

Description

Title of the invention: Wall for a sealed and thermally insulating tank

Technical field

5 [0001] The invention relates to the field of walls for sealed and thermally insulating tanks. In particular, the invention relates to the field of walls for sealed and thermally insulating tanks for storing and/or transporting a liquefied gas, such as liquid hydrogen, which is at approximately -253°C at atmospheric pressure.

Technological background

10 [0002] Sealed and thermally insulating tanks for storing a liquefied gas are known in the current state of the art.

[0003] Such a tank generally comprises a plurality of walls each of a multilayer structure comprising at least a thermally insulating barrier held against a load-bearing structure and a sealing membrane resting against a thermally insulating barrier and intended to be in contact with the liquefied gas contained in the tank.

15 [0004] One of the major difficulties is that in a tank of the above-mentioned type, the sealing membrane of the wall is not stressed uniformly because the membrane deforms notably under the effect of the thermal and mechanical stresses generated by the liquefied gas stored in the tank. Such heterogeneous stress-loading can quickly damage the tank.

20 Summary of the invention

[0005] In order to allow a better distribution of the stresses in the sealing membrane, the inventors have had the idea of a thermally insulating barrier containing discrete support structures each of which supports one area of the sealing membrane and to which the sealing membrane is welded. The discrete support structures comprise for
25 example posts made from a composite material which stand up in the thickness direction of the wall in order to support the sealing membrane. Each of the posts is fitted together socket-wise with, and adhesively bonded to, stainless steel sleeves at the opposite ends of the post. The sleeves extend beyond the opening of the post, thus forming a metal extension outside the post, with which extension the post is in
30 contact.

- [0006] Such an arrangement has numerous disadvantages. Combining a post made of composite material with a sleeve made of stainless steel involves a significant risk of the post and the sleeve becoming damaged during the course of significant temperature variations, for example during the loading and the offloading of the liquefied gas into and from the tank. Specifically, the coefficients of thermal expansion of the composite material and of the stainless steel sleeve are very different, which leads to undesired movements of the post with respect to the sleeve. As a result, thick adhesive joints, which is to say joints greater than 2 mm thick, are applied between the post and the sleeve in order to compensate for these differences in thermodynamic behaviour.
- [0007] Nevertheless, such a solution is unsatisfactory because the thicker the adhesive joint the more difficult it is to precisely determine its ability to withstand the compressive and shear forces.
- [0008] There is therefore still a need to find an alternative in order to overcome the above-mentioned problems.
- [0009] One idea underlying the invention is therefore to solve the above-mentioned problems.
- [0010] Another idea underlying the invention is to propose a wall for a sealed and thermally insulating tank in which the mechanical stresses exerted on the sleeve are reduced, particularly at the join between the post and the sleeve.
- [0011] Another idea underlying the invention is to propose a wall for a sealed and thermally insulating tank that enables the securing of a metal plate on which the sealing membrane is secured to a post made of composite material.
- [0012] Another idea underlying the invention is to eliminate the areas of weakness at the join between the post and the sleeve.
- [0013] According to one embodiment, the invention provides a wall for a sealed and thermally insulating tank for storing a liquefied gas, the wall comprising, in a thickness direction of the wall, a thermally insulating barrier and a metal sealing membrane which rests against the thermally insulating barrier;
the thermally insulating barrier comprising at least one load-bearing element,
the load-bearing element comprising:
- a hollow post made of composite material which stands up in the thickness direction of the wall,

- a sleeve made of composite material pushed onto the hollow post and bonded against a longitudinal surface of the post; and
- an internal end-plate which is made of metal, fixed to the sleeve via a fixing device and to which the sealing membrane is welded, wherein the sleeve has an internal end which lies flush with an internal end of the post, and wherein the internal end-plate bears, directly or indirectly, partly against the internal end of the post and partly against the internal end of the sleeve.

- 5 [0014] By virtue of these features, the thermomechanical stresses exerted on the connection between the sleeve and the post are reduced.
- 10 [0015] Specifically, because the sleeve and the post are both made of composite material, the differential expansion of the one with respect to the other is lower than if the sleeve were made of stainless steel, thereby making it possible to limit the stresses in the layer of adhesive when the tank is cooled and therefore reduce the thickness of the layer of adhesive.
- 15 [0016] Furthermore, when compressive forces are applied to the internal plate in the thickness direction of the wall, part of these forces is reacted by the load-bearing post without passing via the sleeve and the layer of adhesive. The layer of adhesive used for fixing the sleeve to the post is subjected to little or no shear force. Thus, the risk of detachment of the sleeve is greatly reduced.
- 20 [0017] By convention, the terms “external” and “internal” are used to define the relative position of one element with respect to another, with reference to the outside and to the inside of a tank having such a wall. In particular, the internal end of the sleeve means that end of the sleeve that will be closest to the inside of a tank comprising such a wall, and the external end of the sleeve means that end of the sleeve that will be furthest from the inside of the tank. In a similar way to the sleeve, the internal end of the post means that end of the post that will be closest to the inside of a tank comprising such a wall, and the external end of the post means that end of the post that will be furthest from the inside of the tank.
- 25 [0018] According to embodiments, such a wall may comprise one or more of the following features.
- 30 [0019] According to one embodiment, the internal end-plate bears partly against the internal end of the post and partly against the internal end of the sleeve by means of a bearer plate which is interposed between the internal end-plate and the internal end of the

post, the bearer plate having an internal surface in contact with the internal end-plate and an external surface in contact with the internal end of the post and the internal end of the sleeve.

[0020] According to one embodiment, the sleeve has a coefficient of thermal expansion α_1 in a radial direction perpendicular to the thickness direction of the wall which coefficient is comprised within the interval $[0.75 \times \alpha_2; 1.25 \times \alpha_2]$, where α_2 is a coefficient of thermal expansion of the post in the radial direction. That means that the coefficient of thermal expansion of the sleeve, in the radial direction, falls within a range that extends from 25% below the coefficient of thermal expansion, in the radial direction, of the post to 25% above the coefficient of thermal expansion, in the radial direction, of the post.

[0021] By virtue of these features, the relative movement of the sleeve with respect to the post in response to the temperature variations is reduced. As a result, the thermomechanical stresses applied to the adhesive are also lessened.

[0022] According to one embodiment, the coefficient of thermal expansion α_1 in a radial direction perpendicular to the thickness direction of the wall of the sleeve is comprised within the interval $[0.85 \times \alpha_2; 1.15 \times \alpha_2]$.

[0023] According to a preferred embodiment, the coefficient of thermal expansion of the sleeve and of the post are identical, in the radial direction.

[0024] According to one embodiment, the bearer plate has a coefficient of thermal expansion α_3 in the radial direction which is comprised within the interval $[0.75 \times \alpha_1; 1.25 \times \alpha_1]$; and within the interval $[0.75 \times \alpha_2; 1.25 \times \alpha_2]$. In other words, the coefficient of thermal expansion α_1 of the sleeve, α_2 of the post, or α_3 of the bearer plate, in the radial direction, falls within a range of values that extends from 25% below to 25% above the coefficients of thermal expansion of the other elements.

[0025] By virtue of these features, the relative movements of the sleeve, of the post and of the bearer plate in response to the temperature variations are reduced. As a result, the thermomechanical stresses applied to the layer of adhesive are also lessened, thereby encouraging the sleeve to remain in its initial position.

[0026] According to one embodiment, the sleeve has a cylindrical overall shape and comprises a cylindrical cavity. As a preference, the overall shape of the sleeve is a cylinder of revolution. The sleeve may have different shapes in order to facilitate the

bonding of the sleeve against the longitudinal surface of the post and in order to reduce the thickness of the layer of adhesive needed for bonding the sleeve to the post.

[0027] According to one embodiment, the cylindrical cavity of the sleeve has the shape of a cylinder of circular or elliptical cross section.

5 [0028] According to one embodiment, the sleeve is formed of a plurality of distinct sections distributed about a longitudinal axis of the post, the plurality of distinct sections being fixed to the longitudinal surface of the post.

[0029] By virtue of these features, the sleeve is more adaptable and easier to install against the longitudinal surface of the post. Furthermore, such an arrangement makes it
10 possible to reduce the thickness of the layer of adhesive needed for fixing the sleeve to the post.

[0030] According to one embodiment, the sections of the plurality of sections have identical shapes to one another. According to one embodiment, the sections of the plurality of sections have different shapes from one another.

15 [0031] According to one embodiment, the sections of the plurality of sections each have an internal end that lies flush with the internal end of the post.

[0032] According to one embodiment, the plurality of distinct sections comprises a first section and a second section, the first section and the second section being diametrically opposed, one on each side of the longitudinal axis of the post. According to one
20 embodiment, the first section and the second section each have the shape of a half-pipe or of a lunula.

[0033] According to one embodiment, the plurality of distinct sections comprises a first section, a second section, and a third section. According to one preferred embodiment, the first, second and third sections each have the overall shape of a lunula.

25 [0034] According to one embodiment, each section of the plurality of sections is separated by a gap. Thus, dimensional imprecisions introduced into the sleeve during the manufacture of the sleeve do not prevent the sleeve from being installed inside the post provided that the dimensional imprecisions result in a dimensional difference that is less than the dimension of the gap.

30 [0035] According to one embodiment, the cylindrical cavity is large enough to allow the introduction of a tool that enables the plurality of distinct sections of the sleeve to be pressed radially outwards against the longitudinal surface of the post.

[0036] According to one embodiment, the sleeve is formed as a single piece.

[0037] According to one embodiment, the sleeve and the longitudinal surface of the post are bonded together using a layer of adhesive of a thickness, in a radial direction perpendicular to the thickness direction, that is less than 1 mm. According to one preferred embodiment, the layer of adhesive has a thickness greater than 0 mm and less than 0.5 mm, preferably a thickness less than 0.2 mm and more preferably still, a thickness less than 0.1 mm.

[0038] Thus, a lesser thickness of the layer of adhesive reduces the risk of undesirable inclusion of air between the surfaces. Furthermore, a thin thickness of adhesive will cure more rapidly, leading to faster manufacture of the load-bearing element.

[0039] According to one embodiment, the layer of adhesive situated between the sleeve and the longitudinal surface of the post is pressed using a pressing tool.

[0040] By virtue of these features, the pressed layer of adhesive exhibits higher resistance to shear stresses. Specifically, pressing makes it possible notably to increase the area of contact between the layer of adhesive and the post.

[0041] According to one embodiment, the diameter of the bearer plate is greater than or equal to the diameter of the post.

[0042] According to one embodiment, the bearer plate is an aluminium washer.

[0043] Aluminium is advantageous in that it has a greater compression strength than a composite material while having a coefficient of thermal expansion that is closer than the other metals to that of the composite material of the post, particularly when the composite material of the post is a unidirectional glass-epoxy composite.

[0044] According to one embodiment, the fixing device comprises an external plate positioned against an external end of the sleeve and a through-bolt connecting the internal end-plate to the external plate in such a way that the sleeve is clamped between the internal end-plate and the external plate. In other words, the fixing device fixes the internal end-plate to the external plate while tightly sandwiching the sleeve between the internal end-plate and the external plate.

[0045] By virtue of these features, the sleeve is held firmly in position between the external plate and the internal end-plate.

[0046] According to one embodiment, the external plate is an aluminium washer.

- [0047] According to one embodiment, the external plate has an outside diameter smaller than the inside diameter of the post.
- [0048] According to one embodiment, the sleeve is push-fitted inside the post.
- [0049] According to one embodiment, the sleeve is push-fitted onto the outside of the post.
- 5 [0050] According to one embodiment, the sleeve extends along a longitudinal direction of the tube, from the internal end of the post, over a distance comprised between 5 and 10 cm.
- [0051] According to one embodiment, the load-bearing element comprises a first sleeve push-fitted inside the post and a second sleeve push-fitted on the outside of the post.
- 10 [0052] According to one embodiment, the hollow post has an inside diameter comprised between 4 and 10 cm.
- [0053] According to one embodiment, the inside of the hollow post contains an insulating material. According to one embodiment, the insulating material is situated between the first sleeve and the second sleeve. According to one embodiment, the insulating material fills the interior space of the post extending between the first sleeve and the second sleeve. According to one embodiment, the insulating material is an insulating foam. According to one embodiment, the insulating foam has the shape of an elongate cylinder.
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- [0054] According to one embodiment, the fixing device comprises a threaded rod and an element having a female screw thread.
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- [0055] According to one embodiment, the fixing device comprises a screw-nut system.
- [0056] According to one embodiment, the fixing device comprises a threaded rod which passes, in the longitudinal thickness direction, through the internal end-plate, the sleeve and the external plate, the fixing device further comprising a first nut screwed on from a first end of the threaded rod and a second nut fixed onto a second end of the threaded rod so as to clamp the sleeve between the external plate and the internal end-plate.
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- [0057] According to one embodiment, the threaded rod of the fixing device also passes through the metal bearer plate, the sleeve being clamped between the external plate and the metal bearer plate.
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- [0058] According to one embodiment, the fixing device comprises a plurality of threaded rods, each threaded rod being fixed via its internal end to the internal end-plate and screwed via its external end into a tapped hole formed in the external plate.
- 5 [0059] By virtue of these features, it is possible to control the compression force applied to the sleeve. Specifically, the more the threaded rod is screwed into the tapped hole, the closer the external plate is moved towards the internal end-plate, with the effect of clamping the sleeve.
- 10 [0060] According to one embodiment, each threaded rod comprises at least one spring washer mounted on said threaded rod, the spring washer preferably being a Belleville washer.
- [0061] It is thus possible to control the compression force applied to the sleeve.
- [0062] According to one embodiment, the composite material of the post comprises fibres and a matrix, making it possible to achieve satisfactory compression strength for a limited conducting cross section.
- 15 [0063] According to one embodiment, the fibres are selected from glass fibres, carbon fibres, aramid fibres, flax fibres, basalt fibres and blends thereof.
- [0064] According to one embodiment, the matrix is selected from polyethylene, polypropylene, poly(ethylene terephthalate), polyamide, polyoxymethylene, polyetherimide, polyacrylate, polyaryl ether ketone, polyether ether ketone, 20 copolymers thereof, polyester, vinylester, epoxy and polyurethane.
- [0065] According to one preferred embodiment, the posts are made from a glass fibre reinforced epoxy resin.
- [0066] According to one embodiment, the composite material of the sleeve comprises fibres and a matrix.
- 25 [0067] According to one embodiment, the fibres are selected from glass fibres, carbon fibres, aramid fibres, flax fibres, basalt fibres and blends thereof.
- [0068] According to one embodiment, the matrix is selected from polyethylene, polypropylene, poly(ethylene terephthalate), polyamide, polyoxymethylene, polyetherimide, polyacrylate, polyaryl ether ketone, polyether ether ketone, 30 copolymers thereof, polyester, vinylester, epoxy and polyurethane.

- [0069] According to one preferred embodiment, the posts are made from a glass fibre reinforced epoxy resin.
- [0070] According to one preferred embodiment, the composite material of the sleeve and of the post are identical.
- 5 [0071] According to one embodiment, the internal end-plate is made of stainless steel.
- [0072] According to one embodiment, the internal end-plate has a thickness comprised between 4 and 10 mm.
- [0073] According to one embodiment, the adhesive used for bonding the sleeve to the post is selected from polyethylene, polypropylene, poly(ethylene terephthalate), polyamide, polyoxymethylene, polyetherimide, polyacrylate, polyaryl ether ketone, polyether ether ketone, copolymers thereof, polyester, vinylester, epoxy and polyurethane.
- 10 [0074] According to one embodiment, the wall comprises, in succession, in a thickness direction of the wall, a secondary thermally insulating barrier which is intended to rest against a load-bearing structure, a secondary metal sealing membrane which rests against the secondary thermally insulating barrier, a primary thermally insulating barrier which rests against the secondary sealing membrane and a primary sealing membrane which rests against the primary thermally insulating barrier and is intended to be in contact with the liquefied gas contained in the tank.
- 15 [0075] According to one embodiment, the secondary thermally insulating barrier comprises at least one aforementioned load-bearing element.
- 20 [0076] According to one embodiment, the secondary thermally insulating barrier comprises a plurality of aforementioned load-bearing elements.
- [0077] According to one embodiment, the primary thermally insulating barrier comprises at least one aforementioned load-bearing element.
- 25 [0078] According to one embodiment, the primary thermally insulating barrier comprises a plurality of aforementioned load-bearing elements.
- [0079] According to one embodiment, the secondary thermally insulating barrier and the primary thermally insulating barrier each comprise at least one aforementioned load-bearing element. According to one embodiment, the primary thermally insulating barrier and the secondary thermally insulating barrier comprise a plurality of
- 30 aforementioned load-bearing elements.

- [0080] According to one embodiment, the primary sealing membrane comprises a first series of corrugations having first corrugations parallel to one another and a second series of corrugations having second corrugations parallel to one another and perpendicular to the first corrugations, the primary sealing membrane comprising a plurality of planar zones each of which is defined between two adjacent first corrugations and between two adjacent second corrugations,
- 5 the plurality of planar zones of the primary sealing membrane comprising a first planar zone which is respectively welded against the internal end-plate of the load-bearing element.
- 10 [0081] According to one embodiment, the load-bearing element comprises:
- an external end-plate which is made of metal, to which the secondary sealing membrane is welded,
 - an external sleeve made of composite material pushed onto the hollow post and bonded against a longitudinal surface of the post,
- 15 the external end-plate being fixed to the external sleeve via an external fixing device, the external sleeve having an external end which lies flush with an external end of the post, and the external end-plate bearing, directly or indirectly, partly against the external end of the post and partly against the external end of the external sleeve, the primary sealing membrane being welded to the internal end-plate.
- 20 [0082] Depending on the embodiment, the external sleeve has similar features to the sleeve. For example, according to one embodiment, the external sleeve is formed of a plurality of distinct sections distributed about a longitudinal axis of the post, the plurality of distinct sections being fixed to the longitudinal surface of the post.
- [0083] According to one embodiment, the secondary sealing membrane comprises a first series of corrugations having first corrugations parallel to one another and a second series of corrugations having second corrugations parallel to one another and perpendicular to the first corrugations, the secondary sealing membrane comprising a plurality of planar zones each of which is defined between two adjacent first corrugations and between two adjacent second corrugations,
- 25 the plurality of planar zones of the secondary sealing membrane comprising a first planar zone which is respectively welded against the internal end-plate of the load-bearing element.
- 30 [0084] According to one embodiment, the primary thermally insulating barrier has a gas phase under vacuum, preferably at an absolute pressure lower than 1 Pa.

- [0085] According to one embodiment, the secondary thermally insulating barrier has a gas phase under vacuum, preferably at an absolute pressure lower than 1 Pa.
- [0086] According to one embodiment, the liquefied gas is liquid hydrogen.
- [0087] According to one embodiment, the invention also provides a sealed and thermally insulating tank comprising a plurality of the above-mentioned walls.
- [0088] Such a tank may form part of an onshore storage facility, or be installed in a floating, inshore or offshore structure, in particular a ship for transporting liquid hydrogen, which is to say a hydrogen carrier ship, a floating storage and regasification unit (FSRU), a floating production storage and offloading (FPSO) unit, and the like. Such a tank can also be used as a fuel tank on any type of ship.
- [0089] According to one embodiment, a ship used to transport a liquefied gas comprises a double hull and an aforementioned tank arranged inside the double hull.
- [0090] According to one embodiment, the invention also provides a transfer system for a liquefied gas, the system comprising the above-mentioned ship and insulated pipelines that are arranged so as to connect the tank installed in the hull of the ship to a floating or onshore storage facility.
- [0091] According to one embodiment, the transfer system also comprises a pump for causing liquefied gas to flow through the insulated pipelines from or to the floating or onshore storage facility to or from the tank of the ship.
- [0092] According to one embodiment, the invention also provides a method for loading onto or offloading from such a ship, wherein a liquefied gas is conveyed through the insulated pipelines from or to a floating or onshore storage facility to or from the tank of the ship.

Brief description of the figures

- [0093] 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.
- [0094] Figure 1 is a partial and perspective view of a wall of a sealed and thermally insulating tank according to one embodiment.

- [0095] Figure 2 is a partial, schematic cross-sectional view of a load-bearing element according to a first embodiment.
- [0096] Figure 3 is a partial perspective view of a load-bearing element according to a second embodiment.
- 5 [0097] Figure 4 is a partial cross-sectional view of a load-bearing element according to the second embodiment.
- [0098] Figure 5 is a partial view, from above, of the sleeve of the load-bearing element according to the second embodiment, during a step of bonding the sleeve inside the post.
- 10 [0099] Figure 6 is a partial perspective view of a load-bearing element according to a third embodiment.
- [0100] Figure 7 is a partial perspective view of a load-bearing element according to a fourth embodiment.
- [0101] Figure 8 is a partial cross-sectional view of a load-bearing element according to a fifth
15 embodiment.
- [0102] Figure 9 is a schematic and perspective view, with cut-away, of a load-bearing structure intended to support a sealed and thermally insulating tank for storing a liquefied gas.
- [0103] Figure 10 is a cut-away schematic depiction of a tank of a ship, and of a terminal for
20 loading/offloading from this tank.

Description of the embodiments

- [0104] A wall 11 intended to be integrated into a sealed and thermally insulating tank according to one embodiment is described hereinbelow in general terms in connection with Figure 1.
- 25 [0105] The wall 11 has a multilayer structure comprising, in the thickness direction of the wall 11, from the outside towards the inside, a secondary thermally insulating barrier 12, a secondary sealing membrane 13 which is corrugated and fixed to the secondary thermally insulating barrier 12, a primary thermally insulating barrier 14 and a primary sealing membrane 15 which is corrugated and fixed to the primary thermally insulating
30 barrier 14. The primary sealing membrane 15 is intended to be in contact with the liquefied gas, such as liquid hydrogen, contained in the tank.

- [0106] The secondary thermally insulating barrier 12 comprises a plurality of insulating panels 16 which are anchored to a load-bearing structure 1. The insulating panels 16 each have a layer 17 of insulating polymer foam sandwiched between an inner sheet 18 and an outer sheet 19. The inner sheet 18 and outer sheet 19 are, for example, sheets of plywood adhesively bonded to said layer 17 of insulating polymer foam. The insulating polymer foam can notably be a polyurethane-based foam, preferably reinforced by fibres.
- [0107] The primary thermally insulating barrier 14 comprises a plurality of load-bearing elements 20 extending in the thickness direction E of the wall 11, between the secondary sealing membrane 13 and the primary sealing membrane 15. The load-bearing elements 20 each comprise a hollow post 21 of cylindrical shape. Each post 21 is fixed at its internal end to an internal end-plate 22 and is fixed at its external end to an external end-plate 23.
- [0108] The primary sealing membrane 15 is welded, at each planar zone situated between two pairs of corrugations, to a respective internal end-plate 22.
- [0109] Similarly, the secondary sealing membrane 13 is welded, at each planar zone situated between two pairs of corrugations, to a respective external end-plate 23.
- [0110] The post 21 is manufactured from a composite material comprising fibres and a matrix. The internal end-plate 22 and the external end-plate 23 are made of metal, for example made of stainless steel.
- [0111] Furthermore, the gas phase of the primary thermally insulating barrier 14 is advantageously placed under vacuum, for example at an absolute pressure of less than 1 Pa and preferably less than 10^{-2} Pa. To this end, the primary thermally insulating barrier 14 is advantageously connected to a vacuum pump. The thermal insulation properties of the primary insulating barrier 14 are improved by the fact that the gas phase is under partial vacuum. However, the vacuum conditions of the primary thermally insulating barrier 14 will have a tendency to deform the primary sealing membrane 15 and the secondary sealing membrane 13 towards the inside of the primary thermally insulating barrier 15.
- [0112] The arrangement of the plurality of load-bearing elements 20 provides the primary sealing membrane 15 with support by reacting both the load caused by the hydrostatic and dynamic pressures applied to the primary sealing membrane 15 by the liquefied

gas contained inside the tank, and the load caused by the aforementioned vacuum conditions.

[0113] A plurality of embodiments of the load-bearing element is described hereinbelow in connection with Figures 2 to 8.

5 [0114] Identical or similar elements have the same reference numerals in increments of 100.

[0115] A first embodiment of the load-bearing element is described hereinbelow with reference to Figure 2.

[0116] The load-bearing element 120 comprises a sleeve 125 manufactured from a composite material. The sleeve 125 is placed inside the post 121 and is bonded along
10 an interior longitudinal surface 123 of the post 121, at the internal end of the post 121 so that the internal end of the sleeve 125 lies flush with the internal end of the post 121. In other words, the sleeve 125 does not extend beyond the internal end of the post. The thickness of the layer of adhesive situated between the sleeve 125 and the interior longitudinal surface 123 is less than 0.2 mm.

15 [0117] The internal end-plate 122 has an external surface 126 in contact with the internal end of the post and with the internal end of the sleeve. Thus, some of the compressive forces applied to the sealing membrane in the thickness direction E of the wall, for example as a result of the phenomenon of sloshing of the liquefied gas in the tank, pass through the post against which the internal end-plate 122 presses without
20 passing through the layer of adhesive and the sleeve. The fact that the sleeve 125 is arranged flush with the post 121 therefore allows the layer of adhesive to experience no, or greatly limited, shear forces.

[0118] Advantageously, the sleeve 125 and the post 121 are manufactured from the same composite material. As a result, they have the same coefficient of thermal expansion,
25 in a radial direction perpendicular to the thickness direction of the wall. Thus, the relative movement of the sleeve 125 with respect to the post 121 in response to the temperature variations is zero or near-zero. Thus, the layer of adhesive situated between the sleeve 125 and the post 121 experiences little or no stress and therefore offers excellent adhesion properties. As a result, the fixing of the sleeve 125 to the
30 post 121 is durable and stable.

[0119] A second embodiment of the load-bearing element is described hereinbelow with reference to Figures 3 to 5.

- [0120] The load-bearing element 220 comprises a sleeve 225 lying flush with the internal end of the post 221, in a similar way to the first embodiment illustrated in Figure 2.
- [0121] The load-bearing element 220 further comprises a metal bearer plate 230 in the form of a washer which, in the embodiment depicted, has an outside diameter identical to the outside diameter of the post 221. The metal bearer plate 230 is preferably made of aluminium so as to have a coefficient of thermal expansion that is similar to the coefficient of thermal expansion of the post 221 made of composite material. The metal bearer plate 230 has an internal surface 231 which is welded to the internal end-plate 222, and an external surface 232 which is in contact with the internal end of the post 221 and the internal end of the sleeve 225.
- [0122] The sleeve 225 has a first section 227 and a second section 228. The first section 225 and the second section 227 are manufactured from a composite material.
- [0123] The first section 227 is bonded to the interior longitudinal surface 223 of the post 221.
- [0124] The second section 228 is bonded to the interior longitudinal surface 223 diametrically opposite the first section 227. A gap 285 is left between the first section 227 and the second section 228.
- [0125] The first section 227 and the second section 228 each have a shape similar to that of a lunula.
- [0126] The sleeve 225 thus positioned in the post 221 has the overall shape of a cylinder of revolution cut into two and with a cylindrical cavity of elliptical cross section 286 at its centre. The cylindrical cavity of elliptical cross section 286 allows for example the introduction of a pressing tool 82 intended to press the first section 227 and the second section 228 against the interior longitudinal surface 223 of the post 221 so as to bond them firmly to said interior longitudinal surface 223.
- [0127] The external plate 233 is preferably made of aluminium. The external plate 233 of the load-bearing element 220 is situated against the external end of the first section 227 and the second section 228 of the sleeve 225. The external plate 233 has a smaller diameter than the metal bearer plate 230 so that it can be positioned inside the post 221.
- [0128] The external plate 233 is fixed to the internal end-plate 222 via a through-bolt 240 which passes through the sleeve 225 so that said sleeve 225 is sandwiched between

the external plate 233 and the internal end-plate 222. The external plate 233 is thus fixed to the sleeve 225.

[0129] In the embodiment depicted, the through-bolt 240 comprises a threaded rod 241 which passes through the internal end-plate 222, the metal bearer plate 230, the cylindrical cavity of elliptical cross section 286, and the external plate 233. The through-bolt 240 further comprises a first nut 242, through which the threaded rod passes and which is situated against the internal surface of the metal internal end-plate 222, and a second nut 243, through which the threaded rod passes and which is situated against the external surface 234 of the external plate 233. Tightening the first nut 242 and/or the second nut 243 enables the external plate 233 to be fixed to the sleeve 225.

[0130] A sleeve 225 in the process of being installed is notably set out in Figure 5 in which the pressing tool 82 comprises a pressing element 83 for pressing the sleeve 225, and a holding element 84 for holding the post 221. The pressing element 83 has an elliptical shape.

[0131] In order to position the sleeve 225 and fix it correctly, the pressing element 83 is inserted into the cylindrical cavity of elliptical cross section 286 and then a rotation as indicated by the arrow on the pressing element 83 is then applied so as to cause said pressing element 83 to press the first section 227 and the second section 228 against the interior longitudinal surface 223. During this pressing step, the holding element 84 surrounds the post 221 so as to react the forces applied radially by the pressing element 83.

[0132] Thanks to such a pressing tool 82, the sleeve 225 is correctly installed without damaging the structure of the post 221 and the layer of adhesive situated between the post 221 and the sleeve 225 is pressed, thereby giving the layer of adhesive better resistance to shearing.

[0133] A third embodiment of the load-bearing element is described hereinbelow with reference to Figure 6.

[0134] The load-bearing element 320 differs from the load-bearing element 220 presented in connection with Figures 3 to 5 in that the sleeve 325 comprises three sections, namely a first section 327, a second section 328 and a third section 329. In this embodiment, the three sections have the same size and shape.

[0135] The first, second and third sections are bonded to the inside of the post 321 against the interior longitudinal surface 323 of the post 321 and each have a shape similar to

that of a lunula. The first, second and third sections are spaced away from one another by gaps 385. At the centre of the post the sleeve 325 forms a cylindrical cavity 386 which has a cross section of circular overall shape.

5 [0136] In embodiment variants, the various sections of the sleeve may exhibit differences, for example different shapes or different sizes.

[0137] A fourth embodiment of the load-bearing element is described hereinbelow with reference to Figure 7.

10 [0138] The load-bearing element 420 differs from the load-bearing element 220 presented in connection with Figures 3 to 5 in that the sleeve 425 is formed as a single piece and has the overall shape of a cylinder of circular cross section concentric with the circular post 421. There is a space of less than 1 millimetre between the sleeve 425 and the post 421. The space forms an injection zone 441 which is intended to receive adhesive so as to form the layer of adhesive so that the sleeve 425 can be secured to the post 421 via the layer of adhesive. The thickness of the layer of adhesive situated in the
15 injection zone 441 is less than 1 mm.

[0139] The sleeve further exhibits a cylindrical cavity 486 which has the overall shape of a cylinder of circular cross section. As a variant, various shapes of cylindrical cavity are conceivable.

20 [0140] A fourth embodiment of the load-bearing element is described hereinbelow with reference to Figure 8.

[0141] The load-bearing element 520 differs from the load-bearing element 220 presented in connection with Figures 3 to 5 in that the sleeve 525 is push-fitted onto the outside of the post 521. Thus, the sleeve 525 is fixed by adhesive bonding to an external longitudinal surface 550 of the post 521 and surrounds the post 521.

25 [0142] The external plate 533 surrounds the post 521 and is fixed to the metal internal end-plate 522 via through-bolts 540 situated on the outside of the post 521 so that the metal internal end-plate 522 rests against the internal end of the post 521 and the internal end of the sleeve 525. The external plate 533 comprises tapped holes 543 intended to receive the through-bolts 540.

30 [0143] The through-bolts 540 comprise, for example, a screw 542. The screws each comprise a rod 541 which is threaded at its external end and which is fixed into one of the tapped holes in the external plate 533. This fixing method enables the external plate 533 to

be clamped against the internal end of the sleeve 525 via the turning of the first screw and the second screw in the tapped holes 543, so as to clamp the sleeve between the metal internal end-plate 522 and the external plate 533.

[0144] According to embodiment variants which have not been depicted, the load-bearing element comprises a first sleeve fixed against an external longitudinal surface of the post as indicated hereinabove, combined with a second sleeve fixed against an internal longitudinal surface of the post, as indicated hereinabove.

[0145] The above-mentioned wall 11, comprising one or more aforementioned load-bearing elements, is intended to be integrated into a sealed and thermally insulating tank for storing a liquefied gas. The liquefied gas intended to be stored in the tank may in particular be liquid hydrogen, which has the particular feature of being stored at approximately -253°C at atmospheric pressure.

[0146] Such a tank is fixed against a load-bearing structure 1 as illustrated in Figure 9.

[0147] The load-bearing structure 1 may in particular be formed of self-supporting metal sheets or, more generally, of any type of rigid partition having suitable mechanical properties. The load-bearing structure 1 is, for example, formed by the double hull of a ship. In Figure 9, the load-bearing structure 1 has a polyhedral overall shape. It has two load-bearing walls: a front load-bearing wall and a rear load-bearing wall 2, in this instance of octagonal shape, only the rear load-bearing wall 2 being depicted here. The front wall and the rear wall 2 are, for example, cofferdam walls of a ship which extend transversely to the longitudinal direction of the ship. The load-bearing structure 1 also comprises a load-bearing upper wall 3, a load-bearing lower wall 4, and load-bearing side walls 5, 6, 7, 8, 9, 10.

[0148] With reference to Figure 10, a cut-away view of a ship 70 shows a sealed and thermally insulating tank 71 of prismatic overall shape mounted in the double hull 72 of the ship. The wall of the tank 71 comprises a primary sealing membrane intended to be in contact with the liquefied gas, preferably liquid hydrogen, 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 insulating barriers arranged between the primary sealing membrane and the secondary sealing membrane and between the secondary sealing membrane and the double hull 72, respectively.

[0149] In a known manner, loading/offloading pipelines 73 arranged on the upper deck of the ship can be connected, using appropriate connectors, to a sea or port terminal to transfer a cargo of liquefied gas to or from the tank 71.

5 [0150] Figure 10 also shows an example of a sea terminal having a loading and offloading station 75, an underwater pipe 76 and an onshore facility 77. The loading and offloading station 75 is a fixed offshore facility having a movable arm 74 and a column 78 that supports the movable arm 74. The movable arm 74 carries a bundle of insulated flexible hoses 79 that can be connected to the loading/offloading pipelines 73. The orientable movable arm 74 adapts to suit all sizes of hydrogen carrier ship. A
10 connecting pipe (not shown) extends inside the column 78. The loading and offloading station 75 allows the hydrogen carrier ship 70 to be loaded and offloaded from or to the onshore facility 77. This facility has liquefied-gas storage tanks 80 and connecting pipes 81 connected via the underwater pipe 76 to the loading/offloading station 75. The underwater pipe 76 makes it possible to transfer the liquefied gas between the
15 loading/offloading station 75 and the onshore facility 77 over a long distance, for example 5 km, allowing the hydrogen carrier ship 70 to be kept standing off shore by a long distance during the loading and offloading operations.

[0151] In order to generate the pressure needed for transferring the liquefied gas, either use may be made of pumps on board the ship 70 and/or of pumps with which the onshore
20 facility 77 is equipped and/or of pumps with which the loading and offloading station 75 is equipped, or an increase in pressure in the internal space of the tank under the effect of the evaporation of the liquefied gas stored in the tank may be authorized.

[0152] Although the invention has been described in relation to several specific embodiments, it is evidently in no way limited thereto and it includes all of the technical equivalents
25 of the means described and the combinations thereof where these fall within the scope of the invention.

[0153] The use of the verbs “have”, “comprise” or “include” and their conjugated forms does not exclude the presence of elements or steps other than those set out in a claim.

[0154] In the claims, any reference sign between parentheses should not be interpreted as
30 limiting the claim.

CLAIMS

- [Claim 1] Wall for a sealed and thermally insulating tank for storing a liquefied gas, the wall (11) comprising, in a thickness direction of the wall, a thermally insulating barrier (12, 14) and a metal sealing membrane (13, 15) which rests against the thermally insulating barrier;
- 5 the thermally insulating barrier comprising at least one load-bearing element (20, 120, 220, 320, 420, 520),
- the load-bearing element comprising:
- a hollow post (21, 121, 221, 321, 421, 521) made of composite material which stands
 - 10 up in the thickness direction (E) of the wall,
 - a sleeve (25, 125, 225, 325, 425, 525) made of composite material pushed onto the hollow post (21, 121, 221, 321, 421, 521) and bonded against a longitudinal surface of the post; and
 - an internal end-plate (22, 122, 222, 522) which is made of metal, fixed to the sleeve
 - 15 (25, 125, 225, 325, 425, 525) via a fixing device (240, 540) and to which the sealing membrane is welded, wherein the sleeve has an internal end which lies flush with an internal end of the post, and
- wherein the internal end-plate (22, 122, 222, 522) bears, directly or indirectly, partly against the internal end of the post and partly against the internal end of the sleeve.
- 20 [Claim 2] Wall according to Claim 1, wherein the internal end-plate (22, 122, 222, 522) bears partly against the internal end of the post and partly against the internal end of the sleeve by means of a bearer plate (230) which is interposed between the internal end-plate and the internal end of the post, the bearer plate having an internal surface (231) in contact with the internal end-plate and an external surface (232) in contact with
- 25 the internal end of the post and the internal end of the sleeve.
- [Claim 3] Wall according to Claim 1 or 2, wherein the sleeve has a coefficient of thermal expansion α_1 in a radial direction perpendicular to the thickness direction of the wall which coefficient is comprised within the interval $[0.75 \times \alpha_2; 1.25 \times \alpha_2]$, where α_2 is a coefficient of thermal expansion of the post in the radial direction.
- 30 [Claim 4] Wall according to Claims 2 and 3 considered in combination, wherein the bearer plate has a coefficient of thermal expansion α_3 in the radial direction which is comprised within the interval $[0.75 \times \alpha_1; 1.25 \times \alpha_1]$; and
- within the interval $[0.75 \times \alpha_2; 1.25 \times \alpha_2]$.

- [Claim 5] Wall according to one of Claims 1 to 4, wherein the sleeve has a cylindrical overall shape and comprises a cylindrical cavity (286, 386, 486).
- [Claim 6] Wall according to one of Claims 1 to 5, wherein the sleeve is formed of a plurality of distinct sections distributed about a longitudinal axis of the post, the plurality of distinct sections being fixed to the longitudinal surface of the post.
- [Claim 7] Wall according to Claim 6, wherein the plurality of distinct sections comprises a first section (227) and a second section (228), the first section and the second section being diametrically opposed, one on each side of the longitudinal axis of the post.
- [Claim 8] Wall according to Claim 6, wherein the plurality of distinct sections comprises a first section (327), a second section (328), and a third section (329).
- [Claim 9] Wall according to one of Claims 1 to 5, wherein the sleeve is formed as a single piece.
- [Claim 10] Wall according to one of Claims 1 to 9, wherein the sleeve and the longitudinal surface of the post are bonded together using a layer of adhesive of a thickness, in a radial direction perpendicular to the thickness direction, that is less than 1 mm.
- [Claim 11] Wall according to one of Claims 1 to 10, wherein the fixing device comprises an external plate positioned against an external end of the sleeve and a through-bolt connecting the internal end-plate to the external plate in such a way that the sleeve is clamped between the internal end-plate and the external plate.
- [Claim 12] Wall according to one of Claims 1 to 11, wherein the sleeve is push-fitted inside the post.
- [Claim 13] Wall according to one of Claims 1 to 11, wherein the sleeve is push-fitted onto the outside of the post.
- [Claim 14] Sealed and thermally insulating tank comprising a plurality of walls according to any one of Claims 1 to 13.
- [Claim 15] Ship (70) used to transport a liquefied gas, the ship having a double hull (72) and a tank (71) according to Claim 14 arranged inside the double hull.
- [Claim 16] Transfer system for a liquefied gas, the system comprising a ship (70) according to Claim 15 and insulated pipelines (73, 79, 76, 81) that are arranged so as to connect the tank (71) installed in the hull of the ship to a floating or onshore storage facility (77).
- [Claim 17] Method for loading onto or offloading from a ship (70) according to Claim 15, wherein a liquefied gas is conveyed through the insulated pipelines (73, 79, 76, 81)

from or to a floating or onshore storage facility (77) to or from the tank (71) of the ship (70).