

Description

Title of the invention: Sealed and thermally insulating tank

Technical field

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

[0002] In one embodiment, the liquefied gas is LNG, namely a mixture with a high methane content stored at a temperature of around -162°C at atmospheric pressure. Other liquefied gases may also be considered, in particular ethane, propane, butane or ethylene. Liquefied gases can also be stored under pressure, for example at a relative pressure of between 2 and 20 bar, and in particular at a relative pressure close to 2 bar.

Prior art

[0003] WO2014096600 discloses a sealed and thermally insulating tank for the storage of liquefied natural gas, arranged in a support structure and having walls with a multilayer structure, namely, from the exterior to the interior of the tank, a secondary thermally insulating barrier anchored against the support structure, a secondary sealed membrane which is supported by the secondary thermally insulating barrier, a primary thermally insulating barrier which is laid on the secondary sealed membrane and a primary sealed membrane which is supported by the primary thermally insulating barrier and which is intended to be in contact with the liquefied natural gas stored in the tank.

[0004] Each thermally insulating barrier, primary and secondary, comprises a set of insulating panels, primary and secondary, respectively, of generally parallelepiped shape which are juxtaposed and which thus form a support surface for a respective sealed membrane. The insulating panels are anchored on the support structure by means of anchoring devices which are secured to the support structure and which are positioned at corners of the primary and secondary insulating panels. Each anchoring device thus interacts with the

corners of four adjacent secondary insulating panels and with the corners of four adjacent primary insulating panels so as to retain them against the support structure.

[0005] WO2013104850 describes a sealed and thermally insulating tank comprising a multilayer structure in which the corners of the insulating panels of the primary thermally insulating barrier are not located in alignment with the corners of the insulating panels of the secondary insulating barrier. In such a tank, primary anchoring devices interacting with the primary insulating panels are secured to a plate anchored in a secondary insulating panel. Thus, the primary anchoring devices and the primary insulating panels are anchored to the support structure by means of the secondary insulating panels.

[0006] In all cases, the secondary insulating panels are liable to deform and/or move. To be specific, the secondary insulating panels are subjected to thermal gradients which, owing to differential contraction phenomena, may cause them to bend. Moreover, the deformation of the support structure causes deformation and/or movement of the secondary insulating panels. This is in particular the case when the support structure is made up of the inner hull of a floating structure. Moreover, if this hull defines ballast compartments, the shifting of the ballast liquid in the ballast compartments is also liable to cause considerable deformation of the support structure and hence deformation and/or movement of the secondary insulating panels anchored on said support structure.

[0007] Furthermore, the shifting of the liquid contained in the tank may give rise to stresses on the primary sealed membrane, in particular if this membrane comprises protruding parts such as corrugations. These stresses are passed on to the primary insulating panels on which the primary sealed membrane is anchored and tend to move the primary insulating panels laterally. This causes stresses to be concentrated at the primary anchoring devices.

[0008] However, in order to ensure sealing of the secondary sealed membrane, the primary anchoring devices comprise a collar welded sealingly on the secondary sealed membrane. This collar is rigidly secured to a stud carrying a bearing member interacting with the corresponding primary insulating panel or panels. Upon deformation and/or movement of the secondary insulating panels and/or movement of the primary insulating panels, this connection between the primary anchoring devices and the secondary sealed membrane is liable to produce a concentration of the stresses in the weld between the collar and the secondary sealed membrane, which can damage said weld and said secondary sealed membrane.

[0009] In particular, in the case of primary anchoring devices secured to a secondary insulating panel, the deformation and/or the movement of the secondary insulating panels result in movement of the primary anchoring device. This movement of the primary

anchoring device is passed on to the collar rigidly secured to the stud, leading to stresses at the sealed connection between the collar and the secondary sealed membrane. Such stresses can damage the secondary sealed membrane and/or the sealed connection between the collar and the secondary sealed membrane and hence impair the seal of the secondary sealed membrane.

Summary

[0010] An idea forming the basis of the invention is to limit the concentration of stresses at the connections between the secondary sealed membrane and the primary anchoring member of the primary insulating panels. An idea forming the basis of the invention is to create a flexible sealed connection between the primary anchoring member and the secondary sealed membrane. Thus, an idea forming the basis of the invention is to allow a relative movement between the secondary sealed membrane and the primary anchoring member. An idea forming the basis of the invention is to allow this movement whether the primary anchoring member is anchored to the support structure directly, for example by being produced jointly with the secondary anchoring member, or indirectly, for example by being secured to a secondary insulating panel. Thus, another idea forming the basis of the invention is to allow a relative movement between a secondary insulating panel to which a primary anchoring member is secured, and the secondary sealed membrane.

[0011] According to one embodiment, the invention provides a sealed and thermally insulating tank comprising a tank wall, the tank wall comprising, successively from the exterior of the tank to the interior of the tank in a thickness direction of the tank wall, a secondary insulating barrier intended to be anchored on a support wall, a secondary sealed membrane resting on the secondary insulating barrier, a primary insulating barrier resting on the secondary sealed membrane and a primary sealed membrane resting on the primary insulating barrier and intended to be in contact with a product contained inside the tank,

the primary insulating barrier comprising a plurality of juxtaposed primary insulating panels, the tank further comprising a plurality of primary anchoring members intended to be retained, directly or indirectly, on the support wall, each of said primary anchoring members interacting with at least one primary insulating panel of the plurality of primary insulating panels in such a way as to retain said at least one primary insulating panel on the secondary sealed membrane,

in which one or more or each of said primary anchoring members comprises:

- a base intended to be retained, directly or indirectly, on the support wall,
- a stem extending in the thickness direction of the tank wall from said base toward the

primary sealed membrane, said stem passing through an opening in the secondary sealed membrane,

- a bearing element mounted on the stem, said bearing element bearing on a primary insulating panel in such a way as to retain said primary insulating panel on the secondary sealed membrane,
- a sealing washer engaged on the stem between the bearing element and the opening in the secondary sealed membrane, the sealing washer having a central opening through which the stem passes, the sealing washer being secured sealingly to the secondary sealed membrane, for example by a collar of the sealing washer, around the opening in said secondary sealed membrane,
- a deformable seal sealingly connecting said sealing washer and the stem in such a way as to allow a relative movement between the sealing washer and the stem.

[0012] By virtue of these features, a relative movement between the secondary sealed membrane and the primary anchoring member is possible without the risk of damage to the secondary sealed membrane or to the sealed connection between the primary anchoring member and the secondary sealed membrane. In particular, the deformable seal creates a flexible sealed connection between, on the one hand, the stem of the primary anchoring member and, on the other hand, the sealing washer, thereby ensuring sealing of the secondary sealed membrane. Such a primary anchoring member thus allows relative movement between the secondary and/or primary insulating panels and the secondary sealed membrane, without the risk of damage to the secondary sealed membrane or to the connection between the primary anchoring member and said secondary sealed membrane.

[0013] According to embodiments, such a tank may comprise one or more of the following features.

[0014] The primary anchoring member described above may be used over the whole of a tank wall or only in localized portions of the tank wall such as ballast areas. According to one embodiment, the tank wall has a vertical component defining a height of said tank wall in the direction of gravity, the tank wall comprising a plurality of said primary anchoring members each comprising a base, a stem, a bearing element, a sealing washer and a deformable seal as described above, said plurality of primary anchoring members being arranged on a lower portion of the tank wall, for example at least the lower two thirds of the height of said tank wall.

[0015] According to one embodiment, the tank wall is a first tank wall, the tank further comprising a second tank wall, the first tank wall and the second tank wall forming an edge

of the tank, the first tank wall comprising a plurality of said primary anchoring members each comprising a base, a stem, a bearing element, a sealing washer and a deformable seal as described above, said plurality of primary anchoring members being arranged at a distance from the edge of the tank below a predefined threshold. For example, the predefined threshold corresponds to the width of five insulating panels, said plurality of primary anchoring members being for example arranged to retain five successive primary insulating panels in a direction perpendicular to the edge.

[0016] The portions of tank walls located in the bottom portion of the tank are subjected to particularly high stresses, for example owing to the weight of the liquid transported or indeed, for example in the case of transverse tank walls anchored on cofferdam walls, owing to the ballast in the carrier. Likewise, the edge areas of the tank are also subjected to particularly high stresses, including the pressure generated by the water in the ballast of the carrier. These stresses are liable to cause relative movement between, on the one hand, the primary insulating barrier and/or the secondary insulating barrier and, on the other hand, the secondary sealed membrane in the bottom portion of the tank and/or at the edges of the tank. Thus, by virtue of the arrangement of said primary anchoring members, the risk of damage to the secondary sealed membrane is limited thanks to the flexibility of the connection between said primary anchoring members and the secondary sealed membrane.

[0017] The primary insulating panels may be produced in various ways. According to one embodiment, the primary insulating panels are of parallelepiped shape.

[0018] According to one embodiment, the primary insulating panels comprise a bottom plate, a cover plate and an insulating lining inserted between the bottom plate and the cover plate.

[0019] The bearing element may bear on various portions of the primary insulating panels. According to one embodiment, the bearing element bears directly on said primary insulating panel, for example bearing on the bottom plate of said primary panel. According to one embodiment, the bearing element bears indirectly on the primary insulating panel, for example via a wedge inserted between said bearing element and an element of the primary insulating panel, for example the bottom plate of the primary insulating panel.

[0020] According to one embodiment, the corners of the primary insulating panels comprise recesses, said recesses exposing a bearing surface facing the interior of the tank. According to one embodiment, the bearing element of the primary anchoring member bears, directly or indirectly, on the bearing surface of the primary insulating panel. According to one embodiment, said recesses are made in the cover plate and in the

insulating lining. According to one embodiment, the bearing surface is formed by a portion of the bottom plate protruding from the recess made in the insulating lining and in the cover plate. According to one embodiment, the bearing surface is formed by a wedge placed between the bearing element and a portion of the bottom plate protruding from the recess made in the insulating lining and in the cover plate.

[0021] According to one embodiment, a said primary anchoring member interacts with the corners of adjacent primary insulating panels, for example four panels the corners of which are adjacent, in such a way as to anchor said adjacent primary panels to the support wall.

[0022] The sealing washer may be secured to the secondary sealed membrane in various ways. According to one embodiment, the sealing washer or the collar is welded sealingly on the secondary sealed membrane.

[0023] According to one embodiment, the deformable seal is deformable in a thickness direction of the tank wall in such a way as to allow the sealing washer to slide along the stem in a thickness direction of the tank wall.

[0024] According to one embodiment, the central opening in the sealing washer has a transverse dimension greater than the transverse dimension of a portion of stem engaged in said central opening, in such a way as to allow the stem to move in said central opening in the sealing washer in a direction perpendicular to the thickness direction of the tank wall. Such a sealing washer allows freedom of movement of the sealing washer relative to the stem in a direction perpendicular to the thickness direction of the tank wall. More particularly, such a primary anchoring member allows movement of the sealed connection between the sealing washer and the secondary sealed membrane relative to the bearing element mounted on the stem and interacting with the primary insulating panel or panels. Thus, any movement of the secondary and/or primary insulating panels in a plane perpendicular to the thickness direction of the tank wall is not transmitted to the secondary sealed membrane by means of the primary anchoring member, thus reducing the stresses linked to differential contraction, deformation of the support wall or to the shifting of liquid in the tank, and limiting the risk of damage to the secondary sealed membrane or to the sealed connection between the sealing washer and the secondary sealed membrane.

[0025] According to one embodiment, the primary anchoring member further comprises a stop borne by the stem, said stop being arranged on the stem between the bearing element and the sealing washer, the stop having a stop surface facing the sealing washer so as to stop a movement of said sealing washer, relative to the stem, toward the primary sealed membrane in the thickness direction of the tank wall.

[0026] By virtue of these features, deformation of the secondary sealed membrane in the thickness direction of the tank wall is limited at the sealed connection between the sealing washer and the opening in the secondary sealed membrane. In particular, in the event of an overpressure in the secondary insulating barrier or of deformation of the secondary insulating barrier, the secondary sealed membrane is prevented from deforming in a thickness direction of the tank wall. To be specific, since the sealing washer is secured sealingly to the secondary sealed membrane around the opening in the secondary sealed membrane, in the event of a force tending to move the secondary sealed membrane toward the interior of the tank, local deformation of the secondary sealed membrane at the sealed connection with the sealing washer is blocked by the sealing washer coming into abutment against the stop surface. Thus, the risk of damage to the secondary sealed membrane, for example by perforation, is reduced. Moreover, this limitation of the local deformation of the secondary sealed membrane makes it possible to limit the risk of damage to the deformable seal.

[0027] According to one embodiment, the stem has a shoulder, said shoulder projecting laterally from the stem, i.e. in a direction perpendicular to the longitudinal direction of the stem, beyond the central opening in the sealing washer in such a way that an outer face of said shoulder forms the stop surface. Such a stop is simple to produce without the need for additional parts.

[0028] According to one embodiment, the primary anchoring member further comprises a bell mounted on the stem, said bell comprising a mounting portion and a protective portion, the mounting portion having a central passage through which the stem passes, the protective portion extending in the thickness direction of the tank wall from the mounting portion toward the collar of the sealing washer, the protective portion being hollow, the deformable seal being partially or entirely housed in the protective portion. Such a bell surrounding the stem of the primary anchoring member makes it possible to protect the stem and the deformable seal.

[0029] According to one embodiment, the mounting portion of the bell comprises a plateau extending in a plane perpendicular to the thickness direction of the tank wall, said plateau comprising the passage passing through the bell.

[0030] According to one embodiment, the deformable seal is housed entirely in the protective portion of the bell. Thus, the deformable seal is protected by the bell, for example during mounting of the primary anchoring member in the tank. According to one embodiment, the deformable seal is secured to the stem between the passage in the mounting portion of the bell and the sealing washer.

[0031] According to one embodiment, the end of the protective portion opposite to the mounting portion of the bell comprises a lip extending radially outward, an outer face of said lip forming the stop surface so as to stop a movement of the sealing washer in the thickness direction of the tank wall.

[0032] According to one embodiment, an outer end of the protective portion opposite to the mounting portion forms the stop surface facing the sealing washer so as to stop a movement of the sealing washer in the thickness direction of the tank wall.

[0033] According to one embodiment, the bell is secured to the stem. Thus, the stop surface may be formed by the protective portion having a position which is fixed relative to the stem, blocking movement of the sealing washer relative to the stem. According to one embodiment, the mounting portion of the bell is welded on the stem.

[0034] According to one embodiment, the deformable seal comprises a deformable bellows, said deformable bellows being hollow and extending around and axially along the stem, a first axial end of said bellows being secured sealingly to the stem and a second axial end of said bellows being secured sealingly to the sealing washer. Such a deformable seal in the form of a bellows is simple to produce and allows a satisfactory sealed deformation of said deformable seal. Such a bellows may be made of many materials. According to one embodiment, the bellows is made of stainless steel. Such a bellows made of stainless steel is sufficiently thin to allow it to deform elastically. In one embodiment, the bellows is made of stainless steel with a thickness of between 0.1 mm and 0.5 mm, for example between 0.1 mm and 0.3 mm.

[0035] According to one embodiment, the bellows has a plurality of folds of identical or increasing diameter, a central portion of the bellows formed by said plurality of folds thus having substantially the shape of a cylinder of revolution.

[0036] According to one embodiment, the bellows has at least three folds or corrugations, preferably between three and thirty-two folds, ideally between six and twenty-four folds.

[0037] According to one embodiment, the bellows has a flared shape, the second axial end of the bellows secured to the sealing washer having a circumferential dimension greater than the circumferential dimension of the first axial end of the bellows secured to the stem.

[0038] According to one embodiment, the bellows has a plurality of folds with a diameter increasing from the end anchored on the stem toward the end anchored on the sealing washer. Thus, the portion of the bellows formed by this plurality of folds has a conical shape, the largest dimension of which is located at the end secured to the sealing washer.

[0039] According to one embodiment, the sealing washer has an inner surface extending in a plane perpendicular to the thickness direction of the tank wall. According to one embodiment, the inner surface is arranged facing the stop surface in such a way as to interact with said stop surface, which forms part of the bell or of the stem for example, so as to block movement of the sealing washer relative to the stem in the thickness direction of the tank.

[0040] According to one embodiment, the deformable seal is secured to the inner surface of the sealing washer, for example on a radially outer portion of the inner surface of the sealing washer.

[0041] According to one embodiment, the sealing washer comprises a rib projecting from the inner surface of the sealing washer, the deformable seal being secured sealingly to said rib. According to one embodiment, the rib of the sealing washer extends from a radially inner portion of the inner surface of the sealing washer.

[0042] According to one embodiment, the tank comprises a plurality of secondary anchoring members, each secondary anchoring member being intended to be anchored on the support wall and interacting with the secondary insulating barrier in such a way as to bear on said secondary insulating barrier in the direction of the support wall when said secondary anchoring member is anchored on said support wall.

[0043] According to one embodiment, the base of the primary anchoring member is anchored on a secondary anchoring member.

[0044] According to one embodiment, the base of the primary anchoring member is rigidly anchored in the secondary insulating barrier. In this case, the primary anchoring member is retained on the support wall by means of the secondary insulating barrier.

[0045] According to one embodiment, the secondary insulating barrier comprises a plurality of juxtaposed secondary insulating panels. According to one embodiment, one or more or each secondary insulating panel comprises a bottom plate, a cover plate and an insulating lining inserted between the bottom plate and the cover plate, the secondary sealed membrane resting on an inner face of the cover plate opposite to the insulating lining. According to one embodiment, one or more or each secondary insulating panel comprises an intermediate plate inserted between the cover plate and the bottom plate of said secondary insulating panel, the insulating lining of said secondary insulating panel comprising an outer insulating lining inserted between the bottom plate and the intermediate plate and an inner insulating lining inserted between the intermediate plate and the cover plate.

- [0046] According to one embodiment, the secondary insulating barrier comprises an anchoring plate, the base of the primary anchoring member being anchored on said anchoring plate. According to one embodiment, the anchoring plate is housed in a recess made in the cover plate of a secondary insulating panel, the anchoring plate having an inner surface flush with the inner face of the cover plate.
- [0047] According to one embodiment, the anchoring plate comprises a threaded opening and the base has an outer threaded end, the base of the primary anchoring member being anchored on the anchoring plate by screwing the threaded end of the base into the threaded opening in the anchoring plate.
- [0048] According to one embodiment, an inner end of the stem opposite to the base is threaded, and the primary anchoring member further comprises a nut screwed onto said inner threaded end, the bearing element being inserted between said nut and the base of the primary anchoring member.
- [0049] According to one embodiment, the deformable seal is inserted between the bearing element and the sealing washer.
- [0050] According to one embodiment, one or more elastic washers are inserted between the nut and the bearing element.
- [0051] According to one embodiment, the primary anchoring member has an anchoring shoulder projecting laterally from the stem, said anchoring shoulder forming an anchoring surface extending in a plane perpendicular to the thickness direction, said anchoring surface facing the bearing element, the deformable seal being secured sealingly to said anchoring surface.
- [0052] According to one embodiment, the inner end of the deformable seal secured to the stem is inserted between the mounting portion of the bell and the flat anchoring surface of the anchoring shoulder.
- [0053] According to one embodiment, the bell has freedom of movement in the thickness direction of the tank wall. According to one embodiment, the freedom of movement of the bell is limited, on the one hand, by the nut mounted on the stem, or the elastic washer or washers, as applicable, and, on the other hand, by the anchoring surface of the anchoring shoulder.
- [0054] According to one embodiment, the inner axial end of the deformable seal secured to the stem is inserted between the anchoring surface of the anchoring shoulder and the nut mounted on the stem, or the elastic washers, as applicable.

[0055] According to one embodiment, the secondary sealed membrane and/or the primary sealed membrane is made of an alloy of iron and nickel, for example an alloy with a coefficient of expansion typically between 1.2×10^{-6} and $2 \times 10^{-6} \text{ K}^{-1}$. According to one embodiment, the secondary sealed membrane and/or the primary sealed membrane is made of an alloy of iron and manganese, for example with a coefficient of expansion typically around 7 to $9 \times 10^{-6} \text{ K}^{-1}$. According to one embodiment, the secondary sealed membrane and/or the primary sealed membrane comprises a plurality of strakes with raised edges, juxtaposed and welded in pairs via their raised edges.

[0056] According to one embodiment, the primary sealed membrane and/or the secondary sealed membrane comprises a plurality of metal plates, preferably rectangular, welded to one another. According to one embodiment, the primary sealed membrane and/or the secondary sealed membrane comprises a first series of parallel corrugations extending in a first direction and a second series of parallel corrugations extending in a second direction, said first direction and said second direction being secant.

[0057] According to one embodiment, a transfer wedge is arranged around the bell in a gap between the bell and the adjacent primary insulating panels, for example between the bell and the bottom plates of said adjacent primary insulating panels. By virtue of these features, a lateral movement of an insulating panel interacting with the anchoring member is transmitted via the transfer wedge to the bell, to the stem and then to the support of the stem, for example the secondary insulating barrier, making it possible to take up the lateral force exerted by the primary insulating panel without the risk of damage to the sealed connection between the sealing washer and the sealed membrane.

[0058] According to one embodiment, the transfer wedge has a thickness, considered in the thickness direction of the tank wall, smaller than the thickness of the bottom plate of the primary insulating panel. Thus, when the primary insulating panel moves laterally, only the bottom plate is brought into abutment against the transfer wedge, ensuring good transmission of the forces between the primary insulating panel and the transfer wedge.

[0059] According to one embodiment, the transfer wedge comprises an outer portion and a plateau, the outer portion extending around the sealing washer in the thickness direction of the tank wall, the plateau comprising a central opening surrounding the bell, the outer portion and the plateau forming a housing in which the sealing washer is housed with a clearance, such that the wedge can transmit a lateral force to the bell without interfering with the sealing washer.

[0060] According to one embodiment, the transfer wedge further comprises an inner portion extending from the plateau and surrounding the bell.

[0061] According to one embodiment, the outer portion of the transfer wedge is of circular cylindrical shape. According to one embodiment, said outer portion is coaxial with the stem.

[0062] According to one embodiment, the transfer wedge comprises a wing, preferably several wings, extending radially from the outer portion of the transfer wedge and parallel to the thickness direction of the tank wall. According to one embodiment, said wing or wings are housed between two adjacent primary insulating panels.

[0063] According to one embodiment, the transfer wedge is smaller than the space available between the panels. Mounting of the wedge between the panels is thus facilitated.

[0064] According to one embodiment, the sealing washer comprises a flat portion and the bell comprises a flat portion, said flat portions being configured to be gripped by a screwing tool so that the stem and the sealing washer rotate together, without twisting of the deformable seal, when the anchoring member is screwed into its support, for example into the secondary insulating barrier. According to one embodiment, the sealing washer comprises a flat portion and the stem comprises a flat portion, and said flat portions may be gripped by a screwing tool so that the stem and the sealing washer rotate together, without twisting of the deformable seal.

[0065] Such a tank may form part of an onshore storage facility, for example for storing LNG, or be installed in a floating structure, coastal or deep-water, in particular an LNG carrier, a floating storage and regasification unit (FSRU), a remote floating production and storage unit (FPSO), and the like. Such a tank may also be used as a fuel tank in any type of carrier.

[0066] According to one embodiment, the invention also provides a carrier for the transport of a cold liquid product comprising a double hull and a tank as described above arranged in the double hull.

[0067] According to one embodiment, the invention also provides a method for loading or unloading such a carrier, in which a cold liquid product is conveyed through insulated pipelines from or to a floating or onshore storage facility, to or from the tank of the carrier.

[0068] According to one embodiment, the invention also provides a transfer system for transferring a cold liquid product, the system comprising the abovementioned carrier, insulated pipelines arranged so as to connect the tank installed in the hull of the carrier to a floating or onshore storage facility, and a pump for pumping a flow of cold liquid product through the insulated pipelines from or to the floating or onshore storage facility, to or from the tank of the carrier.

Brief description of the figures

[0069] The invention will be better understood, and other objects, details, features and advantages thereof will appear more clearly during the following description of several particular embodiments of the invention, provided solely by way of non-limiting illustration, with reference to the attached drawings:

[0070] [fig.1] figure 1 is a partial view from above, with part cut away, of a wall of a sealed and thermally insulating tank in which the primary sealed membrane is not shown;

[0071] [fig.2] figure 2 is a view in section of the tank wall of figure 1 through the sectional plane A-A shown in figure 1;

[0072] [fig.3] figure 3 is a detailed view of the zone B of figure 2 showing a primary anchoring member anchoring two adjacent primary insulating panels;

[0073] [fig.4] figure 4 is a schematic perspective view of the anchoring member of figure 3;

[0074] [fig.5] figure 5 is a schematic perspective view of the primary anchoring member shown in figure 4 in which the bell is not shown;

[0075] [fig.6] figure 6 is a view in section of a second embodiment of the primary anchoring member;

[0076] [fig.7] figure 7 is a view in section of a third embodiment of the primary anchoring member;

[0077] [fig.8] figure 8 is a view in section of a primary anchoring member according to a fourth embodiment;

[0078] [fig.9] figure 9 schematically depicts, with part cut away, a tank of an LNG carrier and a terminal for loading/unloading this tank;

[0079] [fig.10] figure 10 is a schematic perspective view of a primary anchoring member according to a fifth embodiment;

[0080] [fig.11] figure 11 is a view in section of the primary anchoring member of figure 10 interacting with the two primary insulating panels;

[0081] [fig.12] figure 12 is a schematic perspective view of the anchoring member of figure 11;

[0082] [fig.13] figure 13 is a view in section of a primary anchoring member according to a sixth embodiment, the primary anchoring member comprising a transfer wedge;

[0083] [fig.14] figure 14 is a view from above of the primary anchoring member of figure 13;

[0084] [fig.15] figure 15 is a schematic perspective view with a section through a portion of a secondary thermally insulating barrier on which a portion of a secondary sealed membrane

rests, the secondary thermally insulating barrier comprising an anchoring plate intended to receive a primary anchoring member;

[0085] [fig.16] figure 16 is a schematic perspective view of part of a primary anchoring member and of a tool for mounting said part of a primary anchoring member on the anchoring plate of the secondary thermally insulating barrier of figure 15;

[0086] [fig.17] figure 17 is a schematic perspective view with a section through the primary anchoring member of figure 16 after mounting on the anchoring plate of the secondary thermally insulating barrier and the addition of a bell.

Description of the embodiments

[0087] In the rest of the description, the terms "outer" and "inner" will be used to designate, according to the definitions given in the description, the relative position of an element in relation to another element, with reference to the interior of the tank. Thus, an element close to or facing the interior of the tank is described as an inner element, as opposed to an outer element positioned close to or facing the exterior of the tank. Likewise, the expressions "radially at the periphery" or "radially outer" refer to the portion at a distance from an axis defining a circular element as opposed to the expression "radially inner", which refers to the portion close to said axis. Moreover, the expression "transverse" is used to describe a movement or a direction of extension of an element in a direction in a plane perpendicular to the thickness direction of the tank wall.

[0088] A sealed and thermally insulating tank for the storage of a liquefied fluid, such as liquefied natural gas (LNG), comprises a plurality of tank walls having a multilayer structure. Figures 1 and 2 show a portion of such a wall of a sealed and thermally insulating tank. In these figures 1 and 2, the wall of the tank comprises successively, through the thickness, from the exterior to the interior of the tank, a secondary thermally insulating barrier, hereinafter secondary insulating barrier 1, retained on a support wall (not shown), a secondary sealed membrane 2 resting against the secondary insulating barrier 1, a primary thermally insulating barrier, hereinafter primary insulating barrier 3, resting against the secondary sealed membrane 2 and a primary sealed membrane 4 intended to be in contact with the liquefied natural gas contained in the tank. The support structure may in particular be formed by the hull or the double hull of a carrier. The support structure comprises a plurality of support walls defining the general shape of the tank, usually polyhedral, each tank wall being anchored on a respective support wall.

[0089] The secondary insulating barrier 1 comprises a plurality of secondary insulating panels 5 which are anchored on the support wall by means of secondary anchoring members (not

shown). The secondary insulating panels 5 are of generally parallelepiped shape and are arranged in parallel rows. Beads of mastic (not shown) are laid between the secondary insulating panels 5 and the support wall to make up for gaps between the support wall and a flat reference surface. Kraft paper may be inserted between beads of mastic and the support wall to prevent the beads of mastic from sticking to the support wall. Alternatively, the beads of mastic are directly in contact with the support wall and thus secure the secondary insulating panels 5 by adhesion to the support wall.

[0090] The structure of a secondary insulating panel 5 shown in figure 2 comprises a bottom plate 7, a cover plate 8 and an insulating lining 9 inserted between the bottom plate 7 and the cover plate 8. The bottom plate 7 and cover plate 8 are for example made of plywood. The insulating lining 9 is for example a layer of insulating polymer foam sandwiched between the bottom plate 7 and the cover plate 8. The insulating lining 9 is adhesively bonded on the bottom plate 7 and the cover plate 8. The insulating polymer foam may in particular be a foam based on polyurethane, optionally reinforced with fibers.

[0091] The secondary insulating panels 5 comprise recesses for receiving the secondary anchoring members. Such recesses are for example made in the insulating lining 9 and in the cover plate 8 in such a way as to expose a corner portion of the bottom plate 7. The secondary anchoring members comprise a base anchored on the support wall and a stem extending in the thickness direction of the tank wall. The base is for example hollow and comprises an opening through which the stem passes, a nut being screwed onto the end of the stem housed in the hollow base so as to keep the stem anchored to the base and hence to the support wall. The secondary anchoring members may, in another embodiment, take the form of a stem welded to the inner hull.

[0092] In one embodiment, the recess is positioned in the corner zones. The corner portion of the bottom plate 7 comprises a notch to allow the passage of the stem of the secondary anchoring member. A secondary bearing plate is engaged on the stem and retained on the stem by a nut screwed onto an inner end of the stem opposite to the base. This secondary bearing plate bears on the corner portions of the bottom plate 7 of adjacent secondary insulating panels 5, for example four adjacent secondary insulating panels 5, so as to anchor said secondary insulating panels 5 on the support wall. In one alternative, the secondary bearing plate may bear on the secondary insulating panels 5 via a batten bearing on the corner portion of the bottom plate 7.

[0093] In another alternative, the recess is positioned on two lateral faces of the secondary insulating panels 5 and the secondary anchoring members are positioned in these

recesses between two adjacent secondary insulating panels 5 in the width or length direction of said secondary insulating panels 5.

[0094] The cover plate 8 comprises, on an inner face, i.e. on a face opposite to the insulating lining 9, grooves for receiving welding supports 6.

[0095] The structure of the secondary insulating panels 5 and of the secondary anchoring member are described above by way of example. Thus, in another embodiment, the secondary insulating panels 5 may have another general structure, for example the structure described in WO2012/127141. The secondary insulating panels 7 are in this case made in the form of a box comprising a bottom plate, a cover plate and support webs extending, in the thickness direction of the tank wall, between the bottom plate and the cover plate and delimiting a plurality of compartments filled with an insulating lining, such as perlite, glass wool or rock wool.

[0096] In another embodiment, the secondary insulating panels comprise a bottom plate, a cover plate and an intermediate plate inserted between the bottom plate and the cover plate. The insulating lining then comprises a first layer of insulating lining inserted between the bottom plate and the intermediate plate and a second layer of insulating lining inserted between the intermediate plate and the cover plate. The first layer of insulating lining is for example adhesively bonded to the bottom plate and to the intermediate plate. The second layer of insulating lining is for example adhesively bonded to the intermediate plate and to the cover plate. In this embodiment, the recess may be made in the cover plate and the second layer of insulating lining only, the secondary bearing plate bearing on an exposed portion of the intermediate plate. Furthermore, the notch for the passage of the stem is made in the intermediate plate, the first layer of insulating lining and the bottom plate. Such a secondary insulating panel is for example described in WO2014/096600.

[0097] In one embodiment, the secondary insulating panels are adhesively bonded to the support wall, for example by means of the abovementioned beads of mastic. In this case, it is possible to dispense with the secondary anchoring members and the recesses that receive them.

[0098] Returning to figure 1, it can be seen that the secondary sealed membrane 2 comprises a continuous layer of strakes 10, made of metal, with raised edges. The strakes 10 are welded by their raised edges on parallel welding supports 6 which are secured in the grooves made in the cover plates 8 of the secondary insulating panels 5. The strakes 10 are, for example, made of Invar®, an alloy of iron and nickel with a coefficient of expansion typically between 1.2×10^{-6} and $2 \times 10^{-6} \text{ K}^{-1}$. It is also possible to use alloys of iron and manganese, with a coefficient of expansion typically around 7 to $9 \times 10^{-6} \text{ K}^{-1}$.

[0099] The primary thermally insulating barrier 5 comprises a plurality of primary insulating panels 11 which are anchored on the support wall by means of primary anchoring members 12 described in more detail below. The primary insulating panels 11 have a generally parallelepiped shape and are juxtaposed so as to form the primary insulating barrier 3. Moreover, their dimensions in terms of width, length or thickness may be identical or different to those of the secondary insulating panels 5. In particular, their thickness in the thickness direction of the tank wall may be smaller than the thickness of the secondary insulating panels 5. Each of the primary insulating panels 11 is positioned offset from the secondary insulating panels 5 on which they rest. Thus, the adjacent corners of the primary insulating panels 11 are grouped in line with the cover plate 8 of a secondary insulating panel 5 on which said primary insulating panels 11 rest.

[0100] The primary insulating panels 11 may have a multilayer structure similar to the structure of the secondary insulating panels 5. Thus, in the example shown, the primary insulating panels 11 comprise successively, in the thickness direction of the tank wall, a bottom plate 13, for example made of plywood, a primary insulating lining 14 and a cover plate 15, for example made of plywood. The primary insulating lining is for example a layer of insulating polymer foam, for example a foam based on polyurethane, optionally reinforced with fibers. The insulating lining 14 is preferably adhesively bonded to the bottom plate 13 and to the cover plate 15.

[0101] A primary insulating panel 11 comprises recesses in its corner zones such that the bottom plate 13 protrudes relative to the primary insulating lining 14 and to the cover plate 15. Thus, the bottom plate 13 forms, in the corner zones of the primary insulating panel 11, a bearing zone intended to interact with a primary bearing plate 16 of the primary anchoring member 12. In the embodiment shown in figure 3, a wedge 17 is added to the bottom plate 13, said wedge 17 having a shape similar to that of the bearing zone and interacting with the primary bearing plate 16 for anchoring the primary insulating panel 11.

[0102] The bottom plate 13 of the primary insulating panel 11 comprises grooves 18 for receiving the raised edges of the strakes 10 of the secondary sealed membrane 2. The cover plate 15 comprises anchoring strips 19, shown in figure 1, for anchoring the primary sealed membrane 4. These anchoring strips 19 are housed in counterbores made on the inner face of the cover plate 15. The primary insulating panel 11 may further comprise relaxation slots 20 made in the cover plate 15 and in an inner portion of the primary insulating lining 14. Such relaxation slots 20 have the purpose of preventing deformation of or damage to the primary insulating panel 11 as a result of contraction differentials between the cover plate 15 and the primary insulating lining 14. Such relaxation slots 20

also allow corrugations 21 to warp and thus prevent the creation of stresses in the primary sealed membrane 4 and in the primary insulating barrier 3 in the case of a primary sealed membrane 4 comprising corrugations 21 as described below.

[0103] The structure of the primary insulating panel 11 is described above by way of example. Thus, in another embodiment, the primary insulating panels 11 may have another general structure, for example the structure described in WO2012/127141.

[0104] In another embodiment, the primary insulating barrier 3 comprises primary insulating panels having at least two different types of structure, for example the abovementioned two structures, depending on where they are fitted in the tank.

[0105] The primary sealed membrane 4 comprises a continuous layer of rectangular metal sheets having two series of corrugations 21 which are mutually perpendicular. The rectangular metal sheets are welded together, forming small overlap areas along their edges, as is known. A rectangular metal sheet preferably has dimensions in terms of width and length equal to integer multiples of a spacing between corrugations and also integer multiples of the dimensions of the primary insulating panels 11.

[0106] A primary anchoring member 12 is described below with reference to figures 3 to 5. Figure 3 depicts a detailed view of the primary anchoring member 12 shown in figure 2 with the reference B. Moreover, in figures 4 and 5, the nut 32 and the bearing plate 16 are not shown. In these figures 3 to 5, a single primary anchoring member 12 is shown and the description below for this anchoring member applies analogously to one, several or all of the primary anchoring members 12 incorporated in the sealed and thermally insulating tank.

[0107] As explained above, in the embodiment shown in figures 1 to 5, the primary insulating panels 11 are anchored to the support wall by means of the secondary insulating panels 5. To this end, the cover plate 8 of the secondary insulating panel 5 comprises an anchoring plate 22. This anchoring plate 22 is housed in a recess 23 made in the cover plate 8.

[0108] The recess 23 has an inner section 24 having a first diameter and an outer section 25 having a second diameter. The second diameter is greater than the first diameter such that the outer section 25 of the recess 23 forms lateral reinforcements inserted between a portion of the cover plate 8 surrounding the inner section 24 and the insulating lining 9.

[0109] The anchoring plate 22 has a shape complementary to the recess 23. An inner face 26 of the anchoring plate 22 lies flush with an inner face 27 of the cover plate 8 of the secondary insulating panel 5. Thus, the anchoring plate 22 forms with the cover plate 8 a

substantially continuous flat surface on which the secondary sealed membrane 2 rests. Moreover, an outer section 28 of the anchoring plate 22 is housed in the outer section 25 of the recess 23 and is thus inserted between the cover plate 8 and the insulating lining 9. The anchoring plate 22 is preferably adhesively bonded to the insulating lining 9 of the secondary insulating panel. Movement of the anchoring plate 22 in the thickness direction of the tank wall is thus blocked. This anchoring plate 22 further comprises a threaded central housing 29.

[0110] The primary anchoring member 12 comprises a base 30, a stem 31, the primary bearing plate 16 and a nut 32.

[0111] The base 30 has an outer thread and is screwed into the central housing 29 of the anchoring plate 22. In other words, the base 30 of the primary anchoring member 12 is anchored in the anchoring plate 22.

[0112] The stem 31 extends from the base 30 in the thickness direction of the tank wall toward the interior of the tank. The stem 31 passes through an opening made in the secondary sealed membrane 2. As shown in figures 1 to 3, this stem 31 extends in the space separating the corners of two primary insulating panels 11.

[0113] The primary bearing plate 16 has a central passage 60. This primary bearing plate 16 is engaged on the stem 31. The primary bearing plate 16 bears on the wedges 17 arranged on the protruding portions of the bottom plates 13 of the primary insulating panels 11 with which the primary anchoring member 12 interacts. Moreover, the inner end of the stem 31 opposite to the base 30 is threaded and the nut 32 is screwed onto this inner end of the stem 31 so as to press the primary bearing plate 16 on the wedges 17. In the embodiment shown in figure 3, elastic washers 33, for example Belleville washers, are inserted between the primary bearing plate 16 and the nut 32.

[0114] To ensure sealing of the secondary sealed membrane 2 at the opening in said secondary sealed membrane 2 through which the stem 31 passes, the primary anchoring member 12 further comprises a sealing washer 34.

[0115] This sealing washer 34 comprises an annular body 35 having a central opening 36. The sealing washer 34 further comprises a collar 37 extending radially outward from an outer portion of the radially outer face of the annular body 35. Moreover, an inner face 38 of the annular body 35 comprises a rib 39 projecting in the thickness direction of the tank wall. This rib 39 extends from a radially inner portion of said inner face 38. The collar 37 is for example formed by a peripheral portion of the annular body 35.

[0116] The sealing washer 34 is engaged on the stem 31, the stem 31 passing through the central opening 36 in the sealing washer 34. The sealing washer 34 is inserted between the secondary sealed membrane 2 and the primary bearing plate 16. The central opening 36 in the sealing washer 34 has a diameter greater than the diameter of the portion of stem 31 passing through said central opening 36. Thus, a transverse clearance, i.e. a clearance in a direction perpendicular to the thickness direction of the tank wall, separates a radially inner face delimiting the central opening 36 in the annular body 35 and the stem 31. This clearance allows the sealing washer 34 to move transversely relative to the stem 31, and hence relative to the primary bearing plate 16.

[0117] In an embodiment that has not been shown, the central opening is not circular and has a dimension in at least one transverse direction which is greater than the dimension of the stem 31 in said at least one transverse direction. In such an embodiment, a clearance in said at least one transverse direction thus separates the central opening 36 from the stem so as to allow the sealing washer to move relative to the stem 31 in said at least one transverse direction.

[0118] The collar 37 is secured sealingly on the secondary sealed membrane 2 around the opening in said secondary sealed membrane 2. This is achieved for example by welding.

[0119] The primary anchoring member 12 comprises an anchoring shoulder 40 projecting radially outward from the stem 31. This anchoring shoulder 40 is inserted between the sealing washer 34 and the primary bearing plate 16. The anchoring shoulder 40 has a flat anchoring surface 41 extending in a plane perpendicular to the thickness direction of the tank wall. This anchoring surface 41 is facing the interior of the tank.

[0120] The primary anchoring member 12 comprises a deformable seal that sealingly connects the stem 31 and the sealing washer 34. This deformable seal comprises a bellows 42. An inner axial end of this bellows 42 is secured sealingly on the stem 31. An outer axial end of this bellows 42 is secured sealingly on the sealing washer 34. More particularly, the inner axial end of the bellows 42 is anchored sealingly on the anchoring surface 41 of the anchoring shoulder 40. The outer axial end of the bellows 42 is anchored sealingly on the rib 39 projecting from the inner face 38 of the annular body 35. The inner axial end of the bellows 42 is for example welded to the stem 31. The outer axial end of the bellows 42 is for example welded to the sealing washer 34.

[0121] This bellows 42 has deformable folds 61, numbering three in the embodiment shown in figure 3. In a manner not shown, the number of folds 61 of the bellows 42 is not limited to three and may be greater depending on the space between the shoulder 40 and the surface 38 of the collar 37. Thus, the bellows 42 may have between three and thirty-two

folds 61, ideally between six folds 61 and twenty-four folds 61 depending on said space, said space being for example between 20 and 45mm. The bellows 42 is substantially cylindrical. The folds 61 forming the bellows 42 have identical dimensions. Such a bellows 42 is for example made of stainless steel. To ensure that said bellows 42 is flexible, it has a small thickness, preferably of less than 1 mm, for example between 0.1 and 0.5 mm and more particularly between 0.1 mm and 0.3 mm.

[0122] This bellows 42 forms a flexible, deformable and sealed connection between the stem 31 and the sealing washer 34. This flexible, deformable connection, combined with the clearance between the sealing washer 34 and the stem 31, allows relative movement under sealed conditions between the sealing washer 34 and the stem 31. Thus, since the sealing washer 34 is secured sealingly to the secondary sealed membrane 2 and since the stem 31 with the primary bearing plate 16 bears on the primary insulating panels 11, a relative movement is possible between the secondary sealed membrane 2 and the secondary insulating panels 5 and/or the primary insulating panels 11 without the risk of damage to the secondary sealed membrane 2 or loss of sealing of the secondary sealed membrane 2. In particular, when the stem 31 is secured to a secondary insulating panel, deformation and/or movement of said secondary insulating panel 5 is possible without this deformation and/or this movement placing stress on the secondary sealed membrane 2 or on the connection between the sealing washer 34 and the secondary sealed membrane 2.

[0123] Such a relative movement between the secondary insulating panels 5 and/or the primary insulating panels 11 and the secondary sealed membrane 2 may arise as a result of contraction differentials, deformation of the secondary insulating barrier 1 and/or of the support wall, or indeed stresses on the primary insulating panels 11 due to movement of liquid in the tank.

[0124] In order, on the one hand, to protect the bellows 42, for example during construction of the tank and mounting of the primary anchoring member 12, said primary anchoring member comprises a bell 43. This bell 43 comprises a mounting portion 44 and a protective portion 45. This bell 43 may be combined with the various types of bellows 42 described above and below.

[0125] The mounting portion 44 has a flat shape and a central opening. The bell 43 is mounted on the stem 31 of the primary anchoring member 12, said stem passing through the central opening in the mounting portion 44. The mounting portion is inserted between the anchoring shoulder 40 and the primary bearing plate 16. The bell is thus prevented from

moving in the thickness direction of the tank wall by the primary bearing plate 16 on the one hand, and by the anchoring surface 41 on the other hand.

[0126] The protective portion 45 is hollow and comprises an inner end adjoining a peripheral edge of the mounting portion 44. The protective portion 45 extends from its inner end along the bellows 42 in the direction of the sealing washer 34, the bellows 42 being housed in said hollow protective portion 45. The protective portion 45 is moreover flared in such a way that an outer end of said protective portion 45 is arranged in line with the collar 37 of the sealing washer 34. Thus, the bell 43 entirely surrounds the bellows 42, from the inner end of said bellows 42 on the anchoring surface 41 to the outer end of said bellows 42 secured to the rib 39.

[0127] The outer end of the protective portion 45 has a lip 46 extending in a plane perpendicular to the thickness direction of the tank wall. This lip 46 forms a stop surface 47 positioned facing the collar 37. Such a stop surface 47 blocks the movement of the collar 37, and hence of the sealing washer 34, toward the interior of the tank, the bell 42 being itself blocked by the abutment of its mounting portion 44 on the primary bearing plate 16.

[0128] Thus, since the collar 37 is secured sealingly to the secondary sealed membrane 2, upon deformation of the support wall or in the event of an overpressure in the secondary sealed membrane 2, local deformation of the secondary sealed membrane 2 at the primary anchoring member 12 is blocked by the abutment of the collar 37 of the sealing washer 34 on the stop surface 47. In another embodiment, the mounting portion 44 of the bell 43 is secured to the stem, for example by welding.

[0129] In an embodiment not shown, the primary insulating panels 11 and the secondary insulating panels 5 have identical dimensions and are arranged in such a way that the corners of the secondary insulating panels 5 are aligned in the thickness direction of the tank wall with the corners of the primary insulating panels 11. In such an embodiment, the primary anchoring member 12 is anchored not in a secondary insulating panel 5 but directly on the secondary anchoring member. Such a configuration is for example described in WO2014096600, which discloses a joint anchoring device for the secondary insulating panels 5 and the primary insulating panels 11, the base 30 of the primary anchoring member 12 being secured to one end of the secondary anchoring member. Thus, in this embodiment, a primary anchoring member as described above, the base 30 of the primary anchoring member 12 is anchored not in the anchoring plate 22 housed in a cover plate 8 of a secondary insulating panel 5 but in a base plate secured to the inner end of the secondary anchoring member.

[0130] Figure 6 depicts a primary anchoring member 12 according to a second embodiment. The elements which are identical to or fulfil the same function as the elements described above with reference to figures 1 to 5 bear the same reference.

[0131] This second embodiment differs from the embodiment shown in figures 1 to 5 in that the annular body of the sealing washer has a radially outer face which is beveled, i.e. inclined with respect to the thickness direction of the tank wall.

[0132] Figure 7 depicts a primary anchoring member 12 according to a third embodiment. The elements which are identical to or fulfil the same function as the elements described above with reference to figures 1 to 5 bear the same reference.

[0133] This third embodiment differs from the embodiment shown in figures 1 to 5 in that the bellows 42 is flared. Thus, the folds 61 forming said bellows 42 have dimensions increasing from the inner axial end of the bellows 42 anchored on the anchoring surface 41 toward the outer axial end of the bellows 42 anchored on the sealing washer 34.

[0134] Furthermore, in this third embodiment, the inner face 38 of the annular body 35 of the sealing washer 34 does not include the rib 39, said inner face 38 being flat. In this third embodiment, the outer axial end of the bellows 42 is secured directly to the flat inner surface 38. In particular, since the bellows 42 has a flared shape, the outer axial end of said bellows 42 is secured to a radially outer peripheral edge of said inner surface 38.

[0135] This third embodiment differs from the embodiment described with reference to figures 1 to 5 also in that the primary anchoring member 12 does not include a bell 43. However, such a bell 43 could be added.

[0136] In this third embodiment, the stem 31 has a shoulder 48 projecting laterally. This shoulder 48 is inserted between the anchoring shoulder 40 and the sealing washer 34. Moreover, this shoulder 48 has at least one transverse dimension greater than the dimension of the central opening of the sealing washer 34. Thus, this shoulder 48 has an outer face 49 facing the inner surface 38 of the annular body 35 of the sealing washer 34. In other words, a peripheral portion of this outer face 49 forms the stop surface 47. This shoulder 48 thus acts as a stop for the sealing washer 34, blocking movement toward the interior of the tank of said sealing washer 34 and preventing local deformation of the secondary sealed membrane 2.

[0137] Figure 8 depicts a primary anchoring member 12 according to a fourth embodiment. The elements which are identical to or fulfil the same function as the elements described above with reference to figures 1 to 5 bear the same reference.

[0138] In this fourth embodiment, the primary anchoring plate 16 is replaced by an anchoring cross 54. This anchoring cross 54 has a mounting portion 55 and a plurality of bearing legs 56, for example four bearing legs 56 as shown in figures 7 and 8 of WO2014/057221.

[0139] The mounting portion 55 of the anchoring cross 54 is flat and extends in a plane perpendicular to the thickness direction of the tank wall. This mounting portion 55 has a central opening through which the stem 31 passes, in such a way that the anchoring cross 54 is mounted on the stem 31.

[0140] Each bearing leg 56 has an inner end adjoining a peripheral edge of the mounting portion 55. Each bearing leg 56 extends from the mounting portion 55 to a bearing surface 57 formed by the protruding portion of the bottom plate 13 of a primary insulating panel 11. An outer end of the bearing leg 56 comprises a lip 58 extending in a plane perpendicular to the thickness direction of the tank wall. This lip 58 bears on the bearing surface 57 in such a way as to retain the primary insulating panel 11 on the secondary sealed membrane 2.

[0141] Such an anchoring cross 54 provides a degree of protection for the bellows 42 similar to the protective bell 43 described above with reference to figures 1 to 5.

[0142] In this fourth embodiment, the inner end of the bellows 42 is anchored on a lateral face 59 of the anchoring shoulder 40, for example in a recessed portion made for this purpose in the outer portion of said lateral face 59.

[0143] Figures 10 to 12 depict a primary anchoring member 12 according to a fifth embodiment. In these figures, the elements which are identical to or fulfil the same function as the elements described above with reference to figures 1 to 5 bear the same reference.

[0144] In this fifth embodiment, the protective portion 45 of the bell 43 is cylindrical and has a generatrix parallel to the thickness direction of the tank wall. The outer end of the protective portion 45 of the bell 43 is arranged in line with the inner face 38 of the annular body 35. In other words, the stop surface 47 formed by the lip 46 of the outer end of the protective portion 45 interacts with the inner face 38 of the annular body 35 so as to block the movement of the sealing washer 34 toward the interior of the tank. The collar 37 projects radially outward from the annular body 35, beyond the lip 46. Moreover, the inner axial end of the bellows 42 is anchored sealingly, for example by welding, to an outer face of the anchoring shoulder 40, i.e. to a face of the anchoring shoulder 40 facing the sealing washer 34.

[0145] When liquefied natural gas (LNG) is stored in the tank, the movement of said LNG inside the tank, for example linked to the movement of a carrier in which said tank is

installed, may give rise to lateral stresses on the primary insulating panels 11. Typically, a movement of LNG in the tank may exert a lateral stress on the corrugations 21 of the primary sealed membrane 4. This lateral stress on said corrugation 21 is transmitted to the primary insulating panel 11 on which the primary sealed membrane 4 is anchored. Under the effect of this stress, the primary insulating panel 11 tends to move laterally, i.e. in a plane perpendicular to the thickness direction of the tank wall, and hence to exert a stress on the primary anchoring member 12.

[0146] Since the collar 37 projects radially outward from the annular body 35 beyond the lip 46 of the bell 43, the bottom plate 13 of the primary insulating panel 11 may be brought into abutment against the collar 37 upon movement of said primary insulating panel 11. When the bottom plate 13 comes into abutment like this on the collar 37, this causes significant stress at the sealed connection between the collar 37 and the secondary sealed membrane 2, stress that could jeopardize the integrity of the secondary sealed membrane 2.

[0147] To prevent the forces resulting from lateral movement of the primary insulating panel 11 from being taken up by the sealing washer 34, this fifth embodiment comprises a transfer wedge 62. The transfer wedge 62 makes it possible to transfer the transverse force to the stem 31 and its support, for example the secondary insulating barrier. Moreover, the transverse dimension of the wedge is smaller than the space between neighboring primary insulating panels to allow sufficient mounting tolerance and transmit the forces from a primary insulating panel to the stem 31.

[0148] This transfer wedge 62 in this case comprises a base 63, a surround 64 and wings 65.

[0149] The base 63 has a flat shape extending perpendicularly to the thickness direction of the tank wall. This base 63 is of circular shape, its center being coaxial with the stem 31. The base 63 has a central opening 66. This central opening 66 is circular and coaxial with the stem 31. The dimensions of the central opening 66 are greater than the dimensions of the collar 37 such that a space separates the base 63 from the collar 37.

[0150] The base 63 rests on the secondary sealing membrane 2 around the collar 37. The bottom plates 13 of the primary insulating panels 11 interacting with the primary anchoring member 12 may have an outer counterbore 67 for housing the base 63.

[0151] The surround 64 comprises an outer skirt 68 and an inner skirt 69 connected by a central plateau 82.

[0152] The outer skirt 68 has a circular cylindrical wall with its generatrix parallel to the thickness direction of the tank wall. This outer skirt 68 extends from the inner periphery of

the base 63, i.e. from the edge of the central opening 66 in the base 63. The outer skirt 68 extends toward the interior of the tank over a thickness, in the thickness direction of the tank wall, which is greater than or equal to the thickness, considered in said thickness direction of the tank wall, of the annular body 35. Thus, an inner end of the outer skirt 68 is radially in line with the protective portion 45 of the bell 43.

[0153] The central plateau 82 extends in a plane perpendicular to the thickness direction of the tank wall. This central plateau 82 extends radially inward from the inner end of the outer skirt 68. The central plateau 82 comprises a central opening 83 with an inner diameter slightly greater than the outer diameter of the protective portion 45 of the bell. Thus, the central plateau 82 surrounds the protective portion 45 of the bell 43.

[0154] The inner skirt 69 has a circular cylindrical wall with its generatrix parallel to the thickness direction of the tank wall. This inner skirt 69 extends from the inner periphery of the central plateau 82, i.e. from the edge of the central plateau 82 delimiting the central opening 83. The inner skirt 69 extends toward the interior of the tank over a thickness smaller than the thickness of the protective portion 45 of the bell 43. Thus, the inner skirt 69 surrounds the protective portion 45 of the bell 43 over only part of the thickness of said protective portion 45.

[0155] Typically, the surround 64 surrounds the collar 37 and forms a housing, visible in figures 11 and 12, in which the collar 37 is housed with a clearance, thus protecting said collar 37.

[0156] Thus, when a primary insulating panel 11 experiences a stress causing said primary insulating panel 11 to move laterally, the bottom plate 13 of said primary insulating panel 11 comes into abutment against the transfer wedge 62, typically against the base 63 and/or against the outer skirt 68. Since the transfer wedge 62 surrounds the bell 43 and the distance separating the transfer wedge 62 from the bell 43 is less than the distance separating the transfer wedge 62 from the collar 37, the transfer wedge 62 comes into abutment against the bell 43 without generating a significant stress on the collar 37. In other words, the forces resulting from this lateral movement of the primary insulating panel 11 are routed through the bottom plate 13 of the primary insulating panel 11, which exerts a force on the transfer wedge 62, said transfer wedge then exerting a force on the bell 43 and the stem 31. Thus, the transfer wedge 62 ensures that the forces resulting from a lateral movement of a primary insulating panel 11 are not routed through the collar 37, thus limiting the stresses at the sealed connection between the collar 37 and the secondary sealed membrane 2.

[0157] In the embodiment shown in figures 10 to 12, the transfer wedge 62 further comprises four wings 65 facilitating the positioning of the transfer wedge 62 relative to the adjacent primary insulating panels 11. These positioning wings 65 are distributed circumferentially at regular intervals around the surround 64. These wings 65 extend radially from the surround 64 parallel to the thickness direction of the tank wall. Each of said wings 65 is housed between two primary insulating panels 11 interacting with the primary anchoring member 12. These wings 65 separate compartments independently wedging each of the primary insulating panels 11.

[0158] In an embodiment that has not been shown, the outer skirt 68 extends toward the interior of the tank beyond the bottom plate 13 of the primary insulating panels 11. Thus, upon lateral movement of a primary insulating panel 11, the insulating lining 14 is also brought into abutment against the outer skirt 68 so as to route the forces arising from the lateral movement of the primary insulating panel 11 to the transfer wedge 62.

[0159] Figures 13 and 14 show a primary anchoring member 12 according to a sixth embodiment.

[0160] This sixth embodiment differs from the fifth embodiment shown with reference to figures 10 to 12 in that the outer end of the protective portion 45 of the bell 43 is arranged in line with the collar 37. Moreover, the lip 46 of the outer end of the protective portion 45 projects radially beyond the collar 37. Thus, the stop surface 47 formed by the lip 46 of the outer end of the protective portion 45 interacts with the inner face of the collar 37 so as to block the movement of the sealing washer 34 toward the interior of the tank.

[0161] In this embodiment, the transfer wedge 62 is formed by a block 84. This block 84 comprises a central opening. This central opening has an inner diameter which is slightly greater than the outer diameter of the protective portion 45 of the bell 43 in such a way that the block 84 surrounds the protective portion 45 of the bell 43.

[0162] The block 84 has a thickness, considered in the thickness direction of the tank wall, which is smaller than the thickness of the bottom plate 13 of the adjacent primary insulating panels 11 such that an inner face of the block 84 is arranged on the outside, in the thickness direction of the tank wall, of the inner face of the bottom plates 13. Moreover, in the embodiment shown in figure 13, the block 84 rests on an inner face of the lip 46 of the protective portion 45 of the bell 43.

[0163] A peripheral lateral face of the block 84 has a shape generally complementary to the recesses made in the bottom plates 13 of the primary insulating panels 11 interacting with the primary anchoring member 12. In other words, the distance separating the bottom

plates 13 of the primary insulating panels 11 from the block 84 corresponds substantially to a mounting clearance. Thus, a lateral movement of a primary insulating panel 11 results, almost from the beginning of said movement, in pressing on the peripheral lateral face of the block 84.

[0164] Thus, upon lateral movement of a primary insulating panel 11, the bottom plate 13 of said primary insulating panel 11 comes into abutment against the transfer wedge 62, and more particularly on the peripheral lateral face of the block 84, and the transfer wedge comes into abutment against the bell 43 and the stem 31 substantially without exerting stress on the collar 37. The stress exerted by the primary insulating panel 11 on the transfer wedge 62 is thus transmitted to the stem 31 substantially without passing through the connection between the collar 37 and the secondary sealed membrane 2.

[0165] An example of a method for mounting a primary anchoring member is described below with reference to figures 15 to 17. In these figures 15 to 17 and in the description below, elements which are identical to or fulfil the same function as the elements already described above bear the same reference.

[0166] Like the description above with reference to figures 1 to 5, the anchoring plate 22 is housed in a recess 23 made in the cover plate 8 of a secondary insulating panel 5. The inner face 26 of the anchoring plate 22 lies flush with an inner face 27 of the cover plate 8 of the secondary insulating panel 5. The anchoring plate 22 further comprises a threaded central housing 29 intended to receive the base 30 of the primary anchoring member 12.

[0167] Preferably, the primary anchoring member 12 is at least partially prefabricated. A prefabricated portion of the primary anchoring member 12 comprises for example, as shown in figure 16, the base 30, the stem 31, the bellows 42 with its inner axial end secured to the anchoring shoulder 40, and the sealing washer 34 to which the outer axial end of the bellows is secured.

[0168] However, with such a prefabricated primary anchoring member 12, the sealing washer 34 is integral in rotation with the stem 31 via the bellows 42. Thus, when the stem 31 is rotated to screw the base 30 into the threaded central housing 29, the sealing washer 34 is also rotated. However, this rotation of the sealing washer 34 may give rise to friction between the outer face of said sealing washer 34 and the secondary sealed membrane 2, in particular at the end of screwing the base 30 into the housing 29. Such friction causes twisting of the bellows 42 which can damage said bellows 42 and hence the seal of said bellows 42.

- [0169] To prevent twisting of the bellows 42 when screwing the base 30 into the housing 29, the body 35 of the sealing washer 34 comprises flat portions 85 on its lateral face connecting the collar 37 and the inner face 38 of the body 35. Likewise, the anchoring shoulder 40 also comprises flat portions 86. The flat portions 85 of the sealing washer 34 and the flat portions 86 of the anchoring shoulder 40 preferably extend in the same planes.
- [0170] The method for mounting the primary anchoring member 12 includes the use of a socket wrench 87 comprising inner faces 88 complementary to the flat portions 85 and 86. Moreover, the socket of the wrench 87 preferably has a height greater than the height of the stem 31 and at least greater than or equal to the distance between the inner axial end of the stem and the flat portion 85 on the sealing washer 34. Thus, by virtue of the complementarity between the inner faces 88 of the wrench and of the flat portions 85 and 86, a rotation of the wrench 87 causes a rotation both of the stem 31, and hence the base 30, and of the sealing washer 34. In figure 16, the anchoring shoulder 40 and the body 35 comprise six flat portions 85 and 86, but the number and the dimensions of these flat portions may be different and the primary anchoring member 12 may comprise one, two or more flat portions 85 and 86 complementary to the inner faces 88 of the wrench 87 in such a way that the sealing washer 34 and the anchoring shoulder, and hence the stem 31 and the base 30, rotate together when the wrench 87 is used.
- [0171] To mount the prefabricated portion of the primary anchoring member 12 on the anchoring plate 22, said prefabricated portion is inserted in the socket of the wrench 87. The wrench 87 is then rotated in order to screw the base 30 into the housing 29. Since the sealing washer 34 is rotated with the stem 31, friction between the sealing washer 34 and the secondary sealed membrane 2 does not cause twisting of the bellows 42.
- [0172] When the base 30 is fully screwed into the housing 29, the bell 43 may be added on the stem 31 as shown in figure 17. Alternatively, the prefabricated portion of the anchoring member may also comprise the bell 43 which is in this case secured, for example by welding, to the stem 31.
- [0173] In this alternative shown in figure 17, the bell 43 comprises a flat portion 89 similar to the flat portion 86 of the anchoring shoulder 40. Moreover, the sealing washer 34, and more particularly the flat portion 85, is arranged radially beyond the lip 46 of the bell 43. Thus, the inner faces 88 of the wrench 87 interact with the flat portion of the bell 43 and the flat portion of the sealing washer 34 for screwing the base 30 into the housing 29 while rotating the sealing washer 34 so as not to cause twisting of the bellows 42.

[0174] The technique described above for producing a sealed and thermally insulating tank may be used in different types of storage tanks, for example to build an LNG storage tank in an onshore facility or on a floating structure such as an LNG carrier or the like.

[0175] With reference to figure 9, a view of an LNG carrier 70 with part cut away shows a sealed and insulated tank 71 of generally prismatic shape mounted in the double hull 72 of the carrier. The wall of the tank 71 comprises a primary sealed barrier intended to be in contact with the LNG contained in the tank, a secondary sealed barrier arranged between the primary sealed barrier and the double hull 72 of the carrier, and two insulating barriers arranged respectively between the primary sealed barrier and the secondary sealed barrier and between the secondary sealed barrier and the double hull 72.

[0176] In a manner known per se, loading/unloading pipelines 73 arranged on the upper deck of the carrier may be connected, by means of appropriate connectors, to a maritime or port terminal for transferring a cargo of LNG from or to the tank 71.

[0177] Figure 9 shows an example of a maritime terminal comprising a loading and unloading station 75, an underwater pipe 76 and an onshore facility 77. The loading and unloading station 75 is a fixed offshore facility comprising a movable arm 74 and a tower 78 which supports the movable arm 74. The movable arm 74 carries a bundle of insulated flexible pipes 79 which may be connected to the loading/unloading pipelines 73. The orientable movable arm 74 may be adjusted to suit all sizes of LNG carrier. A connecting pipe (not shown) extends inside the tower 78. The loading and unloading station 75 allows loading and unloading of the LNG carrier 70 from or to the onshore facility 77. This facility comprises tanks 80 for storing liquefied gas and connection pipes 81 connected by the underwater pipe 76 to the loading or unloading station 75. The underwater pipe 76 allows the transfer of the liquefied gas between the loading or unloading station 75 and the onshore facility 77 over a long distance, for example 5 km, which makes it possible to keep the LNG carrier 70 at a long distance from the shore during loading and unloading operations.

[0178] To generate the pressure necessary to transfer the liquefied gas, use is made of pumps on board the carrier 70 and/or pumps fitted to the onshore facility 77 and/or pumps fitted to the loading and unloading station 75.

[0179] Although the invention has been described in connection with several particular embodiments, it is obvious that it is in no way limited thereto and that it includes all technical equivalents of the means described as well as combinations thereof, if these fall within the scope of the invention.

[0180] The use of the verb “comprise” or “include” and conjugated forms thereof does not rule out the presence of other elements or other stages in addition to those stated in a claim.

[0181] In the claims, any reference sign in parentheses should not be interpreted as a limitation of the claim.

Claims

[Claim 1] A sealed and thermally insulating tank comprising a tank wall, the tank wall comprising, successively from the exterior of the tank to the interior of the tank in a thickness direction of the tank wall, a secondary insulating barrier (1) intended to be anchored on a support wall, a secondary sealed membrane (2) resting on the secondary insulating barrier (1), a primary insulating barrier (3) resting on the secondary sealed membrane (2) and a primary sealed membrane (4) resting on the primary insulating barrier (3) and intended to be in contact with a product contained inside the tank,

the primary insulating barrier (3) comprising a plurality of juxtaposed primary insulating panels (11),

the tank further comprising a plurality of primary anchoring members (12) intended to be retained, directly or indirectly, on the support wall, each of said primary anchoring members (12) interacting with at least one primary insulating panel (11) of the plurality of primary insulating panels (11) in such a way as to retain said at least one primary insulating panel (11) on the secondary sealed membrane (2),

in which a said primary anchoring member (12) comprises:

- a base (30) intended to be retained, directly or indirectly, on the support wall,
- a stem (31) extending in the thickness direction of the tank wall from said base (30) toward the primary sealed membrane (4), said stem (31) passing through an opening in the secondary sealed membrane (2),
- a bearing element (16, 54) mounted on the stem (31), said bearing element (16, 54) bearing on a primary insulating panel (11) in such a way as to retain said primary insulating panel (11) on the secondary sealed membrane (2),
- a sealing washer (34) engaged on the stem (31) between the bearing element (16) and the opening in the secondary sealed membrane (2), the sealing washer (34) having a central opening (36) through which the stem (31) passes, the sealing washer (34) being secured sealingly to the secondary sealed membrane (2) around the opening in said secondary sealed membrane (2),
- a deformable seal (42) sealingly connecting said sealing washer (34) and

the stem (31) in such a way as to allow a relative movement between the sealing washer (34) and the stem (31).

[Claim 2] The sealed and thermally insulating tank as claimed in claim 1, in which the central opening (36) in the sealing washer (34) has a transverse dimension greater than the transverse dimension of a portion of stem (31) engaged in said central opening (36), in such a way as to allow the stem (31) to move in said central opening (36) in the sealing washer (34) in a direction perpendicular to the thickness direction of the tank wall.

[Claim 3] The sealed and thermally insulating tank as claimed in claim 1 or 2, in which the primary anchoring member (12) further comprises a stop borne by the stem (31), said stop being arranged on the stem (31) between the bearing element (16) and the sealing washer (34), the stop having a stop surface (47) facing the sealing washer (34) so as to stop a movement of said sealing washer (34), relative to the stem (31), toward the primary sealed membrane (4) in the thickness direction of the tank wall.

[Claim 4] The sealed and thermally insulating tank as claimed in claim 3, in which the stem (31) has a shoulder (48), said shoulder (48) projecting laterally from the stem (31) beyond the central opening (36) in the sealing washer (34) in such a way that an outer face (49) of said shoulder (48) forms the stop surface (47).

[Claim 5] The sealed and thermally insulating tank as claimed in one of claims 1 to 4, in which the primary anchoring member (12) further comprises a bell (43) mounted on the stem (31), said bell (43) comprising a mounting portion (44) and a protective portion (45), the mounting portion (44) having a central passage through which the stem (31) passes, the protective portion (45) extending in the thickness direction of the tank wall from the mounting portion (44) toward the sealing washer (34), the protective portion (45) being hollow, the deformable seal (42) being housed in the protective portion (45).

[Claim 6] The sealed and thermally insulating tank as claimed in claim 3 in combination with claim 5, in which an outer end of the protective portion (45) opposite to the mounting portion (44) forms the stop surface (37) facing the sealing washer (34).

- [Claim 7] The sealed and thermally insulating tank as claimed in claim 5 or 6, in which the bell (43) is secured to the stem (31).
- [Claim 8] The sealed and thermally insulating tank as claimed in one of claims 5 to 7, further comprising a transfer wedge arranged around the bell in a gap between the bell and the adjacent primary insulating panels.
- [Claim 9] The sealed and thermally insulating tank as claimed in one of claims 5 to 8, in which the sealing washer (34) comprises a flat portion (85) and the bell (43) comprises a flat portion (89), said flat portions being configured to be gripped by a screwing tool so that the stem (31) and the sealing washer (34) rotate together, without twisting of the deformable seal (42).
- [Claim 10] The sealed and thermally insulating tank as claimed in one of claims 1 to 9, in which the deformable seal comprises a deformable bellows (42), said deformable bellows (42) being hollow and extending around and axially along the stem (31), a first axial end of said bellows (42) being secured sealingly to the stem (31) and a second axial end of said bellows (42) being secured sealingly to the sealing washer (34).
- [Claim 11] The sealed and thermally insulating tank as claimed in claim 10, in which the bellows (42) has at least three folds.
- [Claim 12] The sealed and thermally insulating tank as claimed in claim 10 or 11, in which the bellows (42) has a flared shape, the second axial end of the bellows (42) secured to the sealing washer (34) having a circumferential dimension greater than the circumferential dimension of the first axial end of the bellows (42) secured to the stem (31).
- [Claim 13] The sealed and thermally insulating tank as claimed in one of claims 1 to 12, in which the base (30) of the primary anchoring member (12) is rigidly anchored in the secondary insulating barrier (1).
- [Claim 14] The sealed and thermally insulating tank as claimed in one of claims 1 to 13, in which an inner end of the stem (31) opposite to the base (30) is threaded, and in which the primary anchoring member (12) further comprises a nut (32) screwed onto said inner threaded end, the bearing element (16, 54) being inserted between said nut (32) and the base (30) of the primary anchoring member (12), the deformable seal being inserted between the bearing element (16, 54) and the sealing washer (34).

- [Claim 15] The sealed and thermally insulating tank as claimed in claim 14, in which an elastic washer (33) is inserted between the nut (32) and the bearing element (16, 54).
- [Claim 16] The sealed and thermally insulating tank as claimed in one of claims 1 to 15, in which the primary anchoring member (12) has an anchoring shoulder (40) projecting laterally from the stem (31), said anchoring shoulder (40) forming an anchoring surface (41) extending in a plane perpendicular to the thickness direction, said anchoring surface (41) facing the bearing element (16, 54), the deformable seal being secured sealingly to said anchoring surface (41).
- [Claim 17] A carrier (70) for the transport of a cold liquid product, the carrier comprising a double hull (72) and a tank as claimed in one of claims 1 to 16 arranged in the double hull.
- [Claim 18] A transfer system for transferring a cold liquid product, the system comprising a carrier (70) as claimed in claim 17, insulated pipelines (73, 79, 76, 81) arranged so as to connect the tank installed in the hull of the carrier to a floating or onshore storage facility (77) and a pump for pumping a flow of cold liquid product through the insulated pipelines from or to the floating or onshore storage facility, to or from the tank of the carrier.
- [Claim 19] A method for loading or unloading a carrier (70) as claimed in claim 17, in which a cold liquid product is conveyed through insulated pipelines (73, 79, 76, 81) from or to a floating or onshore storage facility (77), to or from the tank of the carrier (71).