

Description

Title of the invention : Sealed and thermally insulating tank

Technical field

[0001] The invention relates to the field of tanks, sealed and thermally insulating for storing and/or transporting a liquefied gas, such as tanks for transporting liquefied petroleum gas (also called LPG) having, for example, a temperature of between -50°C and 0°C, or for transporting liquefied natural gas (LNG) at approximately -162°C at atmospheric pressure.

[0002] These tanks can be installed onshore or on a floating structure. In the case of a floating structure, the tank can be intended to transport liquefied gas or to receive liquefied gas serving as fuel to propel the floating structure.

Technological background

[0003] The document WO2013093261 discloses a sealed and thermally insulating tank for storing a liquefied gas in a state of liquid-vapor equilibrium. Because of the heat transfer phenomena between the inside and the outside of the tank, the liquefied gas stored in the tank absorbs heat, which provokes the evaporation thereof. Therefore, the tank is equipped with a collection line which passes through a wall of the tank and which is intended to extract vapor from the gas-filled ceiling of the tank. The collection line opens in the internal space of the tank to define a passage between the internal space of the tank and a vapor collector which is arranged outside the tank and which is linked for example to a degassing mast. The collection line is connected to the vapor collector via a safety valve which is calibrated in order to ensure a discharging of the gas in vapor phase from the tank, when the vapor pressure in the gas-filled ceiling of the tank is above a threshold pressure. This makes it possible to control the pressure inside the tank so as to avoid overpressures likely to damage the tank.

[0004] The walls of the sealed tank have a multilayer structure, that is to say comprise, in succession, from the outside to the inside of the tank, a secondary thermally insulating barrier, a secondary sealed membrane, a primary thermally insulating barrier and a primary sealed membrane. In order to ensure the continuity of the primary sealed membrane around the collection line, the latter is tightly linked to the primary sealed membrane via a collar which has an L-shaped section and which protrudes inside the internal space of the tank. The bottom end of the collection line therefore protrudes in the internal space of the tank, beyond the sealed primary membrane.

[0005] For safety reasons, it is important to ensure that, when the tank is filled to its maximum level, the gas-filled ceiling of the tank remains connected with the interior of the collection line. Now, in order to avoid the bottom end of the collection line from being immersed in the liquid phase of the liquefied gas, thus preventing the gaseous phase present in the top part of the internal space of the tank from being extracted by the collection line, the maximum filling level of the tank is likely to be reduced, which is not fully satisfactory.

[0006] This drawback is also particularly critical when, in order to confer greater flexibility on the link between the sealed primary membrane and the collection line, the height of the collar is great and/or when the internal space of the tank has a low height.

Summary

[0007] One idea on which the invention is based is to propose a tank equipped with a collection line intended to collect vapor from the gas-filled ceiling of the tank and that passes through a ceiling wall of the tank and which makes it possible to take on an optimum quantity of liquefied gas while allowing the vapor to be extracted from the gas-filled ceiling via said collection line, and do so regardless of the vertical dimension of the portion of said vapor collection line protruding inside the internal space of the tank.

[0008] According to one embodiment, the invention provides a sealed and thermally insulating tank for storing a liquefied gas, said tank comprising:

- a plurality of walls defining an internal space intended to store liquefied gas, the plurality of walls comprising a top wall; and
- a collection line intended to extract, from the internal space of the tank, liquefied gas in vapor phase, said collection line passing through the top wall, and comprising a bottom end which opens in the internal space and which protrudes downward, beyond the top wall, to a height h ; and
- at least one first pipe intended to convey liquefied gas in vapor phase from the internal space of the tank to the collection line, said first pipe comprising a first and a second ends, the first end being situated in the internal space of the tank, outside of the collection line, and opening in said internal space at a height h_1 greater than h , the second end opening inside the collection line at a height h_2 greater than h , the first pipe comprising a diverted section which runs under the bottom end of the collection line in order to link the first and the second ends of the first pipe.

[0009] Thus, the first pipe ensures a fluidic connection between the gas-filled ceiling and the internal space of the collection line even if the bottom end of the collection line is immersed in the liquid phase of the liquefied gas.

[0010] According to embodiments, such a tank can comprise one or more of the following features.

[0011] According to one embodiment, the diverted section has a U-shape.

[0012] According to one embodiment, the height h is lower than a maximum loading level h_{max} . Thus, the pipe makes it possible to fill the tank above the bottom end of the collection line while allowing the extraction of vapor from the gas-filled ceiling in cases of overpressure.

[0013] According to one embodiment, the height h_1 is above the maximum loading level h_{max} .

[0014] According to one embodiment, the height h_2 is above the maximum loading level h_{max} .

[0015] According to one embodiment, the collection line is connected to a safety valve which is configured to extract liquefied gas in vapor phase from the collection line when the pressure in the internal space of the collection line is above a threshold pressure P_s .

[0016] According to one embodiment, the threshold pressure P_s satisfies the following inequality:

$$P_s < P_{design} - \varphi * g * \min;$$

$\min$: the smallest value out of $(h_2 - h_3)$ and l .

[0017] According to one embodiment, the threshold pressure P_s satisfies the following inequality:

$$P_s < P_{design} - \varphi * g * (h_2 - h_3);$$

P_{design} : the maximum design pressure for which the tank has been dimensioned;

φ : the density of the liquefied gas intended to be stored in the tank;

g : the normal acceleration of the earth's gravity;

h_2 : the height of the second end of the first pipe; and

h_3 : a height of the lowest point of the first pipe.

[0018] According to one embodiment, the threshold pressure P_s further satisfies the following inequality:

$$P_s > P_{design} - \varphi * g * (h_2 - h_3) - k;$$

with k lying between 100 and 1000 Pa.

[0019] According to another embodiment, the threshold pressure P_s satisfies the following inequality:

$$P_s < P_{design} - \varphi * g * l;$$

P_{design} : the maximum design pressure for which the tank has been dimensioned;

φ : the density of the liquefied gas intended to be stored in the tank;

g : the normal acceleration of the earth's gravity; and

l : a length of the first pipe which is likely to be filled with liquefied gas, when the tank is filled with liquefied gas to a maximum loading level h_{max} .

[0020] According to one embodiment, the threshold pressure P_s further satisfies the following inequality:

$$P_s > P_{design} - \varphi * g * l - k;$$

with k lying between 100 and 1000 Pa.

[0021] According to one embodiment, the top wall comprises a sealed primary membrane intended to be in contact with the liquefied gas stored in the tank, the sealed primary membrane having corrugations protruding toward the interior of the tank and the collection line protrudes inside the internal space, beyond the corrugations of the sealed primary membrane.

[0022] According to one embodiment, the collection line protrudes inside the internal space, beyond the top wall, by a vertical distance greater than 80 mm, preferably greater than 100 mm, for example of the order of 150 mm.

[0023] According to one embodiment, the tank comprises one or more lines intended for the loading and/or the offloading of the tank which run inside the collection line. Thus, the collection line forms both a gas dome structure and a liquid dome structure, which makes it possible to simplify the construction of the tank and reduce its cost.

[0024] According to one embodiment, the top wall comprises at least one primary thermally insulating barrier and a sealed primary membrane secured to the primary thermally insulating barrier, the top wall comprising metal anchoring plates which are fixed onto the primary thermally insulating barrier and to which metal sheets of the sealed primary membrane are tightly welded, the first pipe being anchored in an anchoring zone formed on one of the metal anchoring plates or formed on a portion of the sealed primary membrane which is anchored to one of the metal anchoring plates. This makes it possible to prevent the sealed primary membrane from being torn away.

[0025] According to one embodiment, the tank comprises a second pipe intended to convey liquefied gas in vapor phase from the internal space of the tank to the collection line, said second pipe comprising a first and a second ends, the first end being situated in the internal space of the tank, outside of the collection line and opening in said internal space at a height $h'1$ greater than h , the second end opening inside the collection line at a height $h'2$ greater than h .

[0026] According to one embodiment, the first end of the first pipe and the first end of the second pipe are disposed on either side of a median longitudinal vertical plane of the tank.

[0027] According to one embodiment, the first end of the first pipe and the first end of the second pipe are disposed in proximity to two ends of the top wall, opposite one another in a transverse direction at right angles to the longitudinal direction of the vessel.

[0028] According to one embodiment, the median longitudinal vertical plane of the tank is parallel to the longitudinal direction of the vessel on which the tank is incorporated and runs through the center of gravity of the vessel.

[0029] According to one embodiment, the top wall covers the internal space.

[0030] Such a tank can form part of an onshore storage installation, for example for storing LNG, or be installed in a floating, coastal or deep water structure, notably a methane tanker, a floating storage and regasification unit (FSRU), a floating production and storage offshore unit (FPSO), and the like.

[0031] According to one embodiment, the invention provides a vessel for transporting a fluid, the vessel comprising a double-hull and an abovementioned tank, disposed in the double-hull.

[0032] According to one embodiment, the invention also provides a method for loading or offloading such a vessel, wherein a fluid is conveyed through insulated pipelines from or to a floating or onshore storage installation to or from the tank of the vessel.

[0033] According to one embodiment, the invention also provides a transfer system for a fluid, the system comprising the abovementioned vessel, insulated pipelines arranged so as to link the tank installed in the hull of the vessel to a floating or onshore storage installation and a pump for driving a fluid through the insulated pipelines from or to the floating or onshore storage installation to or from the tank of the vessel.

Brief description of the figures

[0034] The invention will be better understood, and other aims, details, features and advantages thereof will become more clearly apparent from the following description of several particular embodiments of the invention, given purely in an illustrative and nonlimiting manner, with reference to the attached drawings.

[0035] [fig.1] Figure 1 is a schematic view, in transverse cross-section, of a sealed and thermally insulating tank equipped with a collection line and a pipe intended to convey vapor from the gas-filled ceiling of the tank to the interior space of the collection line.

[0036] [fig.2] Figure 2 is a front view illustrating in detail the collection line and the pipe of figure 1.

[0037] [fig.3] Figure 3 is a perspective bottom view illustrating in detail the collection line and the pipe of figure 1.

[0038] [fig.4] Figure 4 is a schematic view, in transverse cross-section, of a sealed and thermally insulating tank according to another embodiment.

[0039] [fig.5] Figure 5 is a schematic view of a zone of the primary sealing membrane of the top wall intended for the anchoring of a pipe, according to a first embodiment.

[0040] [fig.6] Figure 6 is a schematic view of a zone of the primary sealed membrane of the top wall intended for the anchoring of a pipe, according to a second embodiment.

[0041] [fig.7] Figure 7 illustrates means for anchoring the pipe to the top wall according to one embodiment.

[0042] [fig.8] Figure 8 is a cutaway schematic representation of a vessel comprising a liquefied natural gas storage tank and a terminal for loading/offloading this tank.

Description of the embodiments

[0043] In relation to figure 1, a sealed and thermally insulating tank 1 is observed, equipped with a collection line 2 intended to extract liquefied gas in vapor phase from the internal space of the tank. The tank 1 is intended to store a liquefied gas which is, for example, chosen from among liquefied natural gas (LNG) and liquefied petroleum gas (LPG).

[0044] The tank 1 is disposed inside a bearing structure 4 which is, for example, formed by the double-hull of a vessel but can, more generally, be formed by any type of rigid partition having appropriate mechanical properties.

[0045] The tank 1 is advantageously a tank with membranes. The tank 1 has a plurality of walls defining an internal space 3 intended for the storage of the liquefied gas. Each wall has a multilayer structure and comprises in the thicknesswise direction of said wall, from the outside to the inside of the tank 1, a secondary thermally insulating barrier 5 resting against the bearing structure 4, a sealed secondary membrane 6 resting against the secondary thermally insulating barrier 5, a primary thermally insulating barrier 7 resting against the sealed secondary membrane 6 and a sealed primary membrane 8 intended to be in contact with the liquefied gas stored in the tank 1 and resting against the primary thermally insulating barrier 7. According to an alternative embodiment, each wall comprises only a sealed primary membrane 8 and a primary thermally insulating barrier 7 resting against the bearing structure 4.

[0046] According to one embodiment of the invention, the sealed primary membrane 8 is a corrugated membrane. Thus, the sealed primary membrane 8 comprises a plurality of metal sheets comprising corrugations protruding toward the internal space 3 of the tank 1 and thus allowing the sealed primary membrane 8 to be deformed under the effect of the thermal and mechanical stresses generated by the liquefied gas stored in the tank 1. Such a tank 1 is for example of Mark III ® type as described in the patent application FR2691520. As an example, the tank 1 can also be of NO96 ® type, as described in the patent application FR2877638.

[0047] As illustrated in figure 1, the tank 1 comprises a bottom wall 9, a top wall 10 opposite the bottom wall 9, lateral walls 11, 12, 13 linking the bottom wall 9 and the top wall 10 and transverse walls 14 also linking the bottom wall 9 and the top wall 10. In the embodiment represented, the tank 1 has, in cross-section on a transverse plane, a section of octagonal form. Thus, the tank 1 has vertical lateral walls 11 and inclined lateral walls 12, 13 each linking one of the vertical lateral walls 11 to the bottom wall 9 or to the top wall 10.

[0048] The tank 1 comprises a collection line 2 which is intended to extract liquefied gas vapor contained in the gas-filled ceiling, that is to say the top portion of the internal space 3 of

the tank 1 in which the liquefied gas is in the gaseous state. The collection line 2 runs through the top wall 10 of the tank 1. The collection line 2 comprises an open bottom end 15 which opens into the internal space 3 of the tank 1 and protrudes downward, beyond the top wall 10. The bottom end 15 of the collection line 2 is positioned at a height h with respect to the bottom wall 9 of the tank 1. The height h is less than the maximum filling level $h_{\max}$ of the tank 1 such that, when the tank 1 is loaded with liquefied gas to its maximum level $h_{\max}$, the bottom end 15 of the collection line 2 is immersed in the liquid phase of the liquefied gas. The top end 16 of the collection line 2 is closed tightly by a cover 17.

[0049] The internal space 18 of the collection line 2 is connected to a vapor collector, not represented, via at least one line equipped with a safety valve 19. The safety valve 19 is calibrated so as to ensure a discharging of the gas in vapor phase, when the pressure in the internal space 18 of the collection line 2 exceeds a threshold pressure P_s . Thus, the collection line 2 aims, in case of overpressure, to extract vapor from the gas-filled ceiling and thus makes it possible to control the pressure in the gas-filled ceiling so as to avoid overpressures likely to damage the tank 1. As an example, the vapor collector is arranged to convey the extracted vapor to a degassing mast, to a burner, to a propulsion device of the vessel or to a liquefaction device in which the gas in vapor phase is re-liquefied then reintroduced into the tank 1 in liquid phase. In the embodiment represented, the internal space 18 of the collection line 2 is connected to the vapor collector via two safety valves 19, which ensures a level of redundancy that makes it possible to improve the reliability of the vapor extraction.

[0050] The collection line 2 is tightly linked to the sealed primary membrane 8 so as to ensure continuity of seal-tightness. For this, the collection line 2 is linked to the sealed primary membrane 8 via a collar 20 that has an L-shaped section. The collar 20 comprises a cylindrical portion of vertical orientation and an annular flange of horizontal orientation. The cylindrical portion is tightly wound all around the collection line 2. The annular flange protrudes horizontally from the top end of the cylindrical portion and is tightly welded to the sealed primary membrane 8. Such a collar 20 makes it possible to confer on the link between the collection line 2 and the sealed primary membrane 8 a flexibility that makes it possible to absorb the thermal and dynamic stresses.

[0051] Advantageously, as represented in figure 1, the tank 1 comprises one or more lines 21 intended for the loading and/or offloading of the tank 1 which run inside the collection line 2 and pass tightly through its cover 17. The line 21, when it is intended to ensure the offloading of the tank 1, extends to the immediate vicinity of the bottom wall 9. The bottom end of the line 21 is then equipped with an offloading pump, not represented in figure 1.

[0052] According to an embodiment that is not represented, the lines intended for the loading and/or the offloading are formed by vertical masts of a loading/offloading riser. The loading/offloading riser comprises, for example, a tripod structure, that is to say that it comprises three vertical masts which are each fixed to one another by crossmembers. Each of the masts is hollow and passes through the cover 17 of the collection line 2. Each of the masts thus forms a loading line making it possible to load liquefied gas into the tank 1, an offloading line making it possible to offload liquefied gas from the tank 1, or a relief well allowing a backup pump and an offloading line to be lowered, in case of failure of an offloading pump.

[0053] Thus, in the embodiments described above, the collection line 2 forms both a gas dome structure and a liquid dome structure. In other words, the functionalities of management of the pressure of the gas-filled ceiling and the functionalities of loading and/or offloading the tank 1 with liquefied gas are ensured by a single structure, which makes it possible to simplify the construction of the tank 1 and reduce its cost, by limiting the number of particular structures. However, on the other hand, when the collection line 2 is also used for the passage of at least one loading and/or offloading line 21, it has a greater diameter, which leads to an increase in the axial dimension of the collar 20 in order to confer a sufficient flexibility on the link between the collection line 2 and the sealing membrane, and to an increase in the dimension of the part of the collection line 2 which protrudes inside the tank 1.

[0054] As represented in figures 2 and 3, when the sealed primary membrane 8 is a corrugated membrane comprising corrugations protruding toward the internal space 3 of the tank 1, the collection line 2 protrudes, inside the internal space 3 of the tank 1, toward the bottom wall 9, beyond the corrugations.

[0055] According to one embodiment, the collection line 2 protrudes inside the tank 1, by a distance greater than 80 mm, preferably greater than 100 mm and for example of the order of 150 mm, with respect to the reference plane of the sealed primary membrane 8 of the top wall 10.

[0056] Moreover, the tank 1 is equipped with a pipe 22 which is intended to convey liquefied gas from the gas-filled ceiling to the internal space 18 of the collection line 2. The pipe 22 comprises a first end 23 which is situated in the internal space 3 of the tank 1, outside the collection line 2. The first end 23 opens into the internal space 3 of the tank 1 at a height h_1 which is greater than the height h of the bottom end 15 of the collection line 2 and which is also greater than the maximum filling level h_{max} of the tank 1. Moreover, the pipe 22 comprises a second end 24 which opens into the internal space 18 of the collection line 2

at a height h_2 . The height h_2 is greater than the height h of the bottom end 15 of the collection line 2 and greater than the maximum filling level h_{max} .

[0057] Thus, the first and second ends 23, 24 of the pipe 22 are situated above the maximum filling level h_{max} of the tank 1 while the bottom end 15 of the collection line 2 is situated below it, which makes it possible to ensure a fluidic connection between the gas-filled ceiling of the tank 1 and the internal space 18 of the collection line 2, even if the bottom end 15 of the collection line 2 is immersed in the liquid phase of the liquefied gas.

[0058] The pipe 22 further comprises a diverted section 25 which runs under the bottom end 15 of the collection line 2 in order to link the first end 23 and the second end 24 of the collection line 2. In the embodiment represented, the diverted section 25 has a U-shape which allows said pipe 22 to run under the bottom end 15 of the collection line 2 so as to link the first and second ends 23, 24 of the pipe 22 without having to pass through the portion of the collection line 2 which protrudes in the internal space 3 of the tank 1. The lowest portion of the diverted section 25 is disposed at a height h_3 from the bottom wall 9 of the tank 1.

[0059] As represented in figure 1, when the tank 1 is loaded with liquefied gas to its maximum filling level h_{max} such that the bottom end 15 of the collection line 2 is immersed in the liquid phase of the liquefied gas, the diverted section 25 of the pipe 22 is then filled with liquefied gas in liquid phase. However, the liquefied gas in liquid phase which is contained in the diverted section 25 of the pipe 22 can be driven out, provided that the pressure difference between the gas-filled ceiling and the internal space 18 of the collection line 2 is sufficient.

[0060] Advantageously, in order to guarantee that, in normal navigation conditions, the pressure of the gas-filled ceiling never reaches the maximum pressure P_{design} that the tank 1 can withstand, the additional overpressure needed to drive out the liquefied gas in the liquid state from the pipe 22 is taken into account in dimensioning the geometry of the pipe 22 and the threshold pressure P_s of the safety valve 19.

[0061] According to the geometry of the pipe 22, the dimensioning of the threshold pressure P_s depends either on the length l of the pipe 22 which is likely to be filled with liquefied gas, when the tank 1 is loaded with liquefied gas to its maximum loading level h_{max} , or on the height difference $h_2 - h_3$. Note that, in the embodiment of figure 1, the length l corresponds substantially to the length of the diverted portion of the pipe 22 which is situated below the maximum loading level h_{max} , advantageously the length l corresponds to the length of the diverted portion of the pipe 22 which is situated below the maximum loading level h_{max} .

[0062] In the example chosen to represent the invention, the pipe 22 has a U-shape with a central portion extending linearly; the two opposite ends being extended by two distal portions. When the tank does not incur any inclination, because of the pitch or the roll phenomenon, the central portion of the pipe 22 extends horizontally while the two distal portions extend vertically. Thus, the dimensioning of the threshold pressure P_s is done according to two particular cases taking account of the height of the pipe 22, that is to say the length of each distal portion under the maximum loading level h_{max} , and the length of the central portion of this pipe 22; the length l corresponding here to the sum of the lengths of the central portion and of the two distal portions under the maximum loading level h_{max} . The length of the central portion of the pipe 22 makes it possible to take account notably of the roll or pitch phenomena of the vessel, and therefore of the inclination of the liquefied gas, LPG/LNG or other gas, contained in the tank. Obviously, any other forms of the pipe 22, for example in which the central portion and the distal portions did not extend linearly, would not modify the function of this pipe 22 and its relationship to the dimensioning of the threshold pressure P_s .

[0063] According to a first embodiment, the length l of the pipe 22 which is likely to be filled with liquefied gas, when the tank 1 is loaded with liquefied gas to its maximum loading level h_{max} , is greater than the height difference h_2-h_3 . In this case, the threshold pressure P_s of the safety valve 19 observes the following inequality:

$$P_s < P_{design} - \varphi * g * (h_2 - h_3); \text{ with}$$

P_s : the threshold pressure of the safety valve 19;

P_{design} : the maximum design pressure for which the tank 1 has been dimensioned;

φ : the density of the liquefied gas intended to be stored in the tank 1;

g : the normal acceleration of the earth's gravity;

h_2 : the height of the second end 24 of the pipe 22; and

h_3 : the height of the lowest point of the pipe 22.

[0064] Advantageously, in order not to underdimension the threshold pressure P_s of the safety valve 19 and lose a capacity for pressure rise in the tank 1, the threshold pressure P_s also observes the following inequality:

$$P_s > P_{design} - \varphi * g * (h_2 - h_3) - k;$$

with k lying between 50 and 20 000 Pa, advantageously between 100 and 1000 Pa, preferentially of the order of 100 Pa.

[0065] According to a second embodiment, the length l of the pipe 22 which is likely to be filled with liquefied gas, when the tank 1 is loaded with liquefied gas to its maximum loading

level $h_{\max}$, is less than the height difference h_2-h_3 . In this case, the threshold pressure P_s of the safety valve 19 observes the following inequality:

$$P_s < P_{\text{design}} - \varphi \cdot g \cdot l.$$

[0066] Advantageously, in order not to underdimension the threshold pressure P_s , the latter also observes the following inequality:

$$P_s > P_{\text{design}} - \varphi \cdot g \cdot l - k;$$

with k lying between 50 and 20 000 Pa, advantageously between 100 and 1000 Pa, preferentially of the order of 100 Pa.

[0067] In relation to figure 4, another embodiment of the invention is described hereinbelow. In this embodiment, the tank 1 comprises at least two pipes 22, 26 which are each intended to convey liquefied gas in vapor phase from a zone of the gas-filled ceiling to the internal space 18 of the collection line 2.

[0068] The second pipe 26 comprises:

- a first end 27 which is situated in the internal space 3 of the tank 1, outside the collection line 2, and opens at a height h'_1 which is greater than the height h and greater than $h_{\max}$;
- a second end 28 which opens into the internal space 18 of the collection line 2 at a height h'_2 which is greater than h and than $h_{\max}$; and
- a diverted section 29 which runs under the bottom end 15 of the collection line 2 in order to link the first end 27 and the second end 28 of the second pipe 26.

[0069] The first ends 23, 27 of the pipes 22, 26 open inside the tank 1 in two zones of the internal space 3 of the tank 1 which are situated on either side of a median longitudinal plane P which is vertical, parallel to the longitudinal direction of the vessel and runs through the center of gravity of the vessel. Advantageously, the two zones of the internal space 3 of the tank 1 are situated in proximity to two ends of the top wall 10, opposite one another in a transverse direction at right angles to the longitudinal direction of the vessel. Thus, if the vessel is immobilized in an inclined position in which it exhibits a list inclination, at least one of the two pipes 22, 26 opens at the highest point of the tank 1 and is thus able to discharge the vapor phase of the cryogenic fluid stored in the tank 1.

[0070] Moreover, advantageously, the first ends 23, 27 of the two pipes 22, 26 are situated in proximity to the median transverse plane which is orthogonal to the longitudinal direction of the vessel, that is to say that they are situated at a distance from one of the transverse walls 14 of the tank 1 lying between 30 and 70% of the dimension of the tank 1 in the longitudinal direction of the vessel. That makes it possible to limit the risks of the first ends 23, 27 of the pipes 22, 26 being immersed in the liquid phase of the liquefied gas when the vessel is immobilized in an inclined position in which it exhibits a trim inclination.

[0071] In relation to figures 5 and 6, a zone for anchoring a pipe 22 on the top wall 10 is illustrated according to two embodiments. In these two embodiments, in order to limit the stresses of the sealed primary membrane 8 which would be due to the anchoring of the pipe or pipes 22, the latter are anchored on metal anchoring plates 30, 31, 32 which are directly fixed onto the insulating panels of the primary thermally insulating barrier 7 and to which are tightly welded sheets 33, 34, 35, 36, 37 of the sealed primary membrane 8.

[0072] Figure 5 illustrates, in dotted lines, the position of metal anchoring plates 30, 31 which are fixed onto the insulating panels of the primary thermally insulating barrier 7. The metal anchoring plates 30 are disposed in two mutually orthogonal directions. The metal sheets 33, 34, 35, 36 of the sealed primary membrane 8 are lap welded to one another along the metal anchoring plates 30. Furthermore, the edge of the metal plates 33, 34, 35, 36 which is covered by the edge of an adjacent metal sheet is fixed by welding onto one of the metal anchoring plates 30. The corner zones of the metal sheets 33, 34, 35, 36 are cut such that, at the intersection between four adjacent metal sheets 33, 34, 35, 36, a zone of one of the metal anchoring plates 30 is not covered by any of the four adjacent metal sheets 33, 34, 35, 36. Advantageously, this uncovered zone forms an anchoring zone 38 for a pipe 22.

[0073] In figure 6, a metal anchoring plate 32, represented in dotted lines, is covered by a metal sheet 37 of the sealed primary membrane 8. The metal sheet 37 comprises an orifice 39. The metal sheet 37 is tightly welded, to the metal anchoring plate 32, all around said orifice. The zone of the metal anchoring plate 32 which is disposed opposite the orifice 39 of the metal sheet 37 can thus constitute an anchoring zone 40 for a pipe 22. According to an alternative embodiment, the anchoring zone 40 of the pipe can be formed on a metal sheet 37 provided that this anchoring zone is in line with the anchoring of the metal sheet 37 on the metal anchoring plate 32.

[0074] Figure 7 illustrates means for anchoring the pipe 22 to the top wall 10 according to one embodiment. In this embodiment, the anchoring means comprise a clamp 41 in which the pipe 22 runs. The clamp 41 is fixed to an anchoring zone, as described above in relation to figures 5 and 6. According to one embodiment, the pipe 22 is slidingly mounted inside the clamp 41 so as to allow the pipe 22 to contract or expand freely under the effect of the temperature differences.

[0075] According to another embodiment, not represented, the pipe 22 comprises one or more compensation devices making it possible to provide it with flexibility in the longitudinal direction so as to allow its contraction and expansion. The compensation device can notably be produced by bellows or by a compensation loop.

[0076] Referring to figure 8, a cutaway view of a methane tanker vessel 170 shows a sealed and insulated tank 171 of generally prismatic form mounted in the double-hull 172 of the vessel. The wall of the tank 171 comprises a primary membrane intended to be in contact with the LNG contained in the tank, a secondary membrane arranged between the primary membrane and the double-hull 172 of the vessel, and two thermally insulating barriers arranged respectively between the primary membrane and the secondary membrane and between the secondary membrane and the double-hull 172.

[0077] As is known per se, loading/offloading pipelines 173 disposed on the top deck of the vessel can be connected, by means of appropriate connectors, to a maritime or port terminal to transfer an LNG cargo from or to the tank 171.

[0078] Figure 8 also represents an example of a maritime terminal comprising a loading and offloading station 175, a submarine line 176 and an onshore installation 177. The loading and offloading station 175 is a fixed offshore installation comprising a mobile arm 174 and a riser 178 which supports the mobile arm 174. The mobile arm 174 bears a bundle of insulated flexible pipes 179 that can be connected to the loading/offloading pipelines 173. The orientable mobile arm 174 adapts to all methane tanker templates. A link line not represented extends inside the riser 178. The loading and offloading station 175 allows the methane tanker 170 to be loaded and offloaded from or to the onshore installation 177. This comprises liquefied gas storage tanks 180 and link lines 181 linked by the submarine line 176 to the loading or offloading station 175. The submarine line 176 makes it possible to transfer liquefied gas between the loading or offloading station 175 and the onshore installation 177 over a great distance, for example 5 km, which makes it possible to keep the methane tanker vessel 170 at a great distance from the coast during the loading and offloading operations.

[0079] To create the pressure necessary for the transfer of the liquefied gas, pumps onboard the vessel 170 and/or pumps with which the onshore installation 177 is equipped and/or pumps with which the loading and offloading station 175 is equipped are implemented.

[0080] Although the invention has been described in relation to several particular embodiments, it is obvious that it is in no way limited thereto and that it encompasses all the technical equivalents of the means described, and the combinations thereof if they fall within the context of the claimed invention.

[0081] The use of the verb “comprise” or “include” and its conjugate forms does not preclude the presence of elements or steps other than those stated in a claim.

[0082] In the claims, any reference symbol between parentheses should not be interpreted as a limitation of the claim.

[0083] In the claims, any reference symbol between parentheses should not be interpreted as a limitation of the claim.

Claims

[Claim 1] A sealed and thermally insulating tank (1) for storing a liquefied gas, said tank (1) comprising:

- a plurality of walls defining an internal space (3) intended to store liquefied gas, the plurality of walls comprising a top wall (10); and
- a collection line (2) intended to extract, from the internal space (3) of the tank (1), liquefied gas in vapor phase, said collection line (2) passing through the top wall (10), and comprising a bottom end (15) which opens into the internal space (3) and which protrudes downward, beyond the top wall (10), to a height h ; and
- at least one first pipe (22) intended to convey liquefied gas in vapor phase from the internal space (3) of the tank (1) to the collection line (2), said first pipe (22) comprising a first and a second ends (23, 24), the first end (23) being situated in the internal space (3) of the tank (1), outside of the collection line (2), and opening into said internal space (3) at a height h_1 greater than h , the second end (24) opening inside the collection line (2) at a height h_2 greater than h , the first pipe (22) further comprising a diverted section (25) which runs under the bottom end (15) of the collection line (2) in order to link the first and the second ends (23, 24) of the first pipe (22), the collection line (2) being connected to a safety valve (19) which is configured to extract liquefied gas in vapor phase from the collection line (2) when the pressure in the internal space (18) of the collection line (2) is greater than a threshold pressure P_s , and in which the threshold pressure P_s satisfies the following inequality:

$P_s < P_{\text{design}} - \varphi * g * \min$; with:

P_{design} : the maximum design pressure for which the tank (1) has been dimensioned;

φ : the density of the liquefied gas intended to be stored in the tank (1);

g : the normal acceleration of the earth's gravity

$\min$: the smallest value out of $(h_2 - h_3)$ and l ;

h_2 : the height of the second end of the first pipe (22); and

h_3 : a height of the lowest point of the first pipe (22);

l : a length of the first pipe (22) which is likely to be filled with liquefied gas,

when the tank (1) is loaded with liquefied gas to a maximum loading level h_{max} .

[Claim 2] The tank (1) as claimed in claim 1, wherein the diverted section (25) has a U-shape.

[Claim 3] The tank (1) as claimed in claim 1 or 2, wherein the height h is lower than a maximum loading level h_{max} and the heights h_1 and h_2 are above the maximum loading level h_{max} .

[Claim 4] The tank (1) as claimed in any one of claims 1 to 3, wherein the threshold pressure P_s further satisfies the following inequality:

$$P_s > P_{design} - \varphi * g * \min - k ;$$

with k lying between 100 and 1000 Pa.

[Claim 5] The tank (1) as claimed in any one of claims 1 to 4, wherein the top wall (10) comprises a sealed primary membrane (8) intended to be in contact with the liquefied gas stored in the tank (1), the sealed primary membrane (8) having corrugations protruding toward the interior of the tank (1) and wherein the collection line (2) protrudes inside the internal space (3), beyond the corrugations of the sealed primary membrane (8).

[Claim 6] The tank (1) as claimed in any one of claims 1 to 5, wherein the collection line (2) protrudes inside the internal space (3), beyond the top wall (10), by a vertical distance greater than 80 mm.

[Claim 7] The tank (1) as claimed in any one of claims 1 to 6, wherein the tank (1) comprises one or more lines intended for the loading and/or the offloading of the tank (1) which run inside the collection line (2).

[Claim 8] The tank (1) as claimed in any one of claims 1 to 7, wherein the top wall (10) comprises at least one primary thermally insulating barrier (7) and a sealed primary membrane (8) secured to the primary thermally insulating barrier, the top wall (10) comprising metal anchoring plates (30, 31, 32) which are fixed onto the primary thermally insulating barrier (7) and to which metal sheets (33, 34, 35, 36, 37) of the sealed primary membrane (8) are tightly welded, the first pipe (22) being anchored in an anchoring zone (38, 40) formed on one of the metal anchoring plates (30, 31, 32) or formed on a portion of the sealed primary membrane (8) which is anchored to one of the metal anchoring plates (30, 31, 32).

[Claim 9] The tank (1) as claimed in any one of claims 1 to 8, wherein the tank (1) comprises a second pipe (26) intended to convey liquefied gas in vapor phase from the internal space (3) of the tank (1) to the collection line (2), said second pipe (26) comprising a first and a second ends (27, 28), the first end (27) being situated in the internal space (3) of the tank (1), outside of the collection line (2), and opening into said internal space (3) at a height $h'1$ greater than h , the second end (28) opening inside the collection line (2) at a height $h'2$ greater than h .

[Claim 10] The tank (1) as claimed in claim 9, wherein the first end (23) of the first pipe (22) and the first end (27) of the second pipe (26) are disposed on either side of a median longitudinal vertical plane of the tank (1).

[Claim 11] A vessel (170) for transporting a fluid, the vessel comprising a double-hull (172) and a tank (171) as claimed in any one of claims 1 to 10, disposed in the double-hull.

[Claim 12] A system for transferring a fluid, the system comprising a vessel (170) as claimed in claim 11, insulated pipelines (173, 179, 176, 181) arranged so as to link the tank (171) installed in the hull of the vessel to a floating or onshore storage installation (177) and a pump for driving a flow of fluid through the insulated pipelines from or to the floating or onshore storage installation to or from the tank of the vessel.

[Claim 13] A method for loading or offloading a vessel (170) as claimed in claim 11, wherein a fluid is conveyed through insulated pipelines (173, 179, 176, 181) from or to a floating or onshore storage installation (177) to or from the tank (171) of the vessel.