

Description

Title of the invention: Method for manufacturing a wall for a leakproof and thermally insulating tank

Technical field

[0001] The invention relates to the field of the leakproof and thermally insulating tanks, with membranes, for the storage and/or the transportation of fluid. In particular, the invention relates to the field of the sealed and thermally insulating tanks for the storage and/or transportation of liquefied gas at low temperature, such as tanks for the transportation of liquefied petroleum gas (also called LPG) having, for example, a temperature of between -50°C and 0°C, or for the transportation of liquefied natural gas (LNG) at approximately -162°C at atmospheric pressure. These tanks can be installed on shore or on a floating structure. In the case of a floating structure, the tank can be intended for the transportation of liquefied gas or intended to receive liquefied gas serving as fuel for the propulsion of the floating structure.

[0002] The invention relates more particularly to a method for manufacturing a wall of such a leakproof and thermally insulating tank.

Technological background

[0003] In the state of the art, leakproof and thermally insulating tanks with membranes are known. The walls of these tanks comprise a multilayer structure having, from the inside to the outside of the tank, at least one primary leakproof membrane intended to be in contact with the fluid stored in the tank and a primary thermally insulating barrier and, optionally, a secondary membrane and a secondary thermally insulating barrier.

[0004] The thermally insulating barriers comprise a plurality of insulating panels which are juxtaposed in parallel rows. The primary and secondary membranes are respectively supported by the insulating panels of the primary thermally insulating barrier and those of the secondary thermally insulating barrier.

[0005] The insulating panels each comprise a layer of expanded insulating foam. The layer of expanded insulating foam is produced by a continuous free-expansion foaming method. At the output of the foam manufacturing method, the insulating foam is cut to the desired dimensions of the panel to be produced. Furthermore, the inner and outer faces of the layer of insulating foam are ground down in order to ensure their flatness. Subsequently, sheets of plywood are generally glued against one and/or the other of the inner and outer faces of the layer of expanded insulating foam.

[0006] The sealing membranes are either metal membranes or composite membranes. The metal membranes are produced by means of metal sheets which are welded, in situ inside the tank, to one another and to weld supports fixed onto the inner faces of the insulating panels so as to fix the metal sheets to the insulating panels. The composite membranes comprise rigid membrane elements which are glued onto the inner faces of the insulating panels. Flexible membrane elements are glued straddling the rigid membrane elements of the adjacent insulating panels so as to ensure the sealing of the composite membrane.

[0007] Thus, the manufacturing of the walls of the leakproof and thermally insulating tanks with membranes is particularly complex and entails numerous steps.

Summary

[0001] One idea on which the invention is based is to propose a method for manufacturing a wall of a leakproof and thermally insulating tank with membranes which is simpler and less costly.

[0002] According to one embodiment, the invention provides a method for manufacturing a wall for a leakproof and thermally insulating tank comprising at least one thermally insulating barrier and a sealing membrane resting against the thermally insulating barrier, the method comprising:

- manufacturing a plurality of wall elements, the manufacturing of each wall element comprising:
 - supplying a leakproof plate;
 - placing an expandable insulating foam solution against the leakproof plate; and
 - expanding the expandable insulating foam solution against said leakproof plate so as to produce a layer of expanded insulating foam adhering to the leakproof plate;
- anchoring said duly manufactured wall elements to a supporting structure; the layer of expanded insulating foam of said wall elements forming at least a part of the thermally insulating barrier; and
- assembling the leakproof plates of said wall elements tightly such that said leakproof plates form at least a part of the sealing membrane.

[0003] Thus, according to such a method, the layer of expanded insulating foam intended to form a part of the thermally insulating barrier and the leakproof plate intended to form a part of the sealing membrane are fixed to one another directly in the manufacturing of the layer of expanded insulating foam. This makes it possible to considerably simplify the manufacturing of the wall.

- [0004] Furthermore, the leakproof plate forms a reference surface in the foaming such that the flatness of the face of the wall element formed by the leakproof plate does not have to be ground down to ensure its flatness, which makes it possible to even further simplify the production of the wall element.
- [0005] According to embodiments, such a method can comprise one or more of the following features.
- [0006] According to one embodiment, the layer of expanded insulating foam is a polyurethane foam (PUR) or a polyisocyanurate foam (PIR).
- [0007] According to one embodiment, the expandable insulating foam solution comprises at least a polyol, a polyisocyanate and an expansion agent.
- [0008] According to one embodiment, the leakproof plate comprises a leakproof film.
- [0009] According to one embodiment, the step of assembly of the leakproof plates comprises the gluing of an additional leakproof film straddling the rigid composite films.
- [0010] According to one embodiment, the leakproof film is a rigid composite film.
- [0011] According to one embodiment, the rigid composite film comprises an aluminum sheet inserted between two layers of fibers.
- [0012] Obviously, other types of leakproof films can be produced.
- [0013] According to one embodiment, the leakproof plate comprises a metal plate.
- [0014] According to one embodiment, the metal plate comprises corrugations. According to one embodiment, the metal plate comprises two series of parallel corrugations, the corrugations of one of the series of corrugations being at right angles to the corrugations of the other series of corrugations.
- [0015] According to one embodiment, the metal plate has a plurality of reliefs protruding in a thicknesswise direction with respect to the plane of the metal plate.
- [0016] According to one embodiment, each relief comprises a base forming the link between the relief and the flat portion, and comprising at least one peak, the base comprising, in the plane formed by the flat portion, a first dimension equal to the diameter of the smallest circle circumscribed around the base and a second dimension equal to the diameter of the largest circle inscribed in the base, and the distance between the peak and the base in the thicknesswise direction forming a height of the relief. The diameter of the smallest circle circumscribed around the base is understood to be the smallest circle diameter situated around and outside the base, and having at least two points of intersection with the base

such that the circle surrounds the base without cutting it. For example, in the case of a triangular base, this circle is centered on the point of intersection of the right bisectors of the sides of the base. The diameter of the largest circle inscribed in the base is understood to be the diameter of the largest circle situated inside the base and having at least two points of intersection with the base such that the circle is situated entirely in the base without cutting it. For example, in the case of a triangular base, this circle is centered on the point of intersection of the bisectors of the base.

[0017] According to one embodiment, the metal plate comprises, in all the directions of the plane, at least one relief.

[0018] According to one embodiment, the height of the relief is less than 20 mm, advantageously between 8 mm and 20 mm, preferably between 10 mm and 14 mm.

[0019] According to one embodiment, each relief is separated from an adjacent relief in all the directions of the plane by a distance less than or equal to 2 times the first dimension of the base.

[0020] According to one embodiment, the ratio of the first dimension of the base to the height of the relief is less than or equal to 2.

[0021] According to one embodiment, the ratio of the second dimension of the base to the height of the relief is less than or equal to 0.6.

[0022] According to one embodiment, the reliefs are produced by forging, preferably by drawing, or else by stamping, die-stamping, etc.

[0023] According to one embodiment, the metal plate has a thickness of between 0.5 mm and 2 mm.

[0024] According to one embodiment, the metal plates are produced in a metal material with a Young's modulus of between 130 GPa and 230 GPa.

[0025] According to one embodiment, the metal plates are produced in a metal material with a yield strength greater than 170 MPa.

[0026] According to one embodiment, the metal plate is produced in stainless steel or high-manganese steel.

[0027] Thus, for a stainless steel having a Young's modulus of 200 GPa, the minimum thickness of the plate is therefore approximately equal to 0.58 mm. For a high manganese steel having a Young's modulus of 170 GPa, the minimum thickness of the plate is therefore approximately equal to 0.68 mm.

[0028] According to one embodiment, the number of reliefs per linear meter of metal plate N_{relief} lies within the following range:

$$\frac{\alpha \times \Delta T \times 10^6}{11 \times h} \leq N_{\text{relief}} \leq \frac{\alpha \times \Delta T \times 10^7}{35 \times h}$$

with α the coefficient of thermal expansion of the metal plate in K^{-1} , ΔT the temperature difference between the ambient temperature and the temperature of the fluid stored in the tank in K, and h the height of the relief in mm.

[0029] According to one embodiment, each relief has a pyramidal or half-ellipsoid form, for example a half-sphere or pyramid with square base.

[0030] According to one embodiment, the base has an ellipse form, for example a circle, or a polygon form.

[0031] According to one embodiment, each relief has a form flaring toward the base.

[0032] According to one embodiment, the step of assembly of the leakproof plates comprises tightly welding the metal plates to one another.

[0033] According to one embodiment, the metal plates are welded edge-to-edge.

[0034] According to another embodiment, the metal plates are welded to one another by means of additional metal parts which are welded straddling the metal plates of the adjacent wall elements.

[0035] According to one embodiment, the leakproof plate comprises a metal plate and one or more anchoring members intended to anchor a primary insulating panel on said wall element.

[0036] According to one embodiment, the leakproof plate comprises a metal plate and one or more anchoring plates.

[0037] According to one embodiment, the leakproof plate comprises one or more thicker zones in which one or more tappings are formed that are intended to receiving a fixing stud.

[0038] According to one embodiment, the leakproof plate comprises a metal plate and one or more thermal protection bands along the edges of said metal plate.

[0039] According to variant embodiments that are not illustrated and are not covered by the claims, the expandable insulating foam solution is not expanded against the metal plate. Thus, the metal plate is glued to the layer of expanded insulating foam after its formation. Such variant embodiments can be freely combined with the various features of the embodiments described in the present document, and in particular with the following

features:

- one or more thermal protection bands are positioned along the edges of the metal plate glued onto the layer of expanded insulating foam;
- the metal plate comprises one or more anchoring members intended for the anchoring of a primary insulating panel on said wall element; and/or
- the metal plate comprises one or more thicker zones in which one or more tappings are formed that are intended to receive a fixing stud.

[0040] According to one embodiment, the expandable insulating foam solution is expanded in a laminator limiting the expansion of the insulating foam solution.

[0041] According to one embodiment, the laminator is a dual-band laminator comprising a lower band, an upper band and side walls which together form a tunnel of rectangular section.

[0042] According to one embodiment, the laminator is arranged such that the limit to the expansion of the expandable insulating foam solution results in a layer of expanded insulating foam having a volume, at the output of the laminator, representing between 92% and 99% of the expansion volume of this expandable insulating foam solution in the case of free expansion. This makes it possible to give the layer of expanded insulating foam excellent mechanical performance levels.

[0043] According to one embodiment, the manufacturing of each wall element comprises depositing one or more fiber reinforcements on the leakproof plate and impregnating said fiber reinforcements when the expandable insulating foam solution is placed against the leakproof plate.

[0044] According to one embodiment, the fiber reinforcements are fiber mats.

[0045] According to one embodiment, the fiber reinforcements are deposited parallel to one another and to the leakproof plate.

[0046] According to one embodiment, the fiber reinforcements comprise glass fibers which are bound together by a resin, such as a polyurethane resin.

[0047] According to one embodiment, during the manufacturing of each wall element, a support is made to adhere to a face of the layer of expanded insulating foam opposite the leakproof plate.

[0048] According to one embodiment, the support is a sheet of plywood.

[0049] According to one embodiment, the support is glued to the layer of expanded polymer foam.

[0050] According to one embodiment, the leakproof plate is placed on a transfer band, the expandable insulating foam solution is deposited against the leakproof plate resting on the transport band, and the leakproof plate and the insulating foam solution are led to the laminator by means of said transfer band.

[0051] According to one embodiment, at least one face of the layer of expanded insulating foam opposite the leakproof plate is machined. Advantageously, when a laminator is used to limit the expansion of the insulating foam solution, the face of the layer of expanded insulating foam opposite the leakproof plate is machined at the output of the laminator.

[0052] According to one embodiment, the invention also provides a wall for a leakproof and thermally insulating tank obtained by means of the abovementioned method, said wall comprising a plurality of wall elements, each wall element comprising a leakproof plate and a layer of expanded insulating foam adhering directly to the leakproof plate, said wall elements being anchored to a supporting structure and arranged alongside one another such that the layers of expanded insulating foam form a thermally insulating barrier, the leakproof plates of said wall elements being assembled tightly to one another so as to form at least a part of a sealing membrane.

[0053] Since the layer of expanded insulating foam adheres directly to the leakproof plate, there is therefore no intermediate layer of glue.

[0054] According to one embodiment, the invention also provides a leakproof and thermally insulating tank for storing a fluid comprising an abovementioned wall.

[0055] 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.

[0056] According to one embodiment, the invention provides a ship for the transportation of a fluid, the ship comprising a double-hull and an abovementioned tank, arranged in the double-hull.

[0057] According to one embodiment, the invention also provides a method for loading or offloading such a ship, in which a fluid is conveyed through insulated pipelines from or to a floating or onshore storage installation to or from the tank of the ship.

[0058] According to one embodiment, the invention also provides a transfer system for a fluid, the system comprising the abovementioned ship, insulated pipelines arranged so as to link the tank installed in the hull of the ship 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 ship.

Brief description of the figures

[0059] 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 in a purely illustrative and nonlimiting manner, with reference to the attached drawings.

[0060] [Fig.1] figure 1 is a schematic illustration of a multilayer structure of a wall of a tank with membranes.

[0061] [Fig.2] figure 2 is a schematic illustration of a wall element associating a leakproof plate intended to form a part of a sealing membrane and a layer of expanded insulating foam intended to form a part of a thermally insulating barrier.

[0062] [Fig.3] figure 3 is a schematic illustration of an installation for manufacturing a wall element.

[0063] [Fig.4] figure 4 illustrates a wall element according to another embodiment.

[0064] [Fig.5] figure 5 illustrates in detail the leakproof plate of the wall element of figure 4.

[0065] [Fig.6] figure 6 is a schematic cross-sectional view on the line II-II of figure 5.

[0066] [Fig.7] figure 7 is a detail view of a relief according to a variant embodiment of the leakproof plate of figure 5.

[0067] [Fig.8] figure 8 is a cross-sectional view on the plane IV-IV of figure 7.

[0068] [Fig. 9] figure 9 schematically represents a wall element according to a variant embodiment of figure 4.

[0069] [Fig. 10] figure 10 schematically represents a zone of a secondary wall element intended for the anchoring of a primary insulating panel according to one embodiment.

[0070] [Fig. 11] figure 11 schematically represents a wall element according to another embodiment.

[0071] [Fig. 12] figure 12 schematically represents a wall element according to another embodiment.

[0072] [Fig. 13] figure 13 is a perspective view of the corrugated metal plate of the wall element of figure 10.

[0073] [Fig. 14] figure 14 is a cutaway schematic representation of a methane tanker tank and of a terminal for loading/offloading this tank.

Description of embodiments

[0074] Figure 1 represents the structure of a wall 31 of a tank with membranes. The wall has a multilayer structure and comprises, from the outside to the inside of the tank, a secondary thermally insulating barrier 14 comprising secondary insulating panels 17 anchored to a supporting structure 15, a secondary membrane 13 resting against the secondary thermally insulating barrier 14, a primary thermally insulating barrier 12 comprising primary insulating panels 14 resting against the secondary membrane 13 and anchored to the supporting structure 15 or to the secondary insulating panels 14 and a primary membrane 1 which rests against the primary thermally insulating barrier 12 and which is intended to be in contact with the liquefied gas contained in the tank.

[0075] To produce such a wall, several wall elements 32, one of which is represented in figure 2, are previously manufactured. Each wall element 32 comprises a leakproof plate 33 intended to form a part of one of the primary 1 and secondary 13 membranes and a layer of expanded insulating foam 34 intended to form a part of the corresponding thermally insulating barrier.

[0076] A method for manufacture of such a wall element 32 and an installation 35 that allows this method to be implemented are described below in relation to figure 3.

[0077] The installation 35 comprises a transfer band 36, a distributor 37 for distributing an expandable insulating foam solution, and a laminator 38. The transfer band 36 is intended to receive the leakproof plate 33 intended to form a part of one of the primary 1 and second 13 membranes of the wall of the tank. According to one embodiment, before being arranged on the transfer band 36, the leakproof plate 33 has previously been cut to the dimensions of the wall element 32 to be produced. According to another embodiment, the leakproof plate 33 is arranged continuously on the transfer band 36 and is cut to the dimensions of the wall element 32 to be produced after the layer of expanded insulating foam 34 has been formed and expanded.

[0078] Furthermore, as represented in figure 3, the transfer band 36 is also intended to receive fiber reinforcements 39, such as fiber mats. In the embodiment, the fiber reinforcements 39 are supplied in reel form. The fiber reinforcements 39 are wound out and brought parallel to one another against the leakproof plate 33. According to one embodiment, the fiber reinforcements 39 are previously cut to the dimensions of the wall element 32 to be produced. According to another embodiment, the fiber reinforcements

39 are arranged continuously and cut after the formation and the expansion of the layer of expanded insulating foam 34. The fiber reinforcements 39 comprise, for example, glass fibers which are bound together by a resin, such as a polyurethane resin.

[0079] The distributor 37 is situated above the transfer band 36. It is intended to dispense an expandable insulating foam solution 40 on the fiber reinforcements 39 and the leakproof plate 33. The expandable insulating foam solution 40 comprises a mixture of chemical components, of inflating agents and of other possible functional agents allowing the formation of an expanded insulating foam. The components of the expandable foam solution are mixed in a mixer, not represented, before being led to the distributor 37.

[0080] According to one embodiment, the expanded insulating foam to be manufactured is a polyurethane foam (PUR) or a polyisocyanurate foam (PIR). Also, the expanded insulating foam solution comprises at least a polyol, a polyisocyanate and an expansion agent, also referred to as inflating agent.

[0081] The polyol is, for example, chosen from among the polyether polyols, the polyester polyols and the mixtures thereof. The polyisocyanate is, for example, chosen from among the aromatic, aliphatic, cycloaliphatic and arylaliphatic polyisocyanates and the mixtures thereof.

[0082] The inflating agent consists of a physical and/or chemical expansion agent, preferably a combination of both types. According to one embodiment, the physical expansion agent is chosen from among the alkanes and the cycloalkanes that have at least 4 carbon atoms, the dialkyl ethers, the esters, the ketones, the acetals, the fluoroalkanes and the fluoroolefins that have between 1 and 8 carbon atoms and the tetraalkylsilanes that have between 1 and 3 carbon atoms in the alkyl chain, in particular tetramethylsilane, or a mixture thereof. According to another embodiment, the physical expansion agent chosen is 1,1,1,3,3-pentafluoropropane, or HFC-245fa, (marketed by the company Honeywell), 1,1,1,3,3-pentafluorobutane, or 365mfc, (for example solkane® 365mfc marketed by the company Solvay), 2,3,3,3-tetrafluoroprop-1-ene, 1,1,1,2,3,3,3-heptafluoropropane (also internationally designated as HFC-227ea, for example marketed by the company Dupont), 1,1,1,4,4,4-hexafluorobutene (for example HFO FEA1100 marketed by the company Dupont), trans-1-chloro-3,3,3-trifluoropropene (solstice LBA - company Honeywell) or a mixture thereof. According to one embodiment, the chemical expansion agent consists of water.

[0083] According to one embodiment, the expandable insulating foam solution 40 comprises a reaction catalyst which will for example be able to be chosen from among the tertiary

amines, such as N,N-dimethylcyclohexylamine or N,N-dimethylbenzylamine, or from among the organo-metallic compounds based on bismuth, on potassium or on tin.

[0084] The distributor 37 is arranged to dispense the expandable insulating foam solution 40 evenly over the width of the leakproof plate 33. To do this, according to one embodiment, the distributor 37 comprises one or more nozzles which can move transversely, that is to say horizontally and at right angles to the direction of advance of the transfer band 36. According to another embodiment, the distributor 37 comprises a plurality of nozzles evenly distributed in the transverse horizontal direction, at right angles to the direction of advance of the transfer band 36.

[0085] The expandable insulating foam solution 40, and in particular its viscosity, are determined such that said solution impregnates the fiber reinforcements 39 and comes into contact against the leakproof plate 33 during the cream time, corresponding to the period between the dispensing of the expandable insulating foam solution 40 and the start of the expansion of the foam. Thus, with the layer of expanded insulating foam 34 having been expanded in contact with the leakproof plate 33, they adhere to one another.

[0086] The rate of advance of the transfer band 36 and the characteristics of the expandable insulating foam solution 40 are determined such that the cream time has elapsed but the expansion of the expandable insulating foam is not complete when the assembly comprising the leakproof plate 33, the fiber reinforcements 39 and the insulating foam is introduced into the laminator 38. Note that the time of travel between the mixing of the components and the dispensing thereof by the distributor 37 can be disregarded if the mixer is arranged close to the distributor 37.

[0087] In an embodiment that is not represented, the installation 35 comprises, upstream of the laminator 38, a pressure system comprising one or more rollers which are arranged above the transfer band 36 and bearing against the fiber reinforcements 39. The pressure system notably makes it possible to control the thickness of the foam on entering the laminator 38 and to give the top surface a good flatness.

[0088] The laminator 38 makes it possible to limit the expansion of the foam and thus gradually harden the layer of expanded insulating foam 34 in the desired format. According to one embodiment, the laminator 38 is a dual-band laminator 38, known by the acronym DBL. Such a dual-band laminator 38 comprises a lower band 41, an upper band 42 and side walls, not represented in figure 3, which together form a tunnel of rectangular or square section.

[0089] Advantageously, the positioning of the walls of the tunnel of the laminator 38 is defined such that the limit to the expansion of the foam results in a volume of foam, at the output of the laminator 38, representing between 92% and 99% of the expansion volume of this same foam in the case of free expansion, that is to say without the limitation of the walls of the laminator 38. Thus, a layer of expanded insulating foam 34 is obtained in which at least 60%, generally more than 80% and even more than 90% of the cells storing a gas with low thermal conductivity extend longitudinally on an axis parallel to the thicknesswise axis of the layer of expanded insulating foam 34. Furthermore, it contributes also to a better uniformity of the distribution of the fiber reinforcements 39 in the foam block. That makes it possible to obtain a layer of expanded insulating foam 34 that exhibits excellent mechanical properties.

[0090] At the output of the laminator 38, the layer of insulating polymer foam is machined in order, on the one hand, for the wall element 32 to be cut to the desired dimensions and, on the other hand, in order to ensure the flatness of at least the face of the layer of expanded insulating polymer foam which is opposite the leakproof plate 33. Through the use of a leakproof plate 33 forming a reference surface, the flatness of the face of the wall element 32 formed by the leakproof plate 33 does not have to be ground down to ensure its flatness, which makes it possible to even further simplify the production of the wall element 32.

[0091] According to another embodiment not represented, the expansion of the expandable insulating foam is not performed in a laminator. In other words, the expansion is performed on a device comprising a lower band and side walls but not the upper band that aims to limit the expansion of the expandable insulating foam. This case is referred to as free expansion.

[0092] In one embodiment, not represented, the installation comprises, upstream of the distributor 37, a glue distributor which can distribute glue on the leakproof plate 33 and thus makes it possible to promote the adhesion between the leakproof plate 33 and the layer of expanded insulating foam 34. The glue can, for example, be distributed in the form of drops or a continuous or discontinuous film.

[0093] According to an advantageous embodiment, as represented in figure 2, the wall element 32 further comprises a support 43 which adheres to the layer of expanded insulating foam 34 on the face opposite the leakproof plate 33. According to one embodiment, the support 43 is a sheet of plywood 43. The support 43 is glued to the layer of expanded polymer foam at the output of the laminator 38. This is advantageous in that it allows the machining of the face of the layer of expanded insulating foam 34 intended to

receive the support 43 before it is glued and thus makes it possible to obtain low tolerances on the thickness of the wall element 32 thus produced.

[0094] Subsequently, one or more wall elements 32, produced by means of the method described above, are anchored to a supporting structure 15, either directly if the wall element 32 is a secondary wall element, or by being fixed to the secondary membrane 13 or to the secondary thermally insulating barrier 14 if it is a primary wall element. The wall elements 32 are advantageously of parallelepipedal form and are juxtaposed in parallel rows. The gaps between the layers of expanded insulating foam 34 of the wall elements 32 are filled with insulating packing so as to form one of the thermally insulating barriers 12, 14. Furthermore, the leakproof plates 33 are linked tightly to one another in order to form one of the membranes 1, 13.

[0095] According to one embodiment, the leakproof plate 33 comprises a film. According to one embodiment, the film is a composite film which comprises a sheet of aluminum inserted between two layers of glass fibers and of resin. Such a composite film is notably marketed under the trademark Triplex ®. In such a case, the leakproof plate 33 is intended to form a part of a secondary membrane 13. Also, the wall element 32 is a secondary wall element and is consequently fixed directly to the supporting structure 15. The wall elements 32 are, for example, anchored to the supporting structure 15 by means of beads of resin and/or studs welded to the supporting structure 15, as described for example in the document FR2691520.

[0096] According to one embodiment, during the manufacturing of the wall element 32, the expandable insulating foam solution 40 is directly in contact against the composite film. According to another embodiment, the face of the composite film which is intended to be placed in contact with the expandable insulating foam solution 40 is previously coated with a glue making it possible to even further increase the adhesion of the layer of expanded insulating foam 34 on the composite film. According to yet another embodiment, the leakproof plate 33 further comprises a layer of plywood which is glued to the composite film and to which the layer of expanded insulating foam 34 adheres.

[0097] When the wall elements 32 are fixed to the supporting structure 15, flexible composite films are glued straddling the composite films of the adjacent wall elements 32 in order to ensure a leakproof join and thus produce the secondary membrane 13.

[0098] In relation to figures 4 to 6, a wall element is described according to another embodiment. This embodiment differs from the embodiment described above in that the leakproof plate 33 does not comprise a composite film but a metal plate 2 having reliefs 4.

[0099] The metal plate 2, represented in detail in figure 5, comprises a flat portion 3 defining a plane of the plate and a plurality of reliefs 4 protruding from the flat portion 3 in a thicknesswise direction at right angles to the plane of the plate.

[0100] The reliefs 4 are spaced apart from one another and distributed over all of the metal plate 2 in such a way that it is not possible to draw a straight line in the plane of the plate without crossing a relief 4. Indeed, in order to ensure the contraction of the metal plate 2 when the tank is filled, or its expansion when the tank is emptied, the metal plate 2 has reliefs in all the directions of the plane of the plate. The flat portion 3 thus separates the reliefs 4 from one another. Each relief 4 comprises a base 5 and at least one peak 6. The reliefs are produced by forging, preferably by drawing, or else by stamping, die stamping, etc. According to one embodiment, the height of the reliefs is less than 20 mm, for example of the order of 10 mm.

[0101] To produce a wall element 32, as represented in figure 4, the metal plate 2 is arranged on the transfer band 36 in such a way that the reliefs 4 protrude downward. The expandable insulating foam solution 40 penetrates into the reliefs 4, which makes it possible notably to ensure a good adhesion of the metal plate 2 to the layer of expanded insulating foam 34. According to one embodiment, in order to prevent the reliefs 4 from being crushed when the metal plate 2 passes into the laminator 38, the metal plate 2 is positioned on the transfer band 36 by means of a support with cavities having forms that each correspond to one of the reliefs 4.

[0102] As represented in figures 5 and 6, the reliefs 4 have a circular base 5 and have a single peak 6 so as to form half-spheres or half-ellipsoids. The reliefs 4 are here evenly distributed over the metal plate 2 but could, in another embodiment not represented, be distributed unevenly.

[0103] Figure 6 represents a cross-section of one of the reliefs of figure 5 so as to represent the various dimensions of the relief 4. The base 5 comprises, in the plane of the plate, a first dimension 7 and a second dimension 8 which, in the case of the first embodiment, are equal. The first dimension 7 is equal to the diameter of the smallest circuit circumscribed around the base 5, whereas the second dimension 8 is equal to the diameter of the largest circle inscribed in the base 5. Furthermore, the distance between the peak 6 and the base 5 in the thicknesswise direction of the metal plate 2 defines the height 9 of the relief 4.

[0104] In the embodiment of figure 6, each relief 4 is separated from an adjacent relief 4 by a distance less than or equal to one times the first dimension 7 of the base 5. The ratio of the second dimension 8 of the base 5 to the height 9 of the relief 4 is approximately equal

to 3.33. Thus, the ratio of the first dimension 7 of the base 5 to the height 9 of the relief 4 is approximately equal to 0.3.

[0105] Such a wall element 32 can form a secondary wall element or a primary wall element. When the wall elements 32 are anchored to the supporting structure 15, the metal plates 2 are welded edge-to-edge tightly to one another.

[0106] Figures 7 and 8 represent a variant embodiment of the reliefs 4 of the metal plate 2 of figures 4 to 6. In this variant embodiment, the form of the base 5 of the reliefs 4 is different from that of the first embodiment. In fact, the base 5 here is a quadrilateral having a larger dimension 7 formed by the diagonal of the quadrilateral and a smaller dimension 8 formed by the smallest side of the quadrilateral. The ratio between the first dimension 7 of the base 5 and the second dimension 8 of the base 5 is, here, equal to approximately 1.4, whereas the ratio between the second dimension 8 of the base 5 and the height 9 of the relief 4 is approximately equal to 2.5. Thus, the ratio of the first dimension 7 of the base 5 to the height 9 of the relief 4 is approximately equal to 0.56.

[0107] In the first two embodiments, the metal plates 2 comprise reliefs of form and size that are identical from one metal plate to another. In other embodiments that are not illustrated, the reliefs 4 can have different forms and sizes observing the ratios described above, and the metal plate 2 can also comprise more than two different series of reliefs.

[0108] Figure 9 illustrates a wall element 32 according to a variant embodiment of figure 4. The wall element 32 comprises, below the zones of the metal plate 2 intended to be welded to the metal plate 2 of an adjacent wall element 32, thermal protection bands 52. The thermal protection bands 52 make it possible to protect the layer of expanded insulating foam 34 from temperatures likely to degrade it during the operations of welding of the metal plates 2 to one another. To produce such a wall element 32, the leakproof plate 33 on which the expandable insulating foam solution 40 is dispensed comprises a metal plate 2 and thermal protection bands 52 which are glued to the metal plate 2, on the face of the metal plate 2 intended to receive the expandable insulating foam solution 40. The thermal protection bands 52 are, for example, composite bands which comprise a sheet of aluminum inserted between two layers of glass fibers and resin.

[0109] Moreover, the wall element 32 is a secondary wall element. Also, the metal plate 2, represented in figure 9, incorporates one or more anchoring elements 49 intended for the anchoring of a primary insulating panel onto said wall element 32. The anchoring element 49 is, for example, a threaded stud which is fixed to the metal plate, or a threaded nut which is intended to receive a threaded stud.

[0110] In relation to figure 10, a zone of a wall element 32 according to one embodiment is illustrated in detail. In this embodiment, the wall element 32 comprises, in a zone intended to receive a primary panel anchoring device, an anchoring plate 50. This anchoring plate 50 is arranged between the metal plate 2 and the layer of expanded insulating polymer foam 34 and makes it possible to locally reinforce the metal plate 2. According to one embodiment, one or more blind nuts 51 are fixed to the reinforcing plate 50. For this, according to a variant embodiment represented, the nut 51 has a threading that cooperates with a bore formed in the anchoring plate 50.

[0111] The nut 51 comprises a collar which makes it possible to sandwich the metal plate 2 between the collar and the anchoring plate 50. The collar is welded at the periphery onto the metal plate 2 in order to ensure the seal. Moreover, the nut 51 has a threaded blind bore intended to receive a fixing stud of an insulating panel of the primary thermally insulating barrier.

[0112] To produce such a wall element 32, the leakproof plate 33 on which the expandable insulating foam solution 40 is dispensed comprises a metal plate 2, the reinforcing plate 50 and a blind nut 51, as described above.

[0113] According to a variant embodiment that is not represented, the anchoring plate 50 is mounted in a recess formed in a layer of plywood. In this case, the leakproof plate 33 comprises a metal plate 2, the reinforcing plate 50, a blind nut 51 and a layer of plywood against which the expandable insulating foam solution 40 is dispensed.

[0114] In relation to figure 11, a zone of a wall element 32 according to a variant embodiment is illustrated in detail. In this embodiment, the leakproof plate 33 comprises one or more thicker zones 53 in which are formed one or more tappings 54 intended to receive a fixing stud of a primary insulating panel.

[0115] According to another embodiment represented in figures 12 and 13, the leakproof plate 33 is a corrugated metal plate 44. Such a corrugated metal plate 44 is represented in perspective in figure 11.

[0116] The corrugated metal plate 44 comprises a first series of parallel corrugations 45, called low corrugations, extending in a direction y, and a second series of parallel corrugations 46, called high corrugations, extending in a direction x. The directions x and y of the series of corrugations are at right angles. The corrugated metal plate 44 comprises, between the corrugations 45, 46, a plurality of flat surfaces 47. At each intersection between a low corrugation 45 and a high corrugation 46, the metal plate comprises a node zone 48.

- [0117] The corrugated metal plate 44 can notably be made of stainless steel, of aluminum, of Invar ®: that is to say an alloy of iron and of nickel whose expansion coefficient is typically between 1.2×10^{-6} and $2 \times 10^{-6} \text{ K}^{-1}$, or an alloy of iron with strong manganese content whose expansion coefficient is typically of the order of $7 \times 10^{-6} \text{ K}^{-1}$. However, the use of other metals or alloys can also be envisaged.
- [0118] Advantageously, when the leakproof plate 33 is such a corrugated metal plate 44, it is positioned on the transfer band 36 by means of a support having cavities corresponding to the form of the corrugations 45, 46 and into which the latter are inserted. This makes it possible to prevent the corrugations 45, 46 from being crushed when the corrugated metal plate 44 passes into the laminator 38.
- [0119] As represented in figure 12, the layer of expanded insulating foam 34 penetrates into the corrugations 45, 46, which makes it possible notably to ensure a good adhesion of the corrugated metal plate 44 to the layer of expanded insulating foam 34.
- [0120] According to one embodiment, the corrugated metal plate 44 is intended to form a part of a primary membrane 1 and the layer of expanded insulating foam 34 is intended to form a part of the primary thermally insulating barrier 12. According to another embodiment, the corrugated metal plate 44 is intended to form a part of a secondary membrane 13 and the layer of expanded insulating foam 34 is intended to form a part of the secondary thermally insulating barrier 14.
- [0121] When the wall elements 32 have been fixed to the supporting structure 15, the corrugated metal sheets 44 of the wall elements 32 are linked tightly to one another, either by being welded edge-to-edge to one another, or by means of additional metal parts which are welded on straddling the corrugated metal plates 44 of the adjacent wall elements 32.
- [0122] Referring to figure 14, a cutaway view of a methane tanker ship 170 shows a leakproof and insulated tank 171 of generally prismatic form mounted in the double-hull 172 of the ship. 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 ship, 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.
- [0123] As is known per se, loading/offloading pipelines 173 arranged on the top deck of the ship can be connected, by means of appropriate connectors, to a maritime or port terminal to transfer a cargo of LNG from or to the tank 171.

[0124] Figure 14 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 steerable mobile arm 174 adapts to all the methane tanker templates. A link line that is not represented extends inside the riser 178. The loading and offloading station 175 allows the loading and offloading of the methane tanker 170 from or to the onshore installation 177. The latter 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 allows the transfer of the 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 ship 170 at a great distance from the coast during the loading and offloading operations.

[0125] To generate the pressure necessary to the transfer of the liquefied gas, use is made of pumps embedded in the ship 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.

[0126] Although the invention has been described in relation to several particular embodiments, it is perfectly clear that it is in no way limited thereto and that it comprises all the technical equivalents of the means described and the combinations thereof, provided that the latter fall within the framework of the claimed invention.

[0127] Use of the verb “comprise” or “include” and its conjugated forms does not preclude the presence of elements or steps other than those stated in a claim.

[0128] In the claims, any reference sign between parentheses should not be interpreted as a limitation of the claim.

Claims

- [Claim 1] A method for manufacturing a wall (31) for a leakproof and thermally insulating tank comprising at least one thermally insulating barrier (12, 14) and a sealing membrane (1, 13) resting against the thermally insulating barrier, the method comprising:
- manufacturing a plurality of wall elements (32), the manufacturing of each wall element (32) comprising:
 - supplying a leakproof plate (33);
 - placing an expandable insulating foam solution (40) against the leakproof plate (33); and
 - expanding the expandable insulating foam solution (40) against said leakproof plate (33) so as to produce a layer of expanded insulating foam (34) adhering to the leakproof plate (33);
 - anchoring said duly manufactured wall elements (32) to a supporting structure (15); the layer of expanded insulating foam (34) of said wall elements (32) forming at least a part of the thermally insulating barrier (12, 14); and
 - assembling the leakproof plates (33) of said wall elements (32) tightly such that said leakproof plates (33) form at least a part of the sealing membrane (1, 13).
- [Claim 2] The method as claimed in claim 1, wherein the leakproof plate (33) comprises a leakproof film.
- [Claim 3] The method as claimed in claim 2, wherein the step of assembly of the leakproof plates comprises the bonding of an additional film straddling the leakproof films of the wall elements (32).
- [Claim 4] The method as claimed in claim 2 or 3, wherein the leakproof film is a rigid composite film comprising an aluminum sheet inserted between two layers of fibers.
- [Claim 5] The method as claimed in claim 1, wherein the leakproof plate comprises a metal plate (2, 44).
- [Claim 6] The method as claimed in claim 5, wherein the metal plate (44) comprises corrugations (45, 46).

- [Claim 7] The method as claimed in claim 5, wherein the metal plate (2) has a plurality of reliefs (4) protruding in a thicknesswise direction with respect to the plane of the metal plate (2).
- [Claim 8] The method as claimed in any one of claims 5 to 7, wherein the step of assembly of the leakproof plates comprises the tight welding of the metal plates (2, 44) to one another.
- [Claim 9] The method as claimed in any one of claims 1 to 8, wherein the expandable insulating foam solution (40) is expanded in a laminator (38) which limits the expansion of the expandable insulating foam solution (40).
- [Claim 10] The method as claimed in claim 9, wherein the laminator (38) is a dual-band laminator comprising a lower band (41), an upper band (42) and side walls which together form a tunnel of rectangular section.
- [Claim 11] The method as claimed in claim 9 or 10, wherein the laminator (38) is arranged such that the limit to the expansion of the expandable insulating foam solution (40) results in a layer of expanded insulating foam (34) having a volume, at the output of the laminator (38), representing between 92% and 99% of the expansion volume of this expandable insulating foam solution (40) in the case of free expansion.
- [Claim 12] The method as claimed in either one of claims 10 and 11, wherein the leakproof plate (33) is placed on a transfer band (36), the expandable insulating foam solution (40) is deposited against the leakproof plate (33) resting on the transfer band (36), and the leakproof plate (33) and the expandable insulating foam solution (40) are led to the laminator (38) by means of said transfer band (36).
- [Claim 13] The method as claimed in any one of claims 1 to 12, wherein the manufacturing of each wall element (32) comprises depositing one or more fiber reinforcements (39) on the leakproof plate (33) and impregnating said fiber reinforcements (39) when the expandable insulating foam solution (40) is placed against the leakproof plate (33).
- [Claim 14] The method as claimed in any one of claims 1 to 13, wherein, during the manufacturing of each wall element (32), a support (43) is made to adhere to a face of the layer of expanded insulating foam (34) opposite the leakproof plate (33).

- [Claim 15] The method as claimed in claim 14, wherein the support (43) is glued to the layer of expanded polymer foam (34).
- [Claim 16] The method as claimed in any one of claims 1 to 15, wherein at least one face of the layer of expanded insulating foam (34) opposite the leakproof plate (33) is machined.
- [Claim 17] A wall for a leakproof and thermally insulating tank obtained by means of a method as claimed in any one of the claims 1 to 16, said wall (31) comprising a plurality of wall elements (32), each wall element (32) comprising a leakproof plate (33) and a layer of expanded insulating foam (34) adhering directly to the leakproof plate (33), said wall elements (32) being anchored to a supporting structure (15) and arranged alongside one another such that the layers of expanded insulating foam (34) form a thermally insulating barrier (12, 14), the leakproof plates (33) of said wall elements (32) being assembled tightly to one another so as to form at least a part of a sealing membrane (1, 13).
- [Claim 18] A leakproof and thermally insulating tank for the storage of a fluid comprising at least one wall (31) as claimed in claim 17.
- [Claim 19] A ship (170) for transporting a fluid, the ship comprising a double-hull (172) and a tank (171) as claimed in claim 18, arranged in the double-hull.
- [Claim 20] A transfer system for a fluid, the system comprising a ship (170) as claimed in claim 19, insulated pipelines (173, 179, 176, 181) arranged so as to link the tank (171) installed in the hull of the ship 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 ship.
- [Claim 21] A method for loading or offloading a ship (170) as claimed in claim 19, 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 ship. |