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 of the membrane type. In particular, the invention relates to the field of sealed and thermally insulating tanks for storing and/or transporting liquefied gas at low temperature, such as tanks for transporting liquefied petroleum gas (also known as LPG) at a temperature comprised for example between -50°C and 0°C, or for transporting liquefied natural gas (LNG) at approximately -162°C at atmospheric pressure. These tanks may be installed on land or on a floating structure. In the case of a floating structure, the tank may be intended for transporting liquefied gas or for receiving liquefied gas used as a fuel for the propulsion of the floating structure.

Technical background

[0002] Sealed and thermally insulating tanks for storing and/or transporting liquefied gas and comprising at least a sealing membrane which is in contact with the liquefied gas are known from the document WO2011157915. These tanks may be equipped with a loading/unloading column or more simply with loading and unloading pipes that pass through the roof of the tank to reach the internal space of the tank in order to load or unload liquefied gas into or out of the tank.

[0003] In the case of a loading/unloading column, this comprises a structure made up of a plurality of masts connected at a lower end to one another using a base. The loading/unloading column additionally comprises a guide device which is fixed against the underside face of the

base and collaborates with a supporting foot that passes through the bottom wall of the tank and is fixed to the bearing structure.

[0004] Pumps, notably unloading pumps, are fixed inside the tank to the loading/unloading column, to the loading and unloading pipes or to the supporting foot. In order to limit the volume of liquid that is unable to be unloaded from the tank, the lower end of the unloading pump is situated as close as possible to the sealing membrane, at a predefined distance of the order of a few centimetres.

[0005] In addition, in document WO2011157915 the sealing membrane in contact with the liquefied gas is a corrugated metal sealing membrane having a first parallel series of corrugations in a first direction and a second parallel series of corrugations in a second direction.

Summary

[0006] The inventors have observed that the pumps are fixed in the tank at a predefined distance from the sealing membrane of the bottom wall so as not to damage the sealing membrane. However, such an installation prevents the pumps from being positioned as close as possible to the bottom wall and therefore limits the volume of cargo that can be pumped.

[0007] Specifically, the sealing membrane has corrugations projecting towards the inside of the tank and that need to be taken into consideration when siting the pump.

[0008] An idea behind the invention is to reconfigure the area of the membrane in the vicinity of the pump.

[0009] According to one embodiment, the invention provides a sealed and thermally insulating tank incorporated into a bearing structure comprising a bearing wall, said tank comprising a tank wall fixed to the bearing wall of the bearing structure, wherein the tank wall comprises, in a thickness direction from the outside towards the inside of the tank, at least one thermally insulating barrier and at least one sealing membrane supported by the thermally insulating barrier and intended to be in contact with the fluid contained in the tank,

wherein the sealing membrane comprises a plurality of membrane portions that are juxtaposed with and welded to one another, each membrane portion being delimited by a polygonal exterior periphery,

wherein the plurality of membrane portions comprises at least one regular membrane portion, the regular membrane portion comprising a first regular series of corrugations, the first regular series of corrugations consisting of parallel first corrugations extending in a first direction and mutually spaced by a first corrugation spacing in a second direction perpendicular to the first direction,

said regular membrane portion comprising regular planar portions situated between the first corrugations of the first regular series of corrugations and resting on the thermally insulating barrier, the regular planar portions having a dimension less than the first corrugation spacing in the second direction, wherein the plurality of membrane portions comprises at least one singular membrane portion, the singular membrane portion comprising a first singular series of corrugations, the first singular series of corrugations consisting of first parallel corrugations extending in the first direction, the singular membrane portion comprising a singular planar portion having a dimension in the second direction that is strictly greater than N times the first corrugation spacing, N being a natural non-zero integer,

the regular membrane portion being adjacent to the singular membrane portion in the second direction,
and wherein the first singular series of corrugations comprises at least two first corrugations situated respectively on either side of the singular planar portion in the second direction.

[0010] By virtue of these features, the singular planar portion of the singular membrane portion makes it possible to have an area devoid of first corrugations over a greater dimension than in the regular membrane portion or portions while at the same time maintaining sufficient flexibility using the corrugations situated on either side of the singular planar portion.

[0011] Thus, in instances in which this singular planar portion is situated in line with an internal element close to the sealing membrane, the absence of first corrugations in this area means that the separation between the sealing membrane and the internal element can be adapted in such a way as to optimize the pumped volume.

[0012] According to other embodiments, such a tank may comprise one or more of the following features.

[0013] In one embodiment, the majority of the sealing membrane consists of regular membrane portions.

[0014] According to one embodiment, the first singular series of corrugations comprises two groups which are situated respectively on either side of the singular planar portion in the second direction, each group comprising at least N first corrugations mutually spaced by the first corrugation spacing in the second direction, the singular membrane portion comprising regular planar portions situated between the first corrugations of the one same group.

[0015] Thus, the sealing membrane in the singular membrane portion maintains flexibility for thermal expansion/contraction in the second direction despite having a singular planar portion which is more extensive than in the regular membrane portion or portions of the sealing membrane.

[0016] According to one embodiment, the natural integer N is greater than or equal to 2.

[0017] The natural integer N may also be equal to 1, 2 or 3.

[0018] According to one embodiment, the regular membrane portion is adjacent to the singular membrane portion in the second direction so that one said first corrugation of the singular membrane portion adjacent to the exterior periphery is distant from one said first corrugation of the regular membrane portion by a dimension equal to the first corrugation spacing in the second direction.

[0019] According to one embodiment, the tank comprises an internal space delimited by the sealing membrane, the tank comprising an internal element situated in the internal space of the tank,
the singular planar portion of the singular membrane portion being situated in line with the internal element in the thickness direction of the tank wall.

[0020] Thus, in instances in which the sealing membrane has just one series of corrugations and by eliminating the corrugations beneath the internal element, it is possible to increase the separation between the sealing membrane and the internal element by a dimension equal to the height of a corrugation considered in the thickness direction.

[0021] According to one embodiment, the internal element has a dimension in the second direction that is greater than the first corrugation spacing, and preferably less than the dimension of the singular planar portion in the second direction. For example, for a singular planar portion of a dimension of three times the first corrugation spacing in the second direction, the internal element has a dimension in the second direction that is less than three times the first corrugation spacing, and preferably comprised between two times and three times the first corrugation spacing.

[0022] According to one embodiment, the internal element is situated at a predefined distance from the singular planar portion in the thickness direction of the tank wall, the predefined distance being less than 200 mm, preferably comprised between 30 and 150 mm, for example comprised between 95 and 105 mm, the distance being measured when the tank is empty.

[0023] Specifically, the distance is measured only when the tank is empty of its contents, such as liquefied gas. When the tank is mounted in a ship, the measurement is therefore performed in harbour or in a dry dock.

[0024] According to one embodiment, the sealing membrane comprises a second series of corrugations, the second series of corrugations consisting of parallel second corrugations extending in the second direction, said regular and singular planar portions being situated between said second corrugations, the singular membrane portion comprising at least two singular planar portions situated on either side of one said second corrugation.

[0025] According to one embodiment, the second corrugations of the second series of corrugations are mutually spaced by a second corrugation spacing in the first direction, the second corrugation spacing

preferably being identical between said regular and singular planar portions.

[0026] According to one embodiment, the second corrugations have a height in the thickness direction of the tank wall that is less than a height in the thickness direction of the tank wall of the first corrugations.

[0027] Thus, despite the presence of second corrugations between singular planar portions, the absence of first corrugations in this area makes it possible to increase the separation between the sealing membrane and the internal element by a dimension equal to the difference in height between a first corrugation and a second corrugation.

[0028] According to one embodiment, the sealing membrane comprises corrugation nodes, each corrugation node being formed at the intersection between one said first corrugation and one said second corrugation and having a height in the thickness direction of the tank wall that is greater than the height of the first corrugations.

[0029] Thus, despite the presence of second corrugations between singular planar portions, the absence of first corrugations in this area makes it possible to increase the separation between the sealing membrane and the internal element by a dimension equal to the difference in height between a corrugation node and a second corrugation.

[0030] According to one embodiment, the singular membrane portion comprises an opening delimited by a polygonal interior periphery, and the tank comprises a supporting foot fixed to the bearing structure and extending through the tank wall and through said opening, the singular membrane portion comprising at least one anchorage to the supporting foot on at least one side of

the polygonal interior periphery, the anchorage to the supporting foot preferably being on each side of the polygonal interior periphery.

[0031] According to one embodiment, the tank comprises a loading/unloading column, the loading/unloading column comprising a plurality of masts connected at a lower end to one another using a base, the base comprising a guide device collaborating with the supporting foot, the supporting foot being configured to provide guidance in vertical translation of the loading/unloading column, the tank comprising at least one unloading pump situated in the internal space and fixed to the loading/unloading column, the internal element being formed by the unloading pump.

[0032] According to one embodiment, the internal element is connected to the supporting foot.

[0033] According to one embodiment, between any side of the interior periphery and any side of the exterior periphery of the singular membrane portion, of the number of first corrugations and the number of second corrugations that the singular membrane portion comprises, at least one of these numbers is less than or equal to three.

[0034] According to one embodiment, of the total number of first corrugations that the singular membrane portion comprises and the total number of second corrugations that the singular membrane portion comprises, at least one of these numbers is less than or equal to three.

[0035] According to one embodiment, of the total number of first corrugations that the regular membrane portion comprises and the total number of second corrugations that the regular membrane portion comprises, at least one of these numbers is less than or equal to three.

[0036] Thus, these criteria make it possible to limit, in at least one direction, the maximum distance between two sides of a membrane portion that are anchored to the insulating barrier. That makes it possible to ensure that the membrane portion is sufficiently able to withstand the stresses to which it is subjected in service, notably the overpressures, by setting a maximum limit on the maximum distances between the anchorages to the insulating barrier, in at least one direction.

[0037] According to one embodiment, the thermally insulating barrier comprises a plurality of rectangular parallelepipedal insulating blocks juxtaposed with one another, each insulating block comprising lagging and a cover panel facing towards the inside of the tank, an upper face of the cover panel opposite to the lagging bearing a metal anchor plate, the collection of upper faces of the cover panels forming a supporting surface for the sealing membrane.

[0038] According to one embodiment, the anchor plates comprise first anchor plates extending in the first direction and second anchor plates extending in the second direction.

[0039] According to one embodiment, the sealing membrane comprises a plurality of corrugated metal sheets of rectangular shape welded to one another, each corrugated metal sheet comprising two edges parallel to the first direction and two edges parallel to the second direction, each regular membrane portion or each singular membrane portion comprising one or more of said corrugated metal sheets.

[0040] According to one embodiment, each singular membrane portion and/or each regular membrane portion comprises at least one anchorage to the thermally

insulating barrier on each side of the polygonal exterior periphery.

[0041] According to one embodiment, each anchorage to the thermally insulating barrier is arranged continuously along the entire polygonal exterior periphery.

[0042] Such a tank may form part of an on-shore storage facility, for example for storing LNG, or may be installed in an in-shore or off-shore floating structure, notably a methane carrier ship, a floating storage and regasification unit (FSRU), a floating production storage and offloading (FPSO) unit or the like. Such a tank may also serve as a fuel tank in any type of ship.

[0043] According to one embodiment, a ship for transporting a cold liquid product comprises a double hull and an aforementioned tank arranged in the double hull.

[0044] According to one embodiment, the invention also provides a transfer system for transferring a cold liquid product, the system comprising the aforementioned ship, insulated pipes arranged in such a way as to connect the tank installed in the hull of the ship to a floating or on-shore storage facility and a pump for driving a stream of cold liquid product through the insulated pipes from or to the floating or on-shore storage facility to or from the tank of the ship.

[0045] According to one embodiment, the invention also provides a method for loading or unloading such a ship, wherein a cold liquid product is conveyed through insulated pipes from or to a floating or on-shore storage facility to or from the tank of the ship.

Brief description of the figures

[0046] The invention will be better understood and further objects, details, features and advantages thereof will become more clearly apparent during the course of the following description of a number of particular embodiments of the invention, these being given solely by way of nonlimiting illustration and with reference to the attached drawings.

[0047] [Fig. 1] Figure 1 is a partial sectioned schematic depiction of a sealed and thermally insulating tank in the region of a supporting foot.

[0048] [Fig. 2] Figure 2 is a view of detail II of Figure 1 for a tank of the prior art.

[0049] [Fig. 3] Figure 3 is a view of detail II of Figure 1 for a tank according to the invention.

[0050] [Fig. 4] Figure 4 depicts a partial schematic view from above of a bottom wall in the region of a supporting foot and according to a first embodiment.

[0051] [Fig. 5] Figure 5 depicts a partial schematic view from above of a bottom wall in the region of a supporting foot and according to a second embodiment.

[0052] [Fig. 6] Figure 6 depicts a partial schematic view from above of a bottom wall in the region of a supporting foot and according to a third embodiment.

[0053] [Fig. 7] Figure 7 is a schematic depiction with cutaway of a methane carrier ship comprising a sealed and thermally insulating tank and of a terminal for loading/unloading this tank.

Description of the embodiments

[0054] Figure 1 partially shows a sealed and thermally insulating tank 71 intended for storing and/or transporting liquefied gas and consisting of a bottom wall 1 fixed to the interior surface of a bearing structure 2. The bearing structure 2 is, for example, the inner hull of a double-hulled ship or an on-shore construction. In order to contain a cold liquid such as LNG, the tank walls comprise at least one sealing membrane 4 and at least one thermally insulating barrier 3 situated between the sealing membrane 4 and the bearing structure 2. As a safety measure, it is possible to provide a secondary sealing membrane and a secondary thermally insulating barrier, these not being depicted, between the bearing structure and the thermally insulating barrier 3, which in such an instance is then referred to as the primary thermally insulating barrier.

[0055] The liquefied gas intended to be stored in the tank 71 may notably be a liquefied natural gas (LNG), which is to say a gaseous mixture predominantly containing methane together with one or more other hydrocarbons. The liquefied gas may also be ethane or a liquefied petroleum gas (LPG), which is to say a mixture of hydrocarbons derived from the refining of crude oil and essentially containing propane and butane.

[0056] The tank 71 may be produced according to various well known geometries, for example a prismatic geometry in the hull of a ship or a cylindrical geometry on land or the like. Furthermore, there are numerous methods available for creating the thermally insulating barriers and the sealing membranes, for example using prefabricated elements.

[0057] An elongate rigid element constituting a supporting foot 5 has been depicted in the bottom wall 1

of the tank, this foot extending through the thermally insulating barrier 3 and the sealing membrane 4 so that part of the supporting foot 5 bears against the bearing structure 2 and another part projects into the tank some distance from the sealing membrane 4. The supporting foot 5 may for example serve to support equipment 7 that is to be immersed in the tank. For example, to support an unloading pump 7, a loading/unloading column 6 may be arranged in the tank as schematically depicted in Figure 1. In place of a loading/unloading column 6, the tank 71 may comprise loading and unloading pipes that are not connected to one another and are guided using the supporting foot 5.

[0058] In the case of a loading/unloading column 6, this comprises a structure made up of a plurality of masts connected at a lower end to one another using a base. The loading/unloading column 6 additionally comprises a guide device which is fixed against the underside face of the base and collaborates with the supporting foot 5.

[0059] The supporting foot 5 is configured to provide vertical translational guidance of the loading/unloading column 6 (or merely of loading and unloading pipes), the unloading pump 7 being fixed to the loading/unloading column 6 or directly to the supporting foot 5.

[0060] The supporting foot 5 here takes a form of revolution of circular cross section, with a frustoconical lower part 8 connected at its smallest-diameter end to a cylindrical upper part 9. The larger-diameter base of the frustoconical part 8 bears against the bearing structure 2. The frustoconical part 8 extends through the thickness of the bottom wall 1 beyond the sealing membrane 4.

[0061] The thermally insulating barrier 3 comprises a plurality of rectangular parallelepipedal insulating

blocks (not depicted) juxtaposed with one another. Each insulating block may comprise lagging and a cover panel facing towards the inside of the tank, an upper face of the cover panel on the opposite side to the lagging bearing a metal anchor plate. Such insulating blocks are described for example in document US6035795. The collection of upper faces of the cover panels forms a supporting surface for the sealing membrane 4.

[0062] With reference notably to Figures 3 and 4, the sealing membrane 4 consists of a plurality of corrugated metal sheets 10 of which the face referred to as the internal face is intended to be in contact with the fluid contained in the tank. The metal sheets 10 may notably be produced in stainless steel or in an iron-nickel alloy known as Invar® and are welded together at regions of overlap 11. The welds are of the lap welded joint type. The metal sheets 10 may be designed in various ways with regard to their shapes and dimensions, so that the welding regions may be positioned diversely.

[0063] The metal sheets 10 comprise, on their internal face, a first series of corrugations 12 extending in a first direction and a second series of corrugations 13 extending in a second direction which is perpendicular to the first direction.

[0064] The first series of corrugations 12 thus has a plurality of first corrugations 12 that are parallel and mutually spaced in the second direction whereas the second series of corrugations 13 has a plurality of second corrugations 13 that are parallel and mutually spaced in the first direction. The sealing membrane 4 comprises planar portions 14 situated between the first corrugations 12 and between the second corrugations 13 so that the planar portions 14 rest against the thermally insulating barrier 3.

[0065] The first corrugations 12 have a greater height than the second corrugations 13. The height of a corrugation is measured between the crest of the corrugation and the level of the planar portion 14. The sealing membrane 4 additionally comprises corrugation nodes 15 formed at the intersection between a first corrugation 12 and a second corrugation 13. Each corrugation node 15 has a height greater than the height of the first corrugations 12. The corrugations 12, 13 project towards the inside of the tank 71.

[0066] As visible notably in Figure 4, the corrugated metal sheets are of rectangular shape and welded to one another, each corrugated metal sheet comprising two edges parallel to the first direction and two edges parallel to the second direction.

[0067] In addition, in order to anchor the sealing membrane 4 to the thermally insulating barrier 3, certain metal sheets 10 are welded to the metal anchor plates of the insulating blocks of the thermally insulating barrier 3, notably at the regions of overlap 11.

[0068] In order to limit the volume of liquid that cannot be unloaded from the tank 71, the lower end of the unloading pump 7 is situated as close as possible to the sealing membrane 4, at a predefined distance of the order of a few centimetres.

[0069] Figures 2 and 3 more particularly depict an enlarged view of the area situated between the unloading pump 7 and the bottom wall 1, Figure 2 depicting this area according to the prior art and Figure 3 depicting this area according to the invention.

[0070] Thus, as visible in Figure 2, the spacing between the unloading pump 7 and the sealing membrane 4 is minimal at a corrugation node 15. This spacing will be denoted

hereinafter as initial spacing 22. Now, the inventors have found that this predefined distance has a tendency to vary considerably when the tank is being used.

[0071] In order to overcome the abovementioned observation, the invention depicted in Figure 3 proposes reconfiguring the region beneath the unloading pump 7. Thus, in this region, the sealing membrane 4 has no first corrugation 12, and especially has no corrugation node 15. Thus, according to the invention, only second corrugations 13 are present beneath the pump 7 which means that the spacing between the unloading pump 7 and the sealing membrane 4 is minimal at a crest of a second corrugation 13. The gain in spacing 23 compared with the initial spacing 22 is thus equal to the difference in height between a corrugation node 15 and a second corrugation 13, for example of the order of 33 mm with first corrugations having a height of around 55 mm and second corrugations having a height of around 37 mm.

[0072] According to a variant, not depicted but covered by the invention, beneath the unloading pump 7 the sealing membrane 4 could have no second corrugation 13 or first corrugation 12. Thus, the sealing membrane 4 is planar beneath the pump 7. The gain in spacing is thus equal to the height of a corrugation node, for example of the order of 69 mm.

[0073] Figures 4 to 6 more particularly illustrate the arrangement of the sealing membrane 4 of the bottom wall 1 in the vicinity of the supporting foot 5 and of the pump 7 according to various embodiments of the bottom wall 1.

[0074] Figure 4 shows a bottom wall 1 according to a first embodiment comprising a supporting foot 5 equipped with two pumps 7. Figure 5 shows a bottom wall 1 according to a second embodiment comprising a supporting foot 5

equipped with two pumps 7 and a sump 27 aligned with the supporting foot 5 in the first direction. Figure 6 shows a bottom wall 1 according to a third embodiment comprising a supporting foot 5 equipped with two pumps 7 and two sumps 27 which are situated on either side of the supporting foot 5 in the first direction.

[0075] The sealing membrane 4 comprises a plurality of membrane portions 17, 18 that are juxtaposed with and welded to one another. Each membrane portion 17, 18 is made up of one or more metal sheets 10 welded to one another. Each membrane portion 17, 18 is here delimited by a rectangular exterior periphery and comprises anchorages 19 anchoring the metal sheets 10 to the thermally insulating barrier 3 along the four sides of the rectangular exterior periphery. The anchorages 19 anchoring the membrane portions 17, 18 to the thermally insulating barrier 3 are for example achieved by welding the metal sheets 10 and the anchor plates borne by the insulating blocks to one another. These anchorages 19 are embodied by thicker lines in Figures 4 to 6 and are arranged continuously along the four sides of the rectangular exterior periphery of each membrane portion 17 or 18 in the embodiment depicted. In the embodiment depicted, these anchorages 19 are formed at regions of overlap 11 between the metal sheets 10.

[0076] In Figures 4 to 6, the first corrugations 12 and the second corrugations 13 are symbolized by dotted lines, the intersections of these lines indicating the corrugation nodes 15. The location of each pump 7 in line with the sealing membrane 4 is symbolized by a circle.

[0077] The sealing membrane 4 in Figure 4 more particularly comprises regular membrane portions 17 and three singular membrane portions 18. The singular membrane portions 18 are those where elements internal to the tank are situated close to the sealing membrane 4

and where first corrugations 12 have been partially eliminated or interrupted, as depicted. Regular membrane portions 17 are therefore assembled with one another and with the three singular membrane portions 18 in order to form the sealing membrane 4.

[0078] The regular membrane portions 17 thus have first corrugations 12 mutually spaced by a first corrugation spacing 20, second corrugations 13 mutually spaced by a second corrugation spacing 21 and, between these corrugations, regular planar portions 14 of a dimension less than the first corrugation spacing 20 in the second direction and a dimension less than the second corrugation spacing 21 in the first direction. The first corrugation spacing 20 and the second corrugation spacing 21 are measured crest to crest. The first corrugation spacing 20 and the second corrugation spacing 21 may be equal as depicted.

[0079] As visible in Figures 4 to 6, the singular membrane portions 18 also have first corrugations 12 forming a first singular series of corrugations, and second corrugations 13. However, in line with each unloading pump 7, the first corrugations 12, of which there are two here, are interrupted in order to create regions devoid of first corrugations 12 and in which the second corrugations 13 delimit singular planar portions 24 having a dimension in the second direction that is comprised between two and three times the first corrugation spacing 20.

[0080] As depicted notably in Figure 4, the first singular series of corrugations of each singular membrane portion 18 thus comprises two groups situated respectively on either side of the singular planar portions 24 in the second direction. Each group is defined by a plurality of first corrugations 12 mutually spaced by the first corrugation spacing 20, namely:

- in the case of the portions 18A and 18C: four first corrugations 12 in the right-hand group and three first corrugations 12 in the left-hand group
- in the case of the portion 18B: two corrugations 12 in the right-hand group and three corrugations 12 in the left-hand group.

[0081] In the three embodiments depicted, in order advantageously to obtain flexibility to thermal expansion/contraction in the second direction, care is taken to ensure that each group, situated respectively on either side of a singular planar portion 24, comprises a number of first corrugations 12 greater than or equal to the number of first corrugations 12 that have been interrupted in the singular planar portions 24, here in the example, two interrupted first corrugations 12. In this embodiment, the second corrugations 13 are not interrupted in line with each unloading pump 7 which means that there are a plurality of singular planar portions 24, four of them in Figure 4, for each pump 7.

[0082] The first corrugations 12 interrupted just before the singular planar portions 24 are closed with corrugation caps 26 which are welded to the metal sheets 10 so as to seal closed the interrupted first corrugations 12.

[0083] To allow for the passage of the supporting foot 5 and connect the latter to the bearing structure, the corrugated metal sheets 10 that form the sealing membrane 4 are cut in such a way as to delimit an octagonal opening 25 around the supporting foot 5. To ensure the continuity of the sealing membrane 4 at the opening 25, a sealed assembly of connecting pieces is produced between the supporting foot 5 and the adjacent metal sheets 10.

[0084] In the same way as was employed for the interrupting of corrugations at a singular planar portion

24, the first corrugations 12 and the second corrugations 13 are interrupted and closed in a sealed manner using corrugation caps 26 at the edges of the opening 25.

[0085] Because of the proximity between the supporting foot 5 and the pumps 7, the opening 25 is made in the singular membrane portion 18B. The edges of the opening 25 thus form an interior periphery for the singular membrane portion 18B. The interior periphery has an octagonal shape each of the sides of which has an anchorage 19 fixing the metal sheets 10 to the supporting foot 5. These anchorages 19 are embodied by thicker lines in Figures 4 to 6 and are arranged continuously along the eight sides of the octagonal interior periphery in the embodiment depicted.

[0086] As far as the singular membrane portion 18B comprising the opening 25 is concerned, the distances measured in the first direction and in the second direction between any edge of the opening 25 and the sides of the exterior periphery of the singular membrane portion 18B that are closest to this edge are less than or equal to three corrugation spacings 20 or 21. In other words, at most three corrugations 12 or 13 are counted between a side of the exterior periphery and that side of the interior periphery that is parallel and closest to the side of the exterior periphery. Taking Figure 4 as an example, the singular membrane portion 18B containing the opening 25 comprises, to the left of the supporting foot 5, two first corrugations 12, to the right of the supporting foot 5 three first corrugations 12, above the supporting foot 5 three second corrugations and below the supporting foot 5 three second corrugations 13. Thus, by limiting in one direction the number of corrugations 12, 13 per singular membrane portion 18 that makes it possible to ensure that the membrane portion will be sufficiently able to withstand the stresses to which it is subjected in service, notably overpressures,

by setting an upper limit on the maximum distances between the anchorages 19 to the thermally insulating barrier 3 or to the supporting foot 5.

[0087] In the same way as for the singular membrane portions 18A and 18C without opening 25, an upper limit has been applied to the maximum distances between the anchorages 19 by ensuring that of the total number of first corrugations 12 that the singular membrane portion 18 comprises and the total number of second corrugations 13 that the singular membrane portion 18 comprises, at least one of these numbers is less than or equal to three.

[0088] Finally, and still for the same reasons, this time so far as the regular membrane portions 17 are concerned, of the total number of first corrugations 12 that the regular membrane portion 17 comprises and the total number of second corrugations 13 that the regular membrane portion 17 comprises, at least one of these numbers is less than or equal to three.

[0089] In addition, in the example illustrated in Figure 4, the singular membrane portions 18A-C and the regular membrane portions 17 advantageously comprise anchorages 19 to the thermally insulating barrier 3 that are arranged continuously along the entire exterior periphery. In addition, the singular membrane portion 18B advantageously comprises anchorages 19 to the supporting foot 5 which are arranged continuously along the entire interior periphery.

[0090] In Figure 4, only the anchorages 19 of three singular membrane portions 18A-C and of one regular membrane portion 17 have been depicted. Thus, as visible in this figure, the assembly of the three singular membrane portions 18A-C and of the regular membrane portion 17 for which portions the anchorages 19 have been depicted, are adjacent to one another so that together

they form a rectangle containing the supporting foot 5 and situated in line with the two sitings of the pumps 7. In this embodiment, the length of the singular membrane portion 18B and the length of the regular membrane portion 17 extend in the first direction and are contiguous so that they can be welded together. In addition, as depicted, each pump 7 is situated at the interface between two singular membrane portions 18A-C. Thus, one of the pumps straddles the singular membrane portions 18A and 18B, while the other pump straddles the singular membrane portions 18B and 18C.

[0091] However, in another embodiment, the singular membrane portions 18A-C and the regular membrane portions 17 of Figure 4 may comprise anchorages 19 to the thermally insulating barrier 3 that are arranged not continuously along the entire exterior periphery. As a preference, there is at least one anchorage per side.

[0092] Figure 5 relates to a second embodiment which differs from the first embodiment through the presence of a sump 27. Elements identical or similar to those of Figure 4 bear the same reference numeral and are not described again.

[0093] In order to maximize the extent to which a tank can be exploited, it is desirable to optimize the useful volume of cargo that can be loaded into the tank and unloaded from the tank 71. The use of a pump that draws the liquid up towards the top of the tank means that a certain head of liquid needs to be maintained in the bottom of the tank otherwise the suction member of the pump will enter into communication with the gaseous phase, causing the pump to lose its prime and/or to become damaged. This is why it is known practice to create a sump 27 in the bottom wall 1 of such a tank that locally interrupts the sealing membrane 4 so as also to form another opening 25. The sump 27 comprises a container

dipping down through the bottom wall 1 of the tank 71 so that the liquid in the container is at the lowermost level of the tank.

[0094] The sealing membrane 4 is thus interrupted around a sump 27 in the same way as it is around the supporting foot 5. In the embodiment of Figure 5, the sump 27 is arranged in alignment with the supporting foot 5 in the first direction so that with the supporting foot it flanks one of the pumps 7, the latter being laterally offset in the second direction relative to the supporting foot 5 and to the sump.

[0095] Thus, three singular membrane portions 18A, 18B, 18C are also delimited. The portion 18C contains the opening 25 accommodating the sump 27. The portion 18B still contains the opening 25 accommodating the supporting foot 5. Just as in the embodiment of Figure 4, one of the pumps 7 is arranged in line with the interface between the singular membrane portion 18A and the singular membrane portion 18B so as to be positioned above singular planar portions 24 which are regions in which the first corrugations 12 have been interrupted. Similarly, the other of the pumps 7 is arranged in line with the interface between the singular membrane portion 18B and the singular membrane portion 18C.

[0096] These singular membrane portions 18A-18C are symbolized in Figures 4 to 6 as rectangles depicted in dotted line.

[0097] Figure 6 relates to a third embodiment which differs from the second embodiment through the presence of a second sump 27 which is arranged symmetrically with the first sump relative to the supporting foot 5 so that the sumps 27 are arranged on either side of the supporting foot 5 in the first direction. Elements identical or similar to those of Figure 5 bear the same reference

numerals and are not described again. Thus, three singular membrane portions 18A, 18B, 18C are also delimited. The portions 18A and 18C each contain an opening 25 accommodating a sump 27 and the portion 18B still contains the opening 25 accommodating the supporting foot 5. Just as in the embodiment of Figure 5, one of the pumps 7 is arranged in line with the interface between the singular membrane portion 18A and the singular membrane portion 18B so as to be positioned above singular planar portions 24. Similarly, the other of the pumps 7 is arranged in line with the interface between the singular membrane portion 18B and the singular membrane portion 18C.

[0098] In Figures 5 and 6, only the anchorages 19 of the three singular membrane portions 18A, 18B, 18C have been illustrated. In addition, in these embodiments, the singular membrane portions 18A-C comprise anchorages 19 to the thermally insulating barrier 3 that are arranged not continuously around the entire exterior periphery. As a preference, there is at least one anchorage per side. In addition to the anchorages 19 on the exterior periphery and on the interior peripheries of the openings 25, the three singular membrane portions 18A, 18B, 18C also comprise discontinuous anchorages 19 arranged between the interior periphery and the exterior periphery. Thus, for example as depicted in Figure 5 or 6, the discontinuous anchorages may extend from the exterior periphery whether this be at the interface between two singular membrane portions 18 or in one of the singular membrane portions 18. The discontinuous anchorages may also extend parallel to one of the sides of the exterior periphery and some distance from the sides of the exterior periphery and from the sides of the interior periphery.

[0099] In the embodiment of Figure 3, in which the first corrugations 12 are taller than the second corrugations

13, the choice has been made to retain only the lower corrugations, the second corrugations 13 present beneath the pump 7. In another embodiment of the invention which has not been depicted, the first corrugations 12 may be lower than the second corrugations 13. In such an instance, it is the taller corrugations that are maintained beneath the pump 7.

[0100] By eliminating first corrugations 12 beneath the unloading pump 7 in each singular membrane portion, whatever the height of the corrugation concerned, the invention meets its desired objective because a gain in spacing 23 is created thanks to the elimination of the corrugation nodes 15 beneath the unloading pump 7. Thus, even if the taller corrugations still remain present beneath the pump 7, the spacing between the unloading pump 7 and the sealing membrane 4 is nevertheless increased in comparison with the prior art. This spacing is still measured at a crest of the second corrugation 13. The gain in spacing is thus equal to the difference in height between a corrugation node 15 and a second corrugation 13, for example of the order of 15 mm with first corrugations of a height of around 37 mm and second corrugations of a height of around 55 mm and nodes 15 of a height of around 70 mm.

[0101] The invention has been described in connection with an unloading pump 7. However, it also of course applies to any element internal to the tank 71 and situated close to the sealing membrane 4.

[0102] The corrugations of the membrane may be formed differently, for example as described in KR-A-20050050170. Thus, the corrugation nodes 15 and the corrugations 12, 13 may have a different shape from that depicted notably in Figure 3.

[0103] With reference to Figure 7, a cutaway view of a methane carrier ship 70 shows a sealed and insulated 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 LNG contained in the tank, a secondary sealing membrane arranged between the primary sealing membrane and the double hull 72 of the ship, and two thermally insulating barriers arranged respectively between the primary sealing membrane and the secondary sealing membrane and between the secondary sealing membrane and the double hull 72.

[0104] As known per se, loading/unloading pipes 73 arranged on the upper deck of the ship can be coupled, by means of suitable connectors, to a maritime or harbour terminal in order to transfer a cargo of LNG from or to the tank 71.

[0105] Figure 7 depicts an example of a maritime terminal comprising a loading and unloading station 75, an underwater pipe 76 and an on-shore facility 77. The loading and unloading station 75 is a fixed off-shore installation comprising a mobile arm 74 and a column 78 supporting the mobile arm 74. The mobile arm 74 supports a bundle of flexible insulated pipes 79 that can be connected to the loading/unloading pipes 73. The orientable mobile arm 74 adapts to suit all sizes of methane tanker. A connecting pipe, not depicted, extends inside the column 78. The loading and unloading station 75 allows the methane carrier 70 to be loaded and unloaded from or to the on-shore facility 77. The latter comprises liquefied gas storage tanks 80 and connecting pipes 81 connected by the underwater pipe 76 to the loading or unloading station 75. The underwater pipe 76 allows the liquefied gas to be transferred between the loading or unloading station 75 and the on-shore facility 77 over a great distance, for example 5 km, enabling the methane

carrier ship 70 to lay a great distance off the coast during the loading and unloading operations.

[0106] In order to generate the pressure needed for transferring the liquefied gas, use is made of pumps carried on board the ship 70 and/or of pumps with which the on-shore facility 77 is equipped and/or of pumps with which the loading and unloading station 75 is equipped.

[0107] Although the invention has been described in connection with a number of particular embodiments, it is quite obvious that it is not in any way restricted thereto and that it comprises all technical equivalents of the means described and combinations thereof provided that these fall within the scope of the invention.

[0108] The use of the verbs “comprise”, “have” or “include” and of the conjugated forms thereof does not exclude the presence of elements or steps other than those listed in a claim.

[0109] In the claims, any reference sign between parentheses must not be interpreted as a limitation on the claim.

Claims

[Claim 1] Sealed and thermally insulating tank (71) incorporated into a bearing structure (2) comprising a bearing wall, said tank comprising a tank wall (1) fixed to the bearing wall of the bearing structure (2), wherein the tank wall (1) comprises, in a thickness direction from the outside towards the inside of the tank, at least one thermally insulating barrier (3) and at least one sealing membrane (4) supported by the thermally insulating barrier (3) and intended to be in contact with the fluid contained in the tank,

wherein the sealing membrane (4) comprises a plurality of membrane portions that are juxtaposed with and welded to one another, each membrane portion being delimited by a polygonal exterior periphery,

wherein the plurality of membrane portions comprises at least one regular membrane portion (17), the regular membrane portion (17) comprising a first regular series of corrugations, the first regular series of corrugations consisting of parallel first corrugations (12) extending in a first direction and mutually spaced by a first corrugation spacing (20) in a second direction perpendicular to the first direction,

the regular membrane portion (17) comprising regular planar portions (14) situated between the first corrugations (12) of the first regular series of corrugations and resting on the thermally insulating barrier (3), the regular planar portions having a dimension less than the first corrugation spacing (20) in the second direction,

wherein the plurality of membrane portions comprises at least one singular membrane portion (18), the singular membrane portion (18) comprising a first singular series of corrugations, the first singular series of corrugations consisting of first parallel corrugations (12) extending in the first direction, the singular membrane portion (18) comprising a singular planar

portion (24) having a dimension in the second direction that is strictly greater than N times the first corrugation spacing (20), N being a natural non-zero integer, the natural integer N being preferably greater than or equal to 2,
the regular membrane portion (17) being adjacent to the singular membrane portion (18) in the second direction,
wherein the first singular series of corrugations comprises at least two first corrugations situated respectively on either side of the singular planar portion (24) in the second direction,
and wherein the tank comprises an internal space delimited by the sealing membrane (4), the tank comprising an internal element (7) situated in the internal space of the tank,
the singular planar portion (24) of the singular membrane portion (18) being situated in line with and at some distance from the internal element (7) in the thickness direction of the tank wall (1).

[Claim 2] Sealed and thermally insulating tank (71) according to Claim 1, wherein the first singular series of corrugations comprises two groups which are situated respectively on either side of the singular planar portion (24) in the second direction, each group comprising at least N first corrugations (12) mutually spaced by the first corrugation spacing (20) in the second direction, N being said natural integer preferably greater than or equal to 2, the singular membrane portion (18) comprising regular planar portions (14) situated between the first corrugations (12) of the one same group.

[Claim 3] Sealed and thermally insulating tank (71) according to Claim 1 or Claim 2, wherein the regular membrane portion (17) is adjacent to the singular membrane portion (18) in the second direction so that one said first corrugation of the regular membrane portion

(17) adjacent to the exterior periphery is distant from one said first corrugation of the singular membrane portion (18) by a dimension equal to the first corrugation spacing (20) in the second direction.

[Claim 4] Sealed and thermally insulating tank (71) according to one of Claims 1 to 3, wherein the internal element (7) is situated at a predefined distance from the singular planar portion (24) in the thickness direction of the tank wall (1), the predefined distance being less than 200 mm, the distance being measured when the tank is empty.

[Claim 5] Sealed and thermally insulating tank (71) according to one of Claims 1 to 4, wherein the sealing membrane (4) comprises a second series of corrugations, the second series of corrugations consisting of parallel second corrugations (13) extending in the second direction, said regular and singular planar portions being situated between said second corrugations (13), the singular membrane portion (18) comprising at least two singular planar portions (24) situated on either side of one said second corrugation.

[Claim 6] Sealed and thermally insulating tank (71) according to Claim 5, wherein the second corrugations (13) of the second series of corrugations are mutually spaced by a second corrugation spacing in the first direction, the second corrugation spacing preferably being identical between said regular and singular planar portions.

[Claim 7] Sealed and thermally insulating tank (71) according to Claim 5 or 6, wherein the second corrugations (13) have a height in the thickness direction of the tank wall (1) that is less than a height in the thickness direction of the tank wall (1) of the first corrugations (12).

[Claim 8] Sealed and thermally insulating tank (71) according to one of Claims 5 to 7, wherein the sealing membrane (4) comprises corrugation nodes, each corrugation node being formed at the intersection between one said first corrugation and one said second corrugation and having a height in the thickness direction of the tank wall (1) that is greater than the height of the first corrugations (12).

[Claim 9] Sealed and thermally insulating tank (71) according to one of Claims 1 to 8, wherein the singular membrane portion (18) comprises an opening (25) delimited by a polygonal interior periphery, wherein the tank comprises a supporting foot (5) fixed to the bearing structure (2) and extending through the tank wall (1) and through said opening (25), the singular membrane portion (18) comprising at least one anchorage (19) to the supporting foot (5) on at least one side of the polygonal interior periphery, the anchorage (19) to the supporting foot preferably being on each side of the polygonal interior periphery.

[Claim 10] Sealed and thermally insulating tank (71) according to Claim 9, wherein the internal element (7) is connected to the supporting foot (5).

[Claim 11] Sealed and thermally insulating tank (71) according to Claim 9 or 10 taken in combination with one of Claims 5 to 8, wherein, between any side of the interior periphery and any side of the exterior periphery of the singular membrane portion (18), of the number of first corrugations (12) and the number of second corrugations (13) that the singular membrane portion (18) comprises, at least one of these numbers is less than or equal to three.

[Claim 12] Sealed and thermally insulating tank (71) according to one of Claims 5 to 8, wherein of the total number of first corrugations (12) that the singular membrane portion (18) comprises and the total number of second corrugations (13) that the singular membrane portion (18) comprises, at least one of these numbers is less than or equal to three.

[Claim 13] Sealed and thermally insulating tank (71) according to one of Claims 1 to 12, wherein the thermally insulating barrier (3) comprises a plurality of rectangular parallelepipedal insulating blocks juxtaposed with one another, each insulating block comprising lagging and a cover panel facing towards the inside of the tank, an upper face of the cover panel opposite to the lagging bearing a metal anchor plate, the collection of upper faces of the cover panels forming a supporting surface for the sealing membrane (4).

[Claim 14] Sealed and thermally insulating tank (71) according to one of Claims 1 to 13, wherein the sealing membrane (4) comprises a plurality of corrugated metal sheets of rectangular shape welded to one another, each corrugated metal sheet comprising two edges parallel to the first direction and two edges parallel to the second direction, each regular membrane portion or each singular membrane portion comprising one or more of said corrugated metal sheets.

[Claim 15] Sealed and thermally insulating tank (71) according to one of Claims 1 to 14, wherein each singular membrane portion and/or each regular membrane portion comprises at least one anchorage (19) to the thermally insulating barrier (3) on each side of the polygonal exterior periphery, each anchorage to the thermally insulating barrier (3) preferably being arranged continuously along the entire polygonal exterior periphery.

[Claim 16] Ship (70) for transporting a cold liquid product, the ship comprising a double hull (72) and a tank (71) according to one of Claims 1 to 15 arranged in the double hull.

[Claim 17] Transfer system for transferring a cold liquid product, the system comprising a ship (70) according to Claim 16, insulated pipes (73, 79, 76, 81) arranged in such a way as to connect the tank (71) installed in the hull of the ship to a floating or on-shore storage facility (77) and a pump for driving a stream of cold liquid product through the insulated pipes from or to the floating or on-shore storage facility to or from the tank of the ship.

[Claim 18] Method for loading or unloading a ship (70) according to Claim 16, wherein a cold liquid product is conveyed through insulated pipes (73, 79, 76, 81) from or to a floating or on-shore storage facility (77) to or from the tank of the ship (71).