, a secondary thermal insulation barrier comprising insulative panels retained
15 on a support structure, a secondary sealing membrane resting against the secondary thermal insulation barrier, a primary thermal insulation barrier comprising insulative panels resting against the secondary sealing membrane, and a primary sealing membrane resting against the primary thermal insulation barrier and intended to be in contact with the liquefied natural gas contained in the tank. Each insulative panel
20 of the primary thermal insulation barrier has cut-outs along its edges and at its corners. These cut-outs define openings in which are housed anchor devices fixing the insulative panels of the primary thermal insulation barrier to the insulative panels of the secondary thermal insulation barrier. Insulative blocking members are intended to be housed in the openings formed in the primary thermal insulation barrier in order
25 to ensure continuity of the thermal insulation.

The dimensional tolerances of the insulative blocking members are small so that the insulative blocking members are the best possible fit to the dimensions of the openings. In particular, it is necessary that the dimensions of the insulative blocking members and of the openings in the direction of thickness of the tank wall are matched
30 to one another. Indeed, if this is not the case the insulative blocking members locally cause differences of level that affect the flatness of the support surface of the primary

sealing membrane. Now, such differences of level are liable to damage the primary sealing membrane.

A second particular feature is that the openings in the direction perpendicular to the thickness are as limited as possible, with the aim of limiting to the maximum
5 gas movement phenomena that could affect thermal performance.

Summary

An idea on which the invention is based is to propose a method for producing a thermal insulation barrier intended to define an internal support surface of a sealing membrane and featuring openings and insulative blocking members housed in said
10 openings, which method is simple to employ and limits the presence of differences of level in the internal support surface of the sealing membrane in line with the openings.

In accordance with one embodiment, the invention provides a method for producing a thermal insulation barrier for a wall of a fluid-tight and thermally insulative tank integrated into a support structure, said method including the following steps:

- 15 - anchoring a plurality of insulative panels directly or indirectly to the support structure by means of anchor devices; said plurality of insulative panels defining an internal support surface of a sealing membrane and including at least one opening opening at the level of said internal surface;
- 20 - procuring a polymer foam insulative blocking member intended to ensure continuity of thermal insulation at the level of said opening, said insulative blocking member having an internal end;
- 25 - inserting said insulative blocking member in said opening and pushing it in the direction of the support structure until the insulative blocking member comes to bear in the direction of the support structure against a bearing member housed in said opening;
- 30 - pushing the insulative blocking member in the direction of the support structure against the bearing member so as to damage irreversibly the insulative blocking member where it bears against the bearing member and so as to reduce irreversibly the dimension of the insulative blocking member between the internal end of the insulative blocking member and where the insulative

blocking member bears against the bearing member until the internal end of the insulative blocking member reaches a predetermined position in said opening.

Accordingly, in a method of this kind, the initial dimension of the insulative blocking member in the direction of thickness of the tank wall is no longer critical because when the insulative blocking member is pushed into the opening its dimension in the direction of the thickness of the wall is irreversibly reduced, until the internal end of the insulative blocking member reaches the required position. In other words, this method enables direct adjustment of the dimension of the insulative blocking member in the direction of thickness of the tank wall during integration of the thermal insulation barrier onto the support structure. This enables, on the one hand, simplified production of the insulative blocking members by allowing an increase in the dimensional tolerances thereof and, on the other hand, limitation of the amplitude of the differences of level liable to be formed in the internal support surface of the sealing membrane.

In accordance with other advantageous embodiments, a method of the above kind may have one or more of the following features.

In accordance with one embodiment, the insulative blocking member is made of polymer foam having a density between 20 and 60 kg/m³ inclusive. A foam of this kind can therefore be easily and irreversibly deformed by hand without using dedicated tools.

In accordance with one embodiment, the insulative blocking member is made of polyurethane foam.

In accordance with another embodiment, the insulative blocking member is made of expanded polystyrene foam.

In accordance with one embodiment, one of the anchor devices is housed in the opening and said anchor device includes the bearing member against which the insulative blocking member is pushed.

In accordance with one embodiment, said anchor device housed in said opening includes a stud fixed directly or indirectly to the support structure, and during the anchoring of the plurality of insulative panels a retaining member is mounted on the stud in such a manner that it cooperates with a retaining zone of at least one of

the insulative panels so as to retain said insulative panel on the support structure, said stud forming the bearing member against which the insulative blocking member is pushed so that said stud is embedded in said insulative blocking member when the insulative blocking member is pushed in the direction of the support structure.

5 In accordance with one embodiment, when the insulative blocking member is pushed in the direction of the support structure, the stud is embedded in the mass of the insulative blocking member to a distance between 5 and 30 mm inclusive, for example between 8 and 15 mm inclusive.

10 In accordance with one embodiment, one of the anchor devices is housed in the opening and the insulative blocking member has an external end into which opens a housing; said anchor device being at least partly housed in said housing when the internal end of the insulative blocking member reaches its predetermined position.

15 In accordance with one embodiment, during the anchoring of the plurality of insulative panels, there are mounted on a stud that is fixed directly or indirectly to the support structure:

- a retaining member;
- a nut that retains the retaining member on the support structure; and
- at least one elastic washer that is engaged on the stud, between the nut and the retaining member, in such a manner as to produce an elastic force pressing the

20 retaining member against a retaining zone of at least one of the insulative panels so as to retain said insulative panel on the support structure, the nut and at least one elastic washer being housed in the opening opening at the level of the external end of the insulative blocking member when the internal end of the insulative blocking member reaches its predetermined position.

25 In accordance with one embodiment, the opening is bordered on the internal surface side by an adjacent border surface and, in the predetermined position of the internal end of the insulative blocking member, said internal end is positioned less than 1 mm above and less than 3 mm below said adjacent border surface.

30 In the predetermined position of the internal end of the insulative blocking member, said internal end of the insulative blocking member is preferably flush with the level of the adjacent border surface or is disposed at least 2 mm below.

In accordance with one embodiment, the adjacent border surface extends in the plane of the internal surface of the plurality of insulative panels or forms the bottom of a recess in which a closing plate is disposed after positioning the insulative blocking member in the predetermined position.

- 5 In accordance with one embodiment, the insulative blocking member is irreversibly compressed in a thickness direction orthogonal to the support structure where it bears against the bearing member when the insulative blocking member is pushed in the direction of the support structure.

- In accordance with one embodiment, the insulative blocking member has a
10 larger section than the opening and is a tight fit in said opening. In accordance with a variant embodiment, the insulative blocking member has a periphery that is torn during insertion of the insulative blocking member into the opening.

- In accordance with another embodiment, the invention also concerns a thermal insulation barrier for a wall of a fluid-tight and thermally insulative tank
15 integrated into a support structure, including:
- a plurality of insulative panels anchored directly or indirectly to the support structure by means of anchor devices; said plurality of insulative panels defining an internal support surface of a sealing membrane and including at least one opening opening at the level of said internal surface; and
 - 20 - a polymer foam insulative blocking member that is inserted in said opening in such a manner as to ensure continuity of thermal insulation; said insulative blocking member bearing in the direction of the support structure against a bearing member housed in said opening and featuring irreversible damage to the insulative blocking member where it bears against the bearing member, said irreversible damage having
25 been produced by pushing the insulative blocking member in the direction of the support structure until it reaches a predetermined position.

 In accordance with one embodiment, the invention also concerns a fluid-tight and thermally insulative tank including an aforementioned thermal insulation barrier and a sealing membrane resting against said thermal insulation barrier.

- 30 A tank in accordance with one of the aforementioned embodiments 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 an ethane or methane tanker ship, a floating storage and regassification unit (FSRU), a floating production storage and offloading (FPSO) unit, etc. In the case of a floating structure, the tank may be intended to receive liquefied natural gas serving as fuel for the propulsion of the
5 floating structure.

In accordance with one embodiment, a ship for the transportation of a fluid includes a hull, such as a double hull, and one of the aforementioned tanks disposed in the hull.

In accordance with one embodiment, the invention also provides a method
10 for loading or offloading a ship of the above kind, in which a fluid is fed through insulated pipes from or to a floating or terrestrial storage installation to or from the tank of the ship.

In accordance with one embodiment, the invention also provides a fluid transfer system, the system including the aforementioned ship, insulated pipes
15 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 fluid through the insulated pipes from or to the floating or terrestrial storage installation to or from the tank of the ship.

Brief description of the figures

20 The invention will be better understood and other aims, details, features and advantages thereof will become more clearly apparent in the course of the following description of a plurality of particular embodiments of the invention given by way of nonlimiting illustration only and with reference to the appended drawings.

- **Figure 1** is a cutaway perspective view of a tank wall in accordance
25 with a first embodiment.

- **Figure 2** is a view in section showing an anchor device enabling fixing of the primary insulative panels of the primary thermal insulation barrier to the secondary thermal insulation barrier that is housed in an opening formed between two primary insulative panels and an insulative blocking member inserted in said opening.

- **Figure 3** is a view in section of the insulative blocking member from figure 2.

- **Figure 4** is a view from above of the primary insulative panels at the level of an opening formed between two primary insulative panels when the insulative blocking member is housed in said opening and a closing plate covers said opening.

- **Figure 5** is a view in section showing an anchor device that is housed in an opening formed in four corner zones of four adjacent primary insulative panels.

- **Figure 6** is a schematic view showing an anchor device housed in an opening of the primary thermal insulation barrier and an insulative blocking member in accordance with one variant embodiment before its insertion into said opening.

- **Figure 7** is a schematic view similar to that of figure 6 during insertion of the insulative blocking member into the opening.

- **Figure 8** is a schematic view showing an anchor device housed in an opening of the primary thermal insulation barrier and an insulative blocking member in accordance with another variant embodiment during its insertion into the opening.

- **Figure 9** is cutaway perspective view of a tank wall in accordance with a second embodiment.

- **Figure 10** is a perspective view of an insulative blocking member of the primary thermal insulation barrier of the tank wall from figure 9.

- **Figure 11** is a perspective view of an insulative blocking member of the secondary thermal insulation barrier of the tank wall from figure 9.

- **Figure 12** is a view in section showing in detail an anchor device of the tank wall from figure 9.

- **Figure 13** is a cutaway schematic representation of a methane tanker ship tank including walls as shown in figure 1 and a terminal for loading/offloading that tank.

Detailed description of embodiments

By convention, the terms "external" and "internal" are used to define the position of one element relative to one another with reference to the interior and to the exterior of the tank.

In figure 1 there has been represented the multilayer structure of a wall 1 of a fluid-tight and thermally insulative tank for storing a fluid such as liquefied natural gas (LNG). Each wall 1 of the tank includes in succession, in the direction of the thickness, from the exterior toward the interior of the tank, a secondary thermal insulation barrier 2 retained on the support structure 3, a secondary sealing membrane 4 resting against the secondary thermal insulation barrier 2, a primary thermal insulation barrier 5 resting against the secondary sealing membrane 4, and a primary sealing membrane 6 intended to be in contact with the liquefied natural gas contained in the tank.

The support structure 3 may in particular be formed by the hull or the double hull of a ship. The support structure 3 includes a plurality of walls defining the general shape of the tank, usually a polyhedral shape.

The secondary thermal insulation barrier 2 includes a plurality of secondary insulative panels 7 anchored to the support structure 3 by means of beads of resin, not shown, and/or studs, not shown, welded to the support structure 3. Each of the secondary insulative panels 7 includes an insulative polymer foam layer sandwiched between a rigid internal plate and a rigid external plate. The internal and external plates are for example plywood sheets stuck to said insulative polymer foam layer. The insulative polymer foam can in particular be a polyurethane-based foam.

The secondary sealing membrane 4 includes a plurality of corrugated metal plates 10. Adjacent corrugated metal plates 10 are welded together with an overlap. Moreover, the corrugated metal plates 10 are welded to small metal plates 14 that are fixed to the internal plate of the secondary insulative panels 7. The corrugated metal plates 10 include along their longitudinal edges and at their four corners cut-outs enabling the passage of studs 15 that are fixed to the internal plates of the secondary insulative panels 7 and that are intended to fix the primary thermal insulation barrier 5 to the secondary thermal insulation barrier 2.

The primary thermal insulation barrier 5 includes a plurality of primary insulative panels 16 of substantially rectangular parallelepiped shape. Each primary insulative panel 16 includes a layer 17 of polymer foam sandwiched between two rigid plates, namely an internal plate 18 and an external plate 19. The internal plate 18 and
 5 the external plate 19 are for example sheets of plywood. The polymer foam of the layer 17 is for example polyurethane foam, optionally reinforced by fibers, such as glass fibers.

The internal plate 18 of each primary insulative panel 16 is equipped with small metal plates 20, 21 for anchoring the corrugated metal plates 22 of the primary
 10 sealing membrane 6. The small metal plates 20, 21 are fixed in recesses formed in the internal plate 18 of the primary insulative panel 16 and fixed to the latter by screws, rivets or staples for example.

The primary sealing membrane 6 is obtained by assembling a plurality of corrugated metal plates 22. Each corrugated metal plate 22 includes between the
 15 corrugations a plurality of plane surfaces 25 pressed against the internal plates 18 of the primary insulative panels 16. In other words, the internal plates 18 of the primary insulative panels 16 form an internal support surface of the primary sealing membrane 6.

The corrugated metal plates 22 of the primary sealing membrane 6 are
 20 disposed in an offset manner relative to the primary insulative panels 16 so that each of said corrugated metal plates 22 extends conjointly over four adjacent primary insulative panels 16. The corrugated metal plates 22 are welded together with an overlap and are also welded along their edges to the small metal plates 20, 21 that are fixed to the primary insulative panels 16.

Each primary insulative panel 16 includes one or more cut-outs 35 along
 25 each of its two longitudinal edges and a cut-out 36 at each of its corners. Each cut-out 35, 36 passes through the internal plate 18 and extends over all the thickness of the layer 17 of polymer foam. At the level of each of the cut-outs 35, 36 the external plate 19 projects relative to the layer 17 of polymer foam and to the internal plate 18
 30 in such a manner as to form a retaining zone 37 cooperating with an anchor device 38. Each cut-out 35 formed in the edge of one of the primary insulative panels 16 is

disposed facing a cut-out 35 formed in the facing edge of an adjacent primary insulative panel 16. The cut-outs 35 of two adjacent primary insulative panels 16 therefore form two by two an opening 43 in which is housed an anchor device 38. A single anchor device 38 is therefore able to cooperate with two retaining zones 37
 5 respectively belonging to the one and to the other of the two adjacent primary insulative panels 16. Moreover, each cut-out 36 formed at one of the corners of the primary insulative panel 16 opens facing the cut-outs 36 formed at the adjacent corners of the three adjacent primary insulative panels 16. The four cut-outs 36 therefore together form a cruciform opening 39. A single anchor device 38 is then able
 10 to cooperate with the four contact surfaces 37 of the four adjacent primary insulative panels 16.

Referring to figure 2, there is seen an opening 43 formed at the level of cut-outs 35 formed in the edge of two adjacent primary insulative panels 16 together with an anchor device 38 and an insulative blocking member 44 housed in said opening
 15 43.

The anchor device 38 includes a stud 15 that is fixed to the internal plate of the secondary insulative panels 7. The anchor device 38 further includes a retaining member 40 that is fixed to said stud 15. The retaining member 40 comes to bear against the retaining zone 37 of the primary insulative panels 16, that is to say against
 20 the zone of the external plate 19 projecting relative to the internal plate 18 and to the layer 17 of polymer foam. Each retaining zone 37 is therefore sandwiched between the retaining member 40 and the secondary sealing membrane 4.

Here the retaining member 40 is an annular small metal plate that includes a bore fitted over the stud 15. A nut 41 cooperates with a thread of the stud 15 in such
 25 a manner as to fix the retaining member 40 to the stud 15. Moreover, in the embodiment shown, one or more elastic washers, such as Belleville washers 42, is or are fitted over the stud 15, between the nut 41 and the retaining member 40, which enables elastic anchoring of the primary insulative panels 16 to the secondary insulative panels 7.

30 When the anchor device 38 has been put into place, the insulative blocking member 44 is put into place in the opening 43 in order to ensure continuity of thermal insulation.

Moreover, as represented in figures 2 and 4, the internal plates 18 of the primary insulative panels 16 feature a recess 45 the bottom 46 of which borders the opening 43. The recess 45 is intended to receive a closing plate 47 after the insulative blocking member 44 is positioned in the opening 43. The closing plate 47 has an
 5 internal surface that is flush with the internal surface of the primary insulative panels 16 in such a manner as to ensure flatness of the support surface of the primary sealing membrane 6.

In another embodiment, not shown, the primary thermal insulation barrier 5 does not have the aforementioned recesses 45 and closing plates 47. Also, in this
 10 case, it is the internal end 48 of the insulative blocking member 44 that is intended to be flush with the internal surface of the primary insulative panels 16 in such a manner as to ensure flatness of the support surface of the primary sealing membrane 6.

The insulative blocking member 44, represented in figures 2 and 3, is made of polymer foam. By way of example, the insulative blocking member 44 may in
 15 particular be made of a polyurethane foam having a density between 20 and 60 kg/m³ inclusive and advantageously between 30 and 50 kg/m³ inclusive. An insulative blocking member 44 having such characteristics is particularly advantageous in that it can be deformed irreversibly without the stress required to obtain irreversible deformation being too great. Alternatively, the insulative blocking member 44 may
 20 equally be made of expanded polystyrene having a density between 20 and 60 kg/m³ inclusive and advantageously between 30 and 50 kg/m³ inclusive.

The insulative blocking member 44 has a section that is matched to that of the opening 43. Also, the insulative blocking member 44 has a plane internal end 48. The insulative blocking member 44 also has an external end 49 into which opens a
 25 housing 50 intended to receive the anchor device 38 at least partly. More particularly, in the embodiment represented, the housing 50 has two portions 51, 52 with different diameters. The first portion 51 has the larger diameter and opens at the level of the external end 49 of the insulative blocking member 44. This first portion 51 is intended to house the elastic washers 42 and the nut 41. The second portion 52 has a smaller
 30 diameter and extends from the first portion 51 in the direction of the internal end 48 of the insulative blocking member 44. The second portion 52 is intended to house the end of the stud 15. Thus the geometry of the housing 50 is matched to the geometry

of the anchor device 38 in order to optimize the presence of insulative material in the opening 43.

As represented in figure 3, in the initial state, before insertion of the insulative blocking member 44 in the opening 43, the insulative blocking member 45 has a dimension X_0 in the direction of thickness of the tank wall 1 between the bottom 53 of the housing 50 and the internal end 48 of the insulative blocking member 44. The dimension X_0 is greater than the dimension Y in the direction of thickness of the tank wall 1 between the end of the stud 15 and the plane of an adjacent border surface that borders the opening 43.

In the embodiment represented, the adjacent border surface corresponds to the bottom 46 of the recess 45. In other words, here the dimension Y corresponds to the distance between the end of the stud 15 and the bottom 46 of the recess 45. In other variant embodiments, when the primary thermal insulation barrier 5 has no closing plates 47 and the internal end 48 of the insulative blocking member 44 is intended to be flush with the internal surface of the primary insulative panels 16, then the adjacent border surface corresponds to the internal surface of the primary insulative panels 16. In other words, here the dimension Y corresponds to the distance between the end of the stud 15 and the internal surface of the primary insulative panels 16.

Advantageously, $X_0 = Y + \Delta$ with Δ between 5 and 30 mm inclusive and preferably between 8 and 15 mm inclusive.

The mounting of the insulative blocking member 44 in the opening 43 is described in detail below.

Firstly, the insulative blocking member 44 is inserted in the opening 43 and then pushed into the latter in the direction of the support structure 3 until said insulative blocking member 44, and more particularly the bottom 53 of the housing 50, comes to bear against a bearing member, here the end of the stud 15. The insulative blocking member 44 is then pushed against the stud 15 so that the stud 15 penetrates into the polymer foam of the insulative blocking member 44 and damages it irreversibly. In other words, in the zone of the insulative blocking member 44 in contact with the stud 15 said insulative blocking member 44 is deformed beyond its

elastic limit and suffers plastic deformation and/or ruptures. Accordingly, the dimension X_1 of the insulative blocking member 44 in the direction of thickness of the tank wall 1 between the bearing zone of the insulative blocking member 44 against the stud 15 and the internal end of the insulative blocking member 44 is less than the dimension X_0 . In accordance with one embodiment, the stud 15 is pressed into the mass of the insulative blocking member 44 to a distance between 5 and 30 mm inclusive, for example between 8 and 15 mm inclusive.

The predetermined position of the insulative blocking member 44 in the opening 43 corresponds to a position in which the internal end 48 of the insulative blocking member 44 is positioned relative to the adjacent border surface, here the bottom 46 of the recess 45, less than 1 mm above and less than 3 mm below said adjacent border surface. Said internal end 48 of the insulative blocking member 44 is preferably flush with or is less than 2 mm below said adjacent border surface. In other words, in the predetermined position of the insulative blocking member the dimension X_1 may be defined as follows:

$$Y \geq X_1 \geq Y - \varepsilon \text{ with } \varepsilon = 2 \text{ mm}$$

A method of the above kind therefore makes it possible to reduce the amplitude of the differences of level liable to be formed in the internal support surface of the primary sealing membrane 6.

Figure 5 shows an anchor device 54 and the opening 55 formed at the corners of four adjacent primary insulative panels 16 and in which said anchor device 54 is housed. In this embodiment, the retaining member 56 has an X shape and includes four legs each of which is housed inside a cut-out 36 formed in a respective one of the primary insulative panels 16. Five insulative blocking members 57, 58, 59, 60 ensure continuity of thermal insulation. Four insulative blocking members 57, 58, 59, two of which are partly shown and one of which is entirely shown in figure 5, are each housed in a cut-out 36 of a respective primary insulative panel 16 while the fifth insulative blocking member 60 is disposed at the center of the opening 55 between the other four insulative blocking members 57, 58, 59 and therefore serves as a wedge enabling the other insulative blocking members 57, 58, 59 to be retained in position.

By way of example, the insulative blocking members 57, 58, 59, 60 are produced in a material identical to that of the insulative blocking member 44 described with reference to figures 2 to 4.

The mounting of the insulative blocking members 57, 58, 59, 60 in the opening 55 is described in detail below. Firstly, the four insulative blocking members 57, 58, 59 are positioned in the respective cut-out 36 of one of the primary insulative panels 16. In accordance with a variant embodiment, the four insulative blocking members 57, 58, 59 have dimensions in the direction of thickness of the tank wall 1 that are matched to that of the opening so that it is not necessary to damage them irreversibly in order for their internal end 61 to be flush with the internal surface of the adjacent primary insulative panels 16.

In accordance with another variant embodiment, the four insulative blocking members 57, 58, 59 have a dimension in the direction of thickness of the tank that is greater than the dimension in the direction of thickness of the tank wall 1 between the bearing surface of the retaining member 56 intended to receive the external end of the insulative blocking members and the plane of the internal surface of the primary insulative panels 16. Also, in this embodiment, to mount said insulative blocking members 57, 58, 59 in the opening 55 each insulative blocking member 57, 58, 59 is first inserted into the opening 55 in the direction of the support structure 3 until said insulative blocking member 57, 58, 59 comes to bear against a bearing member, here one of the lugs of the retaining member 56. Each insulative blocking member 57, 58, 59 is then pushed against the retaining member 56 so that said insulative blocking member 57, 58, 59 is compressed in an irreversible manner. The dimension of each of the insulative blocking members 57, 58, 59 therefore decreases in an irreversible manner until the internal end 61 of each insulative blocking member 57, 58, 59 reaches a predetermined position in which the internal end 61 of each insulative blocking member 57, 58, 59 is substantially flush with the internal surface of the primary insulative panels 16.

The central insulative blocking member 60 is inserted into the opening 55 between the other four insulative blocking members 57, 58, 59 until it comes to bear against the end of stud 15. As in the embodiment from figures 2 to 4, the insulative blocking member 60 is then pushed against the stud 15 so that the stud 15 penetrates

into the polymer foam of said insulative blocking member 60 and damages it in an irreversible manner. The insulative blocking member 60 is deformed until the internal end 61 of said insulative blocking member 60 reaches a predetermined position.

Each of the predetermined positions of the insulative blocking members 57, 58, 59, 60 corresponds to a position in which the internal end 61 of the respective insulative blocking member 57, 58, 59, 60 is positioned less than 1 mm above the adjacent border surface, here the internal surface of the primary insulative panels 16, and less than 3 mm and preferably less than 2 mm below same.

Figures 6 and 7 represent in a schematic manner an insulative blocking member 62 in accordance with another embodiment. This embodiment differs from the embodiment described hereinabove with reference to figures 1 to 4 in that, in the initial state, the insulative blocking member 62 has a section with dimensions greater than those of the section of the opening 43. As represented in figure 7, when the insulative blocking member 62 is forcibly inserted into the opening 43, the periphery 63 of the insulative blocking member 62 is at least partly torn away from the part of the insulative blocking member 62 that is inserted into the opening 43. An arrangement of this kind makes it possible to avoid clearances between the insulating blocking member 62 and the walls of the opening 43 liable to degrade the thermal insulation.

By way of example, if the insulative blocking member 62 and the opening 43 have a circular section, the insulative blocking member 62 has a diameter from 2 to 10 mm and advantageously from 5 to 7 mm greater than that of the opening 43. If the insulative blocking member 62 has some other shape, for example a parallelepiped shape, at least one of the dimensions of its section is greater than the corresponding dimension of the section of the opening 43.

In accordance with a variant embodiment, the periphery 63 of the insulative blocking member 62 may be precut in such a manner as to facilitate its tearing upon the insertion of the insulative blocking member 62 into the opening 43.

As in the previous embodiments, the insulative blocking member 43 is deformed against the stud 15 of the anchor device until the internal end of said insulative blocking member 62 reaches a predetermined position.

Figure 8 represents in a schematic manner an insulative blocking member 64 in accordance with another variant embodiment. As in the embodiment from figures 6 and 7 above, the insulative blocking member 64 has a section with dimensions greater than those of the section of the opening 43. However, in this embodiment the periphery of the insulative blocking member 64 is not torn during insertion of the insulative blocking member 64 into the opening 43 and the insulative blocking member 64 is mounted with a tight fit in the opening 43.

In figure 9 there has been represented the multilayer structure of a wall 1 of a tank in accordance with another embodiment.

10 The secondary thermal insulation barrier 2 includes a plurality of juxtaposed secondary insulative panels 65. Each secondary insulative panel 65 consists of a parallelepipedal box, for example made of plywood, that includes a bottom plate, a cover plate and walls that extend in the direction of thickness of the wall 1 between the bottom plate and the cover plate and define compartment filled with an insulative filling such as perlite for example. The bottom plates project laterally on two opposite sides of the box so that in each corner of the box battens 68 are fixed to this projecting part.

The primary thermal insulation barrier 5 also includes a plurality of juxtaposed primary insulative panels 66. The primary insulative panels 66 have a structure substantially similar to that of the secondary insulative panels 65. The primary insulative panels 66 have dimensions identical to those of the secondary insulative panels 65 except for their thickness in the direction of thickness of the tank, which can be less than that of the secondary insulative panels 65. The bottom plates of the primary insulative panels project laterally on two opposite sides of the box so that in each corner of the box battens 67 are fixed to this projecting part.

The secondary sealing membrane 4 includes a continuous layer of metal strakes with raised edges. The raised edges of the strakes are welded to parallel weld supports that are fixed into grooves formed on the cover plates of the secondary insulative panels 65. The primary sealing membrane 6 has a similar structure and includes a continuous layer of metal strakes with raised edges. The raised edges of

the strakes are welded to parallel weld supports that are fixed in grooves formed on the cover plates of the primary insulative panels 66.

The metal strakes are for example made of Invar®: that is to say an alloy of iron and nickel the coefficient of expansion of which is typically between 1.2×10^{-6} and $2 \times 10^{-6} \text{ K}^{-1}$ inclusive.

Figure 12 shows an anchor device 69 for anchoring the primary insulative panels 65 and the secondary insulative panels 66. The anchor device 69 includes a bush 82 that is fixed to the support structure 3 at the level of four corners of four adjacent secondary insulative panels 66. Each bush 82 houses a nut 83 into which comes to be screwed the lower end of a stud 84. The anchor device 69 further includes a retaining member 85 fixed to the stud 84. The retaining member 85 comes to bear against the strakes 68 in such a manner as to retain the secondary insulative panels 65 against the support structure 3. A nut 86 cooperates with a thread of the stud 84 in such a manner as to fix the retaining member 85 onto the stud 84. Moreover, the anchor device 69 includes elastic washers 87 that are fitted over the stud 84 between the nut 86 and the retaining member 85, which enables elastic anchoring of the secondary insulative panels 65 onto the support structure 3. The anchor device further includes a small plate 88 that is fixed to the retaining member 85. A spacing element 89, for example made of wood, is disposed between the retaining member 85 and the small plate 88. The spacing member 89 has a thickness such that the small plate 88 is flush with the cover plate of the secondary insulative panels 65. The spacing element 89 includes a central housing intended to receive the upper end of the stud 84, the nut 86 and the elastic washers 87. The spacing element 89 also includes bores intended to have passed through them bolts 90 for securing the small plate 88 to the retaining member 85.

Moreover, the small plate 88 includes a central threaded bore that receives the threaded base of a stud 91. The stud 91 passes through a bore formed through a strake of the secondary sealing membrane 4. The stud 91 features a flange that is welded at its periphery, around the bore, to ensure the sealing of the secondary sealing membrane 4. The stud 91 has a threaded upper end onto which a nut 92 is screwed to clamp a retaining member 93 against the strakes 67 of the primary insulative panels 66. The anchor device 69 also includes at least one elastic washer

94 that is threaded over the stud 91 between the nut 92 and the retaining member 93 and which therefore provides elastic anchoring of the primary insulative panels 66 relative to the small plate 88.

Returning to figure 9, it is seen that the primary thermal insulation barrier 5 and the secondary thermal insulation barrier 2 of a tank wall 1 having this kind of multilayer structure are also provided with insulative blocking members 95, 96.

An insulative blocking member 95 of the secondary thermal insulation barrier 2 is shown in detail in figure 11. Each insulative blocking member 95 has a cruciform shape and includes an internal bore through which the stud 84 of the anchor device 69 is inserted. The insulative blocking member 95 is inserted in an opening formed at the level of the corners of four secondary insulative panels 65 in such a manner that each of the four branches of said insulative blocking member 95 is inserted in an interstice between two adjacent secondary insulative panels 65.

In accordance with one embodiment, the insulative blocking member 95 is made of a material identical to that of the insulative blocking member 44 described with reference to figures 2 to 4. The insulative blocking member 95 is mounted in the opening as follows. The insulative blocking member 95 is positioned so that the stud 91 faces the stud 84 and is then inserted in the opening in the direction of the support structure 3 until it comes to bear against a bearing member, here the bush 82. The insulative blocking member 95 is then pushed against the bush 82 so that the insulative blocking member 95 is deformed irreversibly until said insulative blocking member 95 reaches a predetermined position. In said predetermined position the internal end of the insulative blocking member 95 is substantially flush with the surface of the strakes 68 against which the retaining member 85 comes to bear.

An insulative blocking member 96 of the primary thermal insulation barrier 5 is shown in detail in figure 10. Each insulative blocking member 96 is inserted in an opening formed at the corners of four adjacent primary insulative panels.

In accordance with one embodiment the insulative blocking member 96 is made from a material identical to that of the insulative blocking member 44 described with reference to figures 2 to 4. The insulative blocking member 96 is mounted in the respective opening as follows. The insulative blocking member 96 is positioned in the

housing and pushed in the direction of the support structure 3 until it comes to bear against a bearing member, here the stud 91. The insulative blocking member 96 is then pushed against the stud 91 so that the insulative blocking member 96 is deformed irreversibly until said insulative blocking member 96 reaches a
 5 predetermined position. In said predetermined position the internal end of the insulative blocking member 96 is substantially flush with the internal surface of the primary insulative panels 66.

Referring to figure 13, a cutaway of a methane tanker ship 70 shows a fluid-tight and insulated tank 71 of prismatic general shape mounted in the double hull 72
 10 of the ship. The wall of the tank 71 includes a primary sealing membrane intended to be in contact with the LNG contained in the tank, a secondary sealing membrane arranged between the primary sealing membrane and the double hull 72 of the ship, and two thermally insulative barriers respectively arranged between the primary sealing membrane and the secondary sealing membrane and between the secondary
 15 sealing membrane and the double hull 72.

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.

Figure 13 shows an example of a maritime terminal including a loading and
 20 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.
 25 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 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
 30 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.

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.

Although the invention has been described in connection with a plurality of
5 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 defined by the claims.

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

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

CLAIMS

1. A method for producing a thermal insulation barrier (2, 5) for a wall (1) of a fluid-tight and thermally insulative tank integrated into a support structure (3), said method including the following steps:
 - 5 - anchoring a plurality of insulative panels (16, 65, 66) directly or indirectly to the support structure (3) by means of anchor devices (38, 54, 69); said plurality of insulative panels (16, 65, 66) defining an internal support surface of a sealing membrane (4, 6) and including at least one opening (43, 55) opening at the level of said internal surface;
 - 10 - procuring a polymer foam insulative blocking member (44, 57, 58, 59, 60, 95, 96) intended to ensure continuity of thermal insulation at the level of said opening (43, 55), said insulative blocking member (44, 57, 58, 59, 60, 95, 96) having an internal end (48, 61);
 - 15 - inserting said insulative blocking member (44, 57, 58, 59, 60, 95, 96) in said opening (43, 55) and pushing it in the direction of the support structure (3) until the insulative blocking member comes to bear in the direction of the support structure (3) against a bearing member (15, 82, 91) housed in said opening (43, 55);
 - 20 - pushing the insulative blocking member (44, 57, 58, 59, 60) in the direction of the support structure (3) against the bearing member (15, 82, 91) so as to damage irreversibly the insulative blocking member (44, 57, 58, 59, 60, 95, 96) where it bears against the bearing member (15, 82, 91) and so as to reduce irreversibly the dimension of the insulative blocking member (44, 57, 58, 59, 60, 95, 96) between the internal end (48, 61) of the insulative blocking member (44, 57, 58, 59, 60, 95, 96) and where the insulative blocking member (44, 57, 58, 59, 60, 95, 96) bears against the bearing member (15, 82, 91) until the internal end (48, 61) of the insulative blocking member (44, 57, 58, 59, 60, 95, 96) reaches a predetermined position in said opening (43, 55).

2. The method as claimed in claim 1, in which the insulative blocking member (44, 57, 58, 59, 60, 95, 96) is made of polymer foam having a density between 20 and 60 kg/m³.
3. The method as claimed in claim 1 or 2, in which the insulative blocking member (44, 57, 58, 59, 60, 95, 96) is made of polyurethane foam.
4. The method as claimed in any one of claims 1 to 3, in which one of the anchor devices (38, 54, 69) is housed inside the opening (43, 55) and in which said anchor device (38, 54, 69) includes the bearing member against which the insulative blocking member (44, 57, 58, 59, 60, 95, 96) is pushed.
5. The method as claimed in claim 4, in which said anchor device (38, 54, 69) housed inside said opening includes a stud (15, 91) fixed directly or indirectly to the support structure (3), in which during the anchoring of the plurality of insulative panels (16, 65, 66) a retaining member (40, 56) is mounted on the stud in such a manner that it cooperates with a retaining zone (37) of at least one of the insulative panels (16, 65, 66) so as to retain said insulative panel (16, 65, 66) on the support structure (3), and in which said stud (15, 91) forms a bearing member against which the insulative blocking member (44, 60, 96) is pushed so that said stud (15, 91) is embedded in said insulative blocking member (44, 60, 96) when the insulative blocking member (44, 60, 96) is pushed in the direction of the support structure (3).
6. The method as claimed in claim 5, in which when the insulative blocking member (44, 60, 96) is pushed in the direction of the support structure (3), the stud (15, 91) is embedded in the mass of the insulative blocking member (44, 60, 96) to a distance between 5 and 30 mm inclusive, for example between 8 and 15 mm inclusive.
7. The method as claimed in any one of claims 1 to 6, in which one of the anchor devices (38) is housed inside the opening (43) and in which the insulative blocking member (44) has an external end (49) into which opens a housing (50); said anchor device (38) being at least partly housed in said housing (50) when the internal end (48) of the insulative blocking member (44) reaches its predetermined position.
8. The method as claimed in any one of claims 1 to 7, in which the opening (43, 55) is bordered on the internal surface side by an adjacent border

surface (46) and in which, in the predetermined position of the internal end (48, 61) of the insulative blocking member (44, 57, 58, 59, 60, 95, 96), said internal end (48, 61) is positioned less than 1 mm above and less than 3 mm below said adjacent border surface (45).

- 5 9. The method as claimed in claim 8, in which the adjacent border surface extends in the plane of the internal surface of the plurality of insulative panels (16, 65, 66) or form the bottom (46) of a recess (45) in which a closing plate (43) is disposed after positioning the insulative blocking member (44) in the predetermined position.
- 10 10. The method as claimed in any one of claims 1 to 9, in which the insulative blocking member (44, 57, 58, 59, 60, 95, 96) is irreversibly compressed in a thickness direction orthogonal to the support structure (3) where it bears against the bearing member (15, 82, 91) when the insulative blocking member (44, 57, 58, 59, 60, 95, 96) is pushed in the direction of the support structure (3).
- 15 11. A thermal insulation barrier (2, 5) for a wall (1) of a fluid-tight and thermally insulative tank integrated into a support structure (3), including:
 - a plurality of insulative panels (16, 65, 66) anchored directly or indirectly to the support structure (3) by means of anchor devices (38, 54, 69); said plurality of insulative panels (16, 65, 66) defining an internal support surface of a sealing
 - 20 membrane (4, 6) and including at least one opening (43, 55) opening at the level of said internal surface; and
 - a polymer foam insulative blocking member (44, 57, 58, 59, 60, 95, 96) that is inserted in said opening (43, 55) in such a manner as to ensure continuity of thermal insulation; said insulative blocking member (44, 57, 58, 59, 60, 95, 96) bearing in the
 - 25 direction of the support structure (3) against a bearing member (15, 82, 91) housed in said opening (43, 55) and featuring irreversible damage to the insulative blocking member (44, 57, 58, 59, 60, 95, 96) where it bears against the bearing member (15, 82, 91), said irreversible damage having been produced by pushing the insulative blocking member (44, 57, 58, 59, 60, 95, 96) in the direction of the support structure
 - 30 (3) until it reaches a predetermined position.

12. A fluid-tight and thermally insulative tank including a thermal insulation barrier (2, 5) as claimed in claim 11 and a sealing membrane (4, 6) resting against said thermal insulation barrier (2, 5).

13. A ship (70) for the transportation of a fluid, the ship including a
5 double hull (72) and a tank (71) as claimed in claim 12.

14. A system for transfer of a fluid, the system including a ship (70) as claimed in claim 13, 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 fluid through the insulated pipes from or to
10 the floating or terrestrial storage installation to or from the tank of the ship.

15. A method for loading or offloading a ship (70) as claimed in claim 13, in which a fluid is fed through insulated pipes (73, 79, 76, 81) from or to a floating or terrestrial storage installation (77) to or from the tank (71) of the ship.