

Description

Title of the invention: Method for insulating an inter-panel space

Technical field

[0001] The invention relates to the field of sealed and thermally insulating tanks, with membranes. In particular, the invention relates to the field of sealed and thermally insulating tanks for the storage and/or transport of liquefied gas at low temperature, such as tanks for the transport of Liquefied Natural Gas (LNG) at approximately -163°C at atmospheric pressure, ammonia (NH_3), dry ice (CO_2 in solid form) or hydrogen. These tanks may be installed onshore or on a floating structure. More particularly, the invention relates to the thermal insulation of these tanks.

Prior art

[0002] A multilayer tank structure comprising, from the outside of the tank toward the inside of the tank, a secondary thermally insulating barrier, a secondary sealed membrane, a primary thermally insulating barrier and a primary sealing membrane intended to be in contact with the liquid contained in the tank, has already been described. Such tanks include insulating panels arranged next to one another in such a way as to form thermally insulating barriers. However, there are inter-panel spaces between the insulating panels. These spaces result in a reduction in the insulation efficiency of the thermally insulating barrier. Thus, in order to ensure continuity of the thermal insulation properties of said thermally insulating barriers, it is necessary to fill these inter-panel spaces. Several solutions exist. For example, the addition of insulating elements comprising a sheath and a compressible material, such as glass wool, housed in the sheath has been described in document WO2019155158A1. The sheath is placed under vacuum before insertion of the insulating elements into the inter-panel space, which allows the compressible material to be compressed to facilitate insertion. After insertion of the insulating elements, the sheath is pierced such that the compressible material thus fills the inter-panel space. However, placing elements made of compressible materials under vacuum is difficult to achieve.

[0003] A method for installing a thermal insulation structure in an inter-panel space of a cryogenic liquid storage tank is also known, from document KR20180060576A. The method includes in particular the insertion of a block of glass wool in order to fill the inter-panel space, with the addition of a block of foam in the event that the glass wool is not thick enough relative to the inter-panel space. In order to insert said block of foam into the remaining space, the method notably comprises measurement steps. The inventors have

noted that in such a tank, such a method is tricky to implement and involves technical difficulties when implementing on a large scale. This is because the constituent elements of the tanks present numerous irregularities arising from assembly and manufacturing, such as for example offsets or inaccuracies. Thus, said measurement steps must be repeated for each inter-panel space.

[0004] There is therefore a real need to develop a method for insulating an inter-panel space that is reliable, efficient and easy to implement.

Summary

[0005] An idea forming the basis of the invention is a method for insulating an inter-panel space that makes it possible to ensure continuity of thermal insulation between the adjacent insulating panels.

[0006] Another idea forming the basis of the invention is the installation of efficient and durable inter-panel insulation when there are considerable thermal constraints, particularly in the face of thermal expansion and contraction of the panels.

[0007] Another idea forming the basis of the invention is to facilitate the installation of a compressible insulating element, such as glass wool, in an inter-panel space.

[0008] Another idea forming the basis of the invention is to facilitate the manufacture of a sealed and thermally insulating tank.

[0009] According to one embodiment, the invention provides a method for insulating an inter-panel space formed between a first insulating panel and a second insulating panel of a wall of a sealed and thermally insulating tank for the storage of fluid at low temperature, the first insulating panel comprising a first side face facing a second side face of the second insulating panel, the inter-panel space being delimited by the first side face and the second side face, the method comprising the following steps:

- placing at least one insert element against at least the first side face of the first insulating panel,
- injecting expanding foam into the inter-panel space between the insert element and the second side face of the second insulating panel, such that the expanding foam expands in order to press the insert element between said expanding foam and the first side face of the first insulating panel.

[0010] By virtue of these features, continuity of thermal insulation between the first and second insulating panels is ensured by the expanding foam and the insert element. In addition, thanks to the presence of the insert element, the foam expanded in situ does not adhere directly against the first side face of the first insulating panel and is therefore free

to move relative thereto. This makes it possible to reduce the risks of deterioration of the expanded foam, in particular in the event of relative movements of the insulating panels with respect to one another, for example as a result of thermal contraction, thermal expansion or the swell, since in such circumstances an expanding foam adhering directly against the side faces of the two adjacent insulating panels would tend to crack, impairing its thermal insulation properties.

[0011] According to embodiments, such a method may include one or more of the following features.

[0012] According to one embodiment, the method further comprises a step of compartmentalization of the inter-panel space, said compartmentalization step being carried out before the expanding foam is injected.

[0013] By virtue of these features, the expanding foam is kept inside the inter-panel space, thus reducing the loss of a volume of expanding foam which could flow outside the inter-panel space.

[0014] According to a preferred embodiment, the expanding foam is injected in the liquid state.

[0015] According to one embodiment, the compartmentalization step comprises the insertion of a bottom strip into the inter-panel space, the bottom strip being located at a lower end of the inter-panel space and extending in a longitudinal direction of the inter-panel space over an entire length of the inter-panel space.

[0016] According to one embodiment, the bottom strip has a width greater than or equal to the gap between the first side face of the first insulating panel and the second side face of the second insulating panel.

[0017] According to one embodiment, the bottom strip is compressed between the first side face of the first insulating panel and the second side face of the second insulating panel.

[0018] According to one embodiment, the bottom strip is compressed toward a lower end of the inter-panel space.

[0019] By virtue of these features, the bottom strip seals off the lower end of the inter-panel space.

[0020] According to one embodiment, the compartmentalization step further comprises the insertion of a first side strip and a second side strip respectively located at a first side end and a second side end of the inter-panel space, the first side strip and the second side strip extending in a direction transverse to the longitudinal direction of the inter-panel space.

[0021] According to one embodiment, the first side strip, the second side strip have a width greater than or equal to the gap between the first side face of the first insulating panel and the second side face of the second insulating panel. According to one embodiment, the first side strip or the second side strip is compressed between the first side face of the first insulating panel and the second side face of the second insulating panel.

[0022] According to one embodiment, the compartmentalization step comprises the insertion of at least one retaining strip into the inter-panel space, the retaining strip extending in a direction transverse to the longitudinal direction of the inter-panel space.

[0023] According to one embodiment, the retaining strip is located between the first side strip and the second side strip.

[0024] According to one embodiment, the compartmentalization step comprises covering the inter-panel space with a cover, the cover comprising an opening through which the expanding foam is injected into the inter-panel space.

[0025] By virtue of these features, overflow of the expanding foam is prevented.

[0026] According to one embodiment, the opening has a diameter of between 5 mm and 30 mm, preferably a diameter of 20 mm.

[0027] According to one embodiment, the cover comprises a plurality of openings spaced apart from one another, the openings being located in a longitudinal direction of the cover.

[0028] According to one embodiment, the cover has the general shape of a rectangular parallelepiped with rounded edges.

[0029] According to one embodiment, the cover has the following dimensions:

- a length of between 1 and 5 meters (m), for example 3.5 meters, and preferably between 1.4 and 1.6 m;
- a width of between 15 and 50 centimeters (cm), preferably between 20 and 30 cm;
- a thickness of between 10 and 60 millimeters (mm), preferably between 20 and 30 mm.

[0030] According to one embodiment, the cover has side edges resting against the first and second insulating panels and comprises a plurality of holes made in said side edges opposite the first or second insulating panel. The holes therefore do not open into the inter-panel space.

[0031] According to one embodiment, the holes of the plurality of holes have identical or different dimensions.

[0032] By virtue of these features, the holes make the cover more lightweight, making it easier for the operator to handle the cover.

[0033] According to one embodiment, the plurality of holes comprises an oblong hole.

[0034] According to one embodiment, the cover is attached against the first and second insulating panels via an attachment means. According to one embodiment, the attachment means is chosen from: a screw, which for example is received in a threaded insert attached to the first or second insulating panel, and a toggle clamp.

[0035] According to one embodiment, the attachment means passes through at least one hole of the plurality of holes made in the cover. According to one embodiment, the attachment means passes through an oblong hole made in the cover. The oblong hole makes it possible to adjust the attachment of the cover via the attachment means more easily, in particular in order to compensate for tolerances in the relative positioning of the first insulating panel with respect to the second insulating panel.

[0036] According to one embodiment, the first and second insulating panels respectively comprise two recesses along the edge of the first side face of the first insulating panel and two recesses along the edge of the second side face of the second insulating panel, the cover being attached against the first and second insulating panels via an anchoring system attached to the cover, the anchoring system comprising one anchoring element per recess, each anchoring element comprising: a centering cone and an inflatable seal positioned around the centering cone and connected to an inflation system. After insertion, in the recess, each inflatable seal is inflated using a pneumatic source. Thus, given the orientation of the conical surface, each inflatable seal exerts a downward force on the centering cone, which makes it possible to hold the cover against the first and second insulating panels during the expansion of the expanding foam. After the foam expansion step, the inflatable seals are deflated, and the cover and the anchoring system are removed.

[0037] By virtue of these features, centering of the cover covering the inter-panel space is facilitated and any seals are compressed optimally in order to obtain good sealing.

[0038] According to one embodiment, the pneumatic source is common to the anchoring elements.

[0039] According to one embodiment, the plurality of holes are oblong holes separated from one another. In other words, there is no continuity between said oblong holes.

[0040] By virtue of these features, the cover is made more lightweight while maintaining good rigidity for the purposes of implementing the method for insulating the inter-panel space, that is to say sufficient rigidity to withstand the foam expansion pressure.

- [0041] According to one embodiment, the cover comprises at least one handle attached to the surface opposite the surface of the cover which is intended to be in contact with the expanding foam. Preferably, the cover includes two handles.
- [0042] According to one embodiment, the length of the at least one handle extends in a direction perpendicular to the length direction of the cover.
- [0043] According to one embodiment, the at least one handle is located on the axis of symmetry of the length of the cover.
- [0044] According to one embodiment, the two handles are spaced apart in the length direction of the cover.
- [0045] According to one embodiment, the cover is positioned straddling the first insulating panel and the second insulating panel.
- [0046] According to one embodiment, the cover is attached via seals to the first insulating panel and the second insulating panel.
- [0047] By virtue of these features, during the expansion of the foam, the expanding foam will not overflow from the inter-panel space. The cover is attached in such a way as to withstand the expansion pressure exerted by the expanding foam.
- [0048] According to one embodiment, the seals extend over the entire length of the cover.
- [0049] According to one embodiment, the seals on the first insulating panel and the second insulating panel have a sufficient thickness to form, with the surface intended to be in contact with the expanding foam, an excess foam evacuation corridor, said excess foam evacuation corridor being connected to a foam receptacle located on one side of the first insulating panel and/or one side of the second insulating panel in order to allow the evacuation of any excess foam during the phase of expansion of the foam. For example, the foam receptacle is a box made of wood or composite material.
- [0050] According to one embodiment, the seals forming the excess foam evacuation corridor have a thickness of between 5 mm and 20 mm.
- [0051] According to one embodiment, the seals forming the excess foam evacuation corridor comprise a strip of closed-cell ethylene-propylene-diene monomer (EPDM) foam. According to one embodiment, the seals forming the foam evacuation corridor comprise neoprene adhesive.
- [0052] According to one embodiment, the cover is transparent, preferably made from polymethyl methacrylate (PMME), better known by the trade name Plexiglas®.

- [0053] By virtue of these features, the task of the operator carrying out the method is facilitated, particularly during the step of injection and expansion of the expanding foam because they can watch the foam expand in real time and thus more easily adjust the quantity of expanding foam to be injected.
- [0054] According to one embodiment, the cover has a tongue protruding from the surface of the cover which is intended to be in contact with the expanding foam.
- [0055] By virtue of these features, the expanding foam is prevented from overflowing beyond the inter-panel space, particularly if the foam continues to expand after removal of the cover.
- [0056] According to one embodiment, the tongue extends over the entire length of the cover.
- [0057] According to one embodiment, the tongue has a height of between 2 mm and 15 mm.
- [0058] According to one embodiment, the tongue has a width smaller than the gap between the first side face and the second side face.
- [0059] According to one embodiment, the cover is made from polytetrafluoroethylene (PTFE).
- [0060] According to one embodiment, a film covers the surface of the cover which is intended to be in contact with the expanding foam. According to one embodiment, the film is non-stick. According to one embodiment, the film is made of PTFE.
- [0061] According to one embodiment, the film is made of perfluoroalkoxy (PFA) or fluoroethylene propylene (FEP), which have properties similar to PTFE.
- [0062] By virtue of these features, the expanded foam will not adhere to the cover, which facilitates the removal of said cover after the foam expansion step.
- [0063] According to one embodiment, the method further comprises a step of drying the expanded foam.
- [0064] According to one embodiment, the method further comprises a step of removing the cover.
- [0065] According to one embodiment, the method further comprises a step of removing the foam receptacle.
- [0066] According to one embodiment, the method further comprises a step of leveling off the excess foam present in the foam evacuation corridor.
- [0067] According to one embodiment, the foam is injected until it reaches the height of the first insulating panel and the second insulating panel.

[0068] According to one embodiment, the injection of expanding foam is a first injection of expanding foam, the method further comprising at least a second injection of foam, the second injection of foam being carried out after the expansion of the expanding foam of the first injection of foam.

[0069] By virtue of these features, the operator may, by taking into consideration the quantity of expanding foam injected and the height of the expanded foam generated, adjust the quantity of expanding foam injected during the last foam injection in order to prevent expanding foam from overflowing beyond the inter-panel space.

[0070] According to one embodiment, the expanding foam is injected using a foam injection gun.

[0071] According to one embodiment, the method comprises, prior to the injection of expanding foam:

- placing an inflatable device in an uninflated state in an area defined between at least one of the first and second insulating panels and a third insulating panel adjacent to said first or second insulating panel, the area being transverse to the inter-panel space and the inflatable device being placed facing the inter-panel space,
- inflating the inflatable device so that said inflatable device in an inflated state leans at least on the third insulating panel and covers the first side end of the inter-panel space in order to keep the expanding foam inside the inter-panel space during the injection and expansion of the expanding foam.

[0072] According to one embodiment, the method comprises, prior to the injection of expanding foam:

- placing an inflatable device in an uninflated state in an area defined between at least one of the first and second insulating panels and a third insulating panel adjacent to said first or second insulating panel, the area being transverse to the inter-panel space and the inflatable device being placed facing the inter-panel space,
- inflating the inflatable device so that said inflatable device in an inflated state leans at least on the third insulating panel and covers the first side end of the inter-panel space in order to keep the expanding foam inside the inter-panel space during the injection and expansion of the expanding foam.

[0073] By virtue of these features, the inflatable device can be easily inserted into the area defined between the three insulating panels. Furthermore, the inflation of the inflatable device makes it possible to cancel out any irregularities arising from assembly and manufacturing, such as for example offsets or inaccuracies.

[0074] According to one embodiment, the inflatable device in an inflated state covers the first side end or the second side end of the inter-panel space.

[0075] According to one embodiment, the inflatable device is placed facing the first side strip, the inflatable device being inflated so that said inflatable device leans on the first side strip in order to hold the first side strip in a static position.

[0076] According to one embodiment, the inflatable device is placed facing the second side strip, the inflatable device being inflated so that said inflatable device leans on the second side strip in order to hold the second side strip in a static position.

[0077] Thus, the first side strip or the second side strip is held in a static position over an entire length of the first side strip or the second side strip.

[0078] According to one embodiment, the area is defined between the first insulating panel and the second insulating panel and the third insulating panel adjacent to the first insulating panel and a fourth insulating panel adjacent to the second insulating panel, wherein the inflatable device is inflated so that said inflatable device leans on the third insulating panel, the fourth insulating panel and against the first side strip.

[0079] According to one embodiment, the area is defined between the first insulating panel and the second insulating panel and the third insulating panel adjacent to the first insulating panel and a fourth insulating panel adjacent to the second insulating panel, wherein the inflatable device is inflated so that said inflatable device leans on the third insulating panel, the fourth insulating panel and against the second side strip.

[0080] According to one embodiment, after expansion of the foam, the inflatable device is removed. According to one embodiment, the inflatable device is removed in a deflated state.

[0081] According to one embodiment, the inflatable device comprises an inflatable element and a pump intended to inflate said inflatable element.

[0082] According to one embodiment, the inflatable element is chosen from: a pneumatic or hydraulic inflatable bag.

[0083] According to one embodiment, the inflatable device comprises a pump chosen from: a manual pump or an automatic pump. According to one embodiment, the pump is an air pump or a liquid pump.

[0084] According to one embodiment, the inflatable device comprises a non-stick and/or insulating coating.

[0085] According to one embodiment, the method comprises, prior to the injection of expanding foam:

- placing a first crosspiece made from insulating material in an area defined between at least one of the first and second insulating panels and a third insulating panel adjacent to said first or second insulating panel, the area being transverse to the inter-panel space and the crosspiece being positioned in order to close off a first side end of the inter-panel space during the injection and expansion of the expanding foam.

[0086] According to one embodiment, the area is defined between the first insulating panel and the second insulating panel and the third insulating panel adjacent to the first insulating panel and a fourth insulating panel adjacent to the second insulating panel.

[0087] According to one embodiment, the crosspiece comprises four arms which are respectively positioned between the first and second insulating panels, between the second and third insulating panels, between the third and fourth insulating panels and between the fourth and first insulating panels.

[0088] According to one embodiment, the method comprises, prior to the injection of expanding foam:

- placing a second crosspiece made from insulating material in a similar manner to the first crosspiece in order to close off a second side end of the inter-panel space during the injection and expansion of the expanding foam.

[0089] According to one embodiment, the low temperature fluid is for example Liquefied Natural Gas (LNG), hydrogen or Liquefied Petroleum Gas (LPG), preferably the low temperature fluid is a cryogenic fluid. The expression "low temperature" means for example a liquid having a temperature lower than -20°C , for example lower than -50°C , -163°C .

[0090] According to one embodiment, the expanding foam comprises a thermosetting polymer or a thermoplastic polymer.

[0091] According to one embodiment, the expanding foam comprises a component chosen from: polyurethane (PU), polyisocyanurate (PIR).

[0092] Thus, the properties of the inter-panel insulation are more efficient. Indeed, polyurethane-based expanding foam has excellent insulation properties.

[0093] According to one embodiment, the expanding foam is a low density foam, that is to say a foam having a density of between 30 and 70 kg/m^3 .

[0094] According to one embodiment, the expansion of the expanding foam is carried out by a polymerization reaction.

- [0095] According to one embodiment, the polymerization reaction is carried out in a temperature range between 10 and 150 degrees Celsius (°C), for example between 10°C and 100°C, preferably between 10°C and 40°C.
- [0096] According to one embodiment, the insert element covers at least 50% of the first side face of the first insulating panel, preferably at least 90%, for example 95% or the entire first side face of the first insulating panel.
- [0097] According to one embodiment, the bottom strip comprises a material compressible toward the lower end of the inter-panel space.
- [0098] According to one embodiment, the bottom strip comprises a material chosen from: glass wool or polyurethane foam. The bottom strip preferably comprises polyurethane foam. Polyurethane foam has the advantage of being adhesive to concrete and makes it possible to cancel out any irregularities arising from assembly and manufacturing.
- [0099] According to one embodiment, the first side strip and the second side strip comprise glass wool or poly(methyl methacrylate). Poly(methyl methacrylate) is notably known by the trade name Plexiglas®.
- [0100] According to one embodiment, the retaining strip comprises glass wool.
- [0101] According to one embodiment, the insert element is a compressible insulating element.
- [0102] By virtue of these features, the relative movements of the insulating panels with respect to one another, for example as a result of thermal contraction, thermal expansion or the swell, are counteracted in particular thanks to the presence of the compressed compressible insulating element which has a capacity to expand and contract in the direction of the thickness of said compressible insulating element. Furthermore, by virtue of these features the compressible insulating element is inserted into the inter-panel space without being compressed upstream, which facilitates its insertion. Furthermore, by virtue of these features, the pressure exerted by the expanding foam during the phase of expansion of the foam is directed against the compressible insulating element, thus causing its compression.
- [0103] According to one embodiment, the compressible insulating element has a capacity for compression in the thickness direction of greater than 1 millimeter (mm), preferably greater than 2 mm, for example between 1 mm and 10 mm, in response to the pressure exerted by the expansion of the expanding foam.
- [0104] By virtue of these features, the inter-panel insulation may expand and/or compress in the thickness direction in response to the phenomena of contraction and expansion of the adjacent first and/or second insulating panels.

- [0105] According to one embodiment, the compressible insulating element has a thickness of 5 mm to 50 mm before compression by the expanding foam, preferably a thickness of between 5 mm and 30 mm, for example a thickness of 10 mm.
- [0106] According to one embodiment, the compressible insulating element has the shape of a plate covering the first side face of the first insulating panel.
- [0107] According to one embodiment, the compressible insulating element comprises glass wool, the glass wool being compressed during the expansion of the expanding foam.
- [0108] According to one embodiment, the insert element comprises kraft paper, a non-stick stretch film or a mold release agent, preferably, the insert element comprises kraft paper. According to one embodiment, the mold release agent is a lubricant.
- [0109] According to one embodiment, the method for insulating an inter-panel space further comprises placing a second insert element against the second side face of the second insulating panel.
- [0110] According to one embodiment, the second insert element comprises kraft paper, a non-stick stretch film or a mold release agent, preferably, the second insert element comprises kraft paper.
- [0111] By virtue of these features, the insert elements will not adhere to the side faces of the first and second insulating panels. Thus, the risks of deterioration of the expanded foam are greatly reduced, particularly in the event of relative movements of the insulating panels with respect to one another.
- [0112] According to another embodiment, the compressible insulating element is attached against the first side face of the first insulating panel during a step of premanufacture of the insulating panel.
- [0113] According to one embodiment, the first insulating panel or the second insulating panel comprises an insulating foam sandwiched between a first plywood plate intended to carry a sealed membrane and a second plywood plate intended to be placed on a support.
- [0114] According to one embodiment, the first plywood plates of the first and second panels each have a threaded bore, for example formed in an insert attached to the first or second panel, the cover being attached against the first plywood plates of the first and second insulating panels via attachment means having a threaded rod, the threaded rods each being engaged in a hole made in the side edge of the cover and in the threaded bore made in the first plywood plate of the first or second insulating panel.

[0115] According to one embodiment, a bead of mastic is laid continuously around the periphery of the second plywood plate of the first insulating panel and the second insulating panel.

[0116] According to one embodiment, the compartmentalization step comprises:

- laying a first bead of mastic on an outer face of the second plywood plate of the first insulating panel, the first bead of mastic extending continuously along the inter-panel space;
- laying a second bead of mastic on an outer face of the second plywood plate of the second insulating panel, the second bead of mastic extending continuously along the inter-panel space.

[0117] A method for insulating an inter-panel space formed between a first and a second insulating panel of a wall of a sealed and thermally insulating tank for the storage of fluid at low temperature as mentioned above is carried out in particular during the manufacture of a sealed and thermally insulating tank. Such a tank is for example described in document FR2724623 or document FR2599468.

[0118] Such a tank may form part of an onshore storage facility, for example for storing LNG, or may be installed on a floating structure, coastal or deep-water, in particular a liquefied gas carrier, a floating storage and regasification unit (FSRU), a remote floating production and storage unit (FPSO), and the like.

Brief description of the figures

[0119] The invention will be better understood, and other aims, details, features and advantages thereof will appear more clearly during the following description of several particular embodiments of the invention, provided solely by way of non-limiting illustration, with reference to the attached drawings.

[0120] [fig.1] Figure 1 schematically illustrates the steps of a method for insulating an inter-panel space according to one embodiment.

[0121] [fig.2] Figure 2 is a perspective view of two adjacent insulating panels and a bottom strip intended to be placed in the inter-panel space formed between said insulating panels.

[0122] [fig.3] Figure 3 is a perspective view of two adjacent insulating panels similar to figure 2 along with an insert element intended to be placed in the inter-panel space formed between said insulating panels.

[0123] [fig.4] Figure 4 is a view in section along the axis II-II of figure 3, after the insert element has been fitted.

[0124] [fig.5] Figure 5 is a perspective view of two adjacent insulating panels similar to figures 2 and 3 along with two side strips intended to be placed in the inter-panel space formed between said insulating panels.

[0125] [fig.6] Figure 6 is a perspective view of two adjacent insulating panels after the attachment of a cover covering the inter-panel space.

[0126] [fig.7] Figure 7 is a perspective view of two adjacent insulating panels the inter-panel space of which has been filled according to one embodiment.

[0127] [fig.8] Figure 8 is a perspective view of an area of intersection between four insulating panels comprising an inflatable device in an inflated state according to one embodiment.

[0128] [fig.9] Figure 9 is a schematic view of figure 6 in section along the axis III-III.

[0129] [fig.10] Figure 10 is a top view of six insulating panels placed facing one another in pairs, after the attachment of a cover covering an inter-panel space, according to another embodiment.

[0130] [fig.11] Figure 11 is a view in section of two adjacent insulating panels along with a cover attached via seals according to another embodiment.

[0131] [fig.12] Figure 12 is a top view of a cover according to a variant embodiment.

[0132] [fig.13] Figure 13 is a schematic perspective view of the cover shown in figure 12.

[0133] [fig. 14] Figure 14 is a view in section of two adjacent insulating panels comprising beads of mastic according to another embodiment.

[0134] [fig. 15] Figure 15 is a bottom view of four insulating panels placed facing one another in pairs, comprising the beads of mastic according to the embodiment illustrated in figure 14.

[0135] [Fig.16] Figure 16 is a top view of two adjacent insulating panels according to another embodiment with an inter-panel space.

[0136] [Fig. 17] Figure 17 is a view in section of the first circular recess located in the area III.

Description of the embodiments

[0137] Figure 1 shows the steps of an inter-panel space insulation method. Said inter-panel space is formed between a first and a second insulating panel of a wall of a sealed and thermally insulating tank for the storage of fluid at low temperature, in particular for the storage of LNG.

[0138] The first insulating panel has a first side face positioned facing a second side face of the second insulating panel. The inter-panel space is delimited by the first and second side faces.

[0139] Step 100 corresponds to the insertion of an insert element in the inter-panel space. The insert element, for example glass wool or kraft paper, is placed against the first side face of the first insulating panel. Step 100 is shown in particular in figures 3 and 4 and is described in detail below.

[0140] Figure 3 depicts a first insulating panel 1 and a second insulating panel 2, which are adjacent. Said first and second insulating panels 1, 2 respectively comprise a layer of insulating foam 3, for example polyurethane foam, sandwiched between a first plywood plate 4 and a second plywood plate 5. The first plywood plate 4 is intended to carry a sealed membrane and the second plywood plate 5 is intended to be positioned on a support, for example a wall of a carrier. Beads of mastic 6 are laid on an outer face of the second plywood plate 5 in particular to even out the support on which the first insulating panel 1 and the second insulating panel 2 will be placed. Other types of insulating panels could also be used. An inter-panel space 7 is formed by the gap between the first insulating panel 1 and the second insulating panel 2 and more particularly by a first side face 8 of the first insulating panel 1 positioned facing a second side face 9 of the second insulating panel 2. Also shown, above the inter-panel space 7, is the insert element 10 intended to be inserted in the inter-panel space 7. The insert element 10 is for example a plate of glass wool 10 or a sheet of kraft paper of generally rectangular shape. The insert element 10 has a dimension enabling it to cover the first side face 8 once fitted in the inter-panel space 7. The insert element 10 has a thickness smaller than the gap between the first side face 8 and the second side face 9. Figure 4 is a view in section along the axis II-II of figure 3, after insertion of the insert element. The insert element 10 is positioned against the first side face 8 and completely covers said first side face 8. At this stage of the method the inter-panel space 7 comprises an empty space, that is to say without material, which is located between the insert element 10 and the second side face 9. This empty space is intended to be filled with expanding foam subsequently in the insulation method.

[0141] According to a variant embodiment of step 100, the insert element 10 is attached against the first side face of the first insulating panel during premanufacture of the insulating panel.

[0142] The next step 101 indicated in figure 1 corresponds to an injection of expanding foam into the inter-panel space, between the insert element and the second side face of the second insulating panel in order to fill said inter-panel space. The expanding foam is, for

example, a polyurethane-based foam. This expanding foam injection step makes it possible to fill the inter-panel space 7.

[0143] The next step 102 is the expansion of the expanding foam. This step makes it possible to compress the insert element between said expanding foam and the first side face of the first panel when the insert element is a compressible insulating element such as glass wool. For example, when the expanding foam is based on polyurethane, a chemical polymerization reaction is carried out. The polymerization reaction makes it possible to increase the volume of the expanding foam initially injected. This increase in volume makes it possible to press and compress, in the thickness direction, the compressible insulating element against the first side face of the first insulating panel.

[0144] The polymerization reaction is carried out at a temperature of between 10°C and 150°C for 5 to 60 minutes. The polymerization reaction makes it possible to fill the inter-panel space 7, and to press the insert element 10 against the first face 8.

[0145] As shown in figures 2 to 7, the method for insulating an inter-panel space further comprises a step of compartmentalization of the inter-panel space. Said compartmentalization step has a plurality of variant embodiments which may be carried out alone or in combination.

[0146] Figure 2 shows two adjacent insulating panels 1 and 2 as well as an inter-panel space 7 similar to figure 3. The insert element 10 is not shown in this figure 2. Also shown, above the inter-panel space 7, is a bottom strip 11 before its insertion into the inter-panel space 7. The bottom strip 11 has the general shape of a rectangular parallelepiped. Figure 4 depicts the bottom strip 11 after insertion into the inter-panel space 7.

[0147] As shown in figure 4, the compartmentalization step includes the insertion of the bottom strip 11 into the inter-panel space 7 as far as a first lower end of the inter-panel space 7. This step is advantageously carried out before the step of inserting the insert element 10. The first lower end is located between the second plywood plate 5 of the first insulating panel 1 and the second plywood plate 5 of the second insulating panel 2, and defines a bottom of the inter-panel space 7. The first lower end extends in a longitudinal direction of the inter-panel space 7 over the entire length of the inter-panel space 7. The bottom strip 11 has a width at least equal to the gap between the first side face 8 and the second side face 9 in order to fill the bottom of the inter-panel space 7. Preferably, the bottom strip 11 is compressed between the first side face 8 of the first insulating panel 1 and the second side face 9 of the second insulating panel 2 and is compressed toward a lower end of the inter-panel space. Such a bottom strip 11 makes it possible to prevent the

expanding foam from flowing outside the inter-panel space 7, in particular beyond an outer surface of the second plywood plate 5.

[0148] In the embodiment shown in figure 5, the compartmentalization step comprises the insertion of a first side strip 12 and a second side strip 13, carried out before or after the insertion of the insert element, preferably before the insertion of the insert element.

[0149] The first side strip 12 and the second side strip 13 are depicted above the inter-panel space 7, before insertion into the inter-panel space 7. The first side strip 12 and the second side strip 13 have the general shape of a rectangular parallelepiped and extend in a direction transverse to the longitudinal direction of the inter-panel space 7 over the entire thickness of the insulating panels 1, 2. The first side strip 12 is inserted at a first side end of the inter-panel space 7 and the second side strip 13 is inserted at a second side end of the inter-panel space 7, at a distance from the first side end. Such a compartmentalization step makes it possible to prevent, during the injection of expanding foam, said expanding foam from flowing outside the inter-panel space 7, in particular at the first side end and the second side end of the inter-panel space 7.

[0150] As shown in figure 6, the compartmentalization step further comprises covering the inter-panel space 7 with a cover 14 upstream of the expanding foam injection step. The cover 14 has the shape of a rectangular plate and is positioned straddling the first plywood plate 4 of the first insulating panel 1 and the first plywood plate 4 of the second insulating panel 2 and extends along the entire length of the inter-panel space in order to cover the upper surface of the inter-panel space 7. The cover 14 includes an opening 15 which is in communication with the inter-panel space. This opening 15 is circular in shape and allows the injection of the expanding foam into the inter-panel space, between the insert element 10 and the second side face of the second insulating panel 2. Subsequently, the expanding foam is injected into the inter-panel space and then it expands (not shown in figure 6). After the expansion step, the expanded foam 21 fills said inter-panel space, between the insert element 10 and the second side face of the second insulating panel 2 and presses on said insert element 10 as shown in figure 9. When the insert element is a compressible insulating element, it is also compressed. The cover 14 is then removed in order to obtain an inter-panel insulation 16 filling the entire inter-panel space and having excellent thermal insulation properties, as shown in figure 7. The inter-panel insulation 16 is thus made up of the bottom strip 11, the insert element 10, the first side strip 12 and the second side strip 13 as well as the expanded foam.

[0151] According to a variant shown in figure 8, the method comprises, prior to the injection of expanding foam, putting in place an inflatable device 17. Figure 8 shows an area located

between four insulating panels comprising the first insulating panel 1, the second insulating panel 2, a third insulating panel 18 and a fourth insulating panel 19, which are adjacent. The inter-panel space 7 and the first side strip 12 as described previously are visible in figure 8. The first insulating panel 1 has, as stated above, a first side face facing a second side face of the second insulating panel 2 forming the inter-panel space 7. The first insulating panel 1 also has another side face facing a side face of the third insulating panel 18 forming a second inter-panel space. Similarly, the second insulating panel 2 also has another side face facing a side face of the fourth insulating panel 19 forming a third inter-panel space. Similarly, the third insulating panel 18 also has another side face facing a side face of the fourth insulating panel 19 forming a fourth inter-panel space.

[0152] The inflatable device 17 is placed, in an uninflated state, in the area defined between the first, the second, the third and the fourth insulating panels, the area being transverse to the inter-panel space 7, that is to say formed by the second inter-panel space and the third inter-panel space, which are consecutive. The inflatable device 17 is placed facing the first side strip 12. The inflatable device is then inflated using a pump 20, for example a manual pump, in order to hold the side strip 12 in a static position during the injection and expansion of the expanding foam and to cancel out any irregularities arising from assembly and manufacturing, before the expanding foam is injected into the inter-panel space 7.

[0153] Figure 10 is a top view of six insulating panels placed in two parallel rows. Each of the four side faces of each insulating panel 2 is arranged opposite a side face of another insulating panel and is aligned therewith. Figure 10 shows a cover 14 covering the inter-panel space between a first insulating panel 1 and a second insulating panel 2, which are adjacent. This embodiment differs from previous embodiments in that two insert elements, for example kraft paper, are placed in the inter-panel space. A first insert element 111 is located against the first side face of the first insulating panel 1 and a second insert element 112 is located against the second side face of the second insulating panel 2.

[0154] The cover 14 is attached via attachment means 30 located on the first insulating panel 1 and on the second insulating panel 2 in order to hold the cover 14 in a static position in a sealed manner so that the expanding foam does not overflow beyond the cover 14 during expansion of the foam.

[0155] The method further comprises, prior to the injection of expanding foam, putting in place a first crosspiece 32 located at the intersection of the first insulating panel 1, the second insulating panel 2, a third insulating panel 18 and a fourth insulating panel 19. The first crosspiece 32 comprises four arms which are each inserted in an inter-panel space formed

between two of the aforementioned insulating panels 18. The first crosspiece 32 is positioned in such a way as to close off a first side end of the inter-panel space.

[0156] The method further comprises putting in place a second crosspiece 33 located, in a manner similar to the first crosspiece, at the intersection of the first insulating panel 1, the second insulating panel 2, a fifth insulating panel 28 and a sixth insulating panel 29. The second crosspiece 33 is positioned in such a way as to close off a second side end of the inter-panel space. The method further comprises the insertion of a retaining strip 31, for example made of glass wool, which is placed between the first crosspiece 32 and the second crosspiece 33.

[0157] According to a variant embodiment shown in figure 11, the cover 114 is attached using attachment means, for example using screws which may in particular be screwed into a threaded insert attached to the first or second insulating panel. The cover 114 rests against the first and second insulating panels via a first seal 131 which extends over the entire length of the cover, along the edge of the first side face 8 of the first insulating panel 1 and via a second seal 132 which extends over the entire length of the cover, along the edge of the second side face 9 of the second insulating panel 2. The gap between the first seal 131, the second seal 132 and the cover 114 forms an excess foam evacuation corridor 50. The excess foam evacuation corridor 50 is intended to evacuate excess foam during the implementation of the inter-panel space insulation method.

[0158] Moreover, a film 40 made of a non-stick material covers the surface of the cover which is intended to be in contact with the expanding foam. The film 40 is for example made of Teflon®, that is to say made of PTFE.

[0159] Thus, in the case where the expanding foam expands and reaches a height greater than the height of the first insulating panel 1 and the second insulating panel 2, the excess foam characterized by the volume of foam exceeding said height is evacuated via the foam evacuation corridor 50 to a container (not shown) which is located near an edge of the first panel 1 or the second panel 2.

[0160] Figures 12 and 13 illustrate a variant embodiment of a cover that may be used in the present method. The cover 115 has a generally rectangular shape with rounded edges. The cover 115 comprises a plurality of openings 15 similar to that shown in figure 6, the openings 15 are through openings and open out toward the inter-panel space, the openings 15 are spaced apart from one another in the longitudinal direction of the cover 115. The openings 15 each have a diameter of 20 mm, for example. The injection of expanding foam may be carried out independently via one or more openings 15. The

openings 15 may be closed using plugs, in particular after the expanding foam injection step in order to contain the foam in the inter-panel space.

[0161] The cover 115 also has a plurality of oblong holes 41, some of which have different dimensions. The oblong holes 41 make the cover more lightweight and therefore facilitate the work of the operator carrying out the method. The oblong holes 41 may be through holes and open out opposite the first insulating panel or the second insulating panel. Thus, the oblong holes 41 do not open into the inter-panel space.

[0162] The oblong holes 41 also make it possible to provide a through passage in order to allow the cover 115 to be attached to the first and second insulating panels using an attachment means.

[0163] According to a variant embodiment, the cover 115 has a tongue 34 protruding from the surface of the cover which is intended to be in contact with the expanding foam. Such a tongue 34 makes it possible to prevent the foam from overflowing beyond the inter-panel space by limiting the volume of the inter-panel space.

[0164] According to another variant embodiment illustrated in figures 14 and 15, the bottom strip 11 placed in the inter-panel space 7, as shown in particular in figures 2, 4, 6 and 9, is replaced by beads of mastic.

[0165] In this variant embodiment, a first bead of mastic 42 is laid on an outer face of the second plywood plate 5 of the first insulating panel 1. The first bead of mastic 42 extends continuously along the first insulating panel 1, near the inter-panel space 7, in order to form a first barrier intended to prevent the expanding foam from propagating beyond the first bead of mastic 42, in particular to prevent the expanding foam from flowing largely under the first insulating panel 1.

[0166] A second bead of mastic 43 is laid on an outer face of the second plywood plate 5 of the second insulating panel 2. The second bead of mastic 43 extends continuously along the second insulating panel 2, near the inter-panel space 7, in order to form a second barrier intended to prevent the expanding foam from propagating beyond the second bead of mastic 43, in particular to prevent the expanding foam from flowing largely under the second insulating panel 2.

[0167] The distance D between the first bead of mastic 42 and the second bead of mastic 43 is equal to or greater than the distance between the first side face 8 of the first insulating panel 1 and the second side face 9 of the second insulating panel 2 forming the inter-panel space 7. The first bead of mastic 42 and the second bead of mastic 43 have the particular role of defining the lower lateral limits of the inter-panel space 7 so that the expanding

foam can expand in the inter-panel space 7, in a manner similar to the bottom strip 11 shown in particular in figures 2, 4, 6 and 9.

[0168] The expanding foam injected into the inter-panel space will therefore be partly housed in the space located between the first bead of mastic 42 and the second bead of mastic 43 and partly housed in the inter-panel space 7.

[0169] The expanding foam then expands in a manner similar to the embodiments described above and forms an inter-panel insulation 116 in the shape of an inverted T.

[0170] The same arrangement may be applied to a plurality of adjacent insulating panels as shown in figure 14 with four insulating panels each comprising a bead of mastic laid around the periphery of the plywood plate 5.

[0171] Another variant embodiment of the attachment of the cover is illustrated in figures 16 and 17. In this embodiment, the first insulating panel 1 and the second insulating panel 2 differ from the first and second insulating panels of figure 4 in that they respectively have a first circular recess 44, 45 and a second circular recess 46, 47 along the edge of the first side face 8 of the first insulating panel and along the edge of the second side face 9. The cover 117 is attached via an anchoring system comprising one anchoring element 51 per circular recess 44, 45. The diagram on the left shown in figure 17 depicts an anchoring element 51 in the raised position, housed in the first recess 44. The anchoring element 51 comprises, from the cover 117, a rod 52 which extends longitudinally in the recess 44 and which is attached to a centering cone 55. The centering cone has a conical surface the apex of which is oriented upward and defining a cam surface 56. The anchoring element 51 also includes an inflatable annular seal 54 which surrounds the cam surface 56 of the centering cone 55 and which is shown in the deflated state in this diagram.

[0172] The diagram on the right shown in figure 17 depicts the anchoring element 51 in the lowered position, securing the cover 117 and the seal 133 against the first and second insulating panels.

[0173] To this end, the inflatable annular seal 54 is inflated via an inflation system, such as a pump (not shown).

[0174] The inflation of the inflatable annular seal 54 causes:

- the centering cone 55 to move, downward, toward the second plywood plate of the insulating panel 2 in order to secure the cover 117 and to compress the seal 133.

[0175] After the foam expansion step, the inflatable annular seal 54 is deflated, and the cover and the anchoring system may be removed.

[0176] This explanation concerning the anchoring element 51 inserted in the recess 44 is applicable in an identical manner to each anchoring element, inserted for example respectively in the first and the second circular recesses 45, 47 in the first insulating panel 1 and the second circular recess 46 in the second insulating panel.

[0177] Such a method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank is easily adaptable in order to allow the insulation of several types of inter-panel space.

[0178] Although the invention has been described in connection with several particular embodiments, it is obvious that it is in no way limited thereto and that it includes all technical equivalents of the means described as well as combinations thereof, if these fall within the scope of the invention.

[0179] The use of the verb “comprise” or “include” and conjugated forms thereof does not rule out the presence of other elements or other steps in addition to those stated in a claim.

[0180] In the claims, any reference sign in parentheses should not be interpreted as a limitation of the claim.

Claims

- [Claim 1] A method for insulating an inter-panel space formed between a first insulating panel (1) and a second insulating panel (2) of a wall of a sealed and thermally insulating tank for the storage of fluid at low temperature, the first insulating panel (1) comprising a first side face (8) facing a second side face (9) of the second insulating panel (2), the inter-panel space (7) being delimited by the first side face (8) and the second side face (9), the method comprising the following steps:
- placing at least one insert element (10, 111, 112) against at least the first side face (8) of the first insulating panel (1),
 - injecting expanding foam into the inter-panel space (7) between the insert element (10, 111, 112) and the second side face (9) of the second insulating panel (2), such that the expanding foam expands in order to press the insert element (10, 111, 112) between said expanding foam and the first side face (8) of the first insulating panel (1).
- [Claim 2] The method for insulating an inter-panel space as claimed in claim 1, wherein the method further comprises a step of compartmentalization of the inter-panel space, (7), said step of compartmentalization being carried out before the expanding foam is injected.
- [Claim 3] The method for insulating an inter-panel space as claimed in claim 2, wherein the step of compartmentalization comprises the insertion of a bottom strip (11) into the inter-panel space (7), the bottom strip (11) being located at a lower end of the inter-panel space (7) and extending in a longitudinal direction of the inter-panel space (7) over an entire length of the inter-panel space (7).
- [Claim 4] The method for insulating as claimed in claim 3, wherein the bottom strip (11) comprises polyurethane foam.
- [Claim 5] The method for insulating an inter-panel space as claimed in any one of claims 2 to 4, wherein the step of compartmentalization further comprises the insertion of a first side strip (12) and a second side strip (13) respectively located at a first side end and a second side end of the inter-panel space (7), the first side strip (12) and the second side strip (13) extending in a direction transverse to the longitudinal direction of the inter-panel space (7).
- [Claim 6] The method for insulating as claimed in one of claims 2 to 5, wherein the step of compartmentalization comprises the insertion of at least one retaining strip (31) into the inter-panel space (7), the retaining strip (31) extending in a direction transverse to the longitudinal direction of the inter-panel space (7).
- [Claim 7] The method for insulating an inter-panel space as claimed in claim 5 or the combination of claims 5 and 6, wherein the first side strip (12) and the second side strip (13) comprise glass wool.

[Claim 8] The method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank as claimed in one of claims 2 to 7, comprising, prior to the injection of expanding foam:

- placing an inflatable device (17) in an uninflated state in an area defined between at least one of the first and second insulating panels and a third insulating panel adjacent to said first or second insulating panel, the area being transverse to the inter-panel space and the inflatable device being placed facing the inter-panel space (7),
- inflating the inflatable device (17) so that said inflatable device (17) in an inflated state leans at least on the third insulating panel and covers the first side end of the inter-panel space (7) in order to keep the expanding foam inside the inter-panel space (7) during the injection and expansion of the expanding foam.

[Claim 9] The method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank as claimed in claim 8 in combination with claim 5, wherein the inflatable device (17) is placed facing the first side strip (12), the inflatable device (17) being inflated so that said inflatable device (17) leans on the first side strip (12) in order to hold the first side strip (12) in a static position.

[Claim 10] The method for insulating an inter-panel space as claimed in one of claims 1 to 7, comprising, prior to the injection of expanding foam:

- placing a first crosspiece (31) made from insulating material in an area defined between at least one of the first insulating panel (1) and second insulating panel (2) and a third insulating panel (18) adjacent to said first or second insulating panel, the area being transverse to the inter-panel space (7) and the crosspiece (31) being positioned in order to close off a first side end of the inter-panel space (7) during the injection and expansion of the expanding foam.

[Claim 11] The method for insulating an inter-panel space as claimed in one of claims 2 to 10, wherein the step of compartmentalization comprises covering the inter-panel space (7) with a cover (14), the cover (14) comprising an opening (15) through which the expanding foam is injected into the inter-panel space (7).

[Claim 12] The method for insulating an inter-panel space as claimed in claim 11, wherein the cover (14) has a tongue (34) protruding from a surface of the cover which is intended to be in contact with the expanding foam.

[Claim 13] The method for insulating an inter-panel space as claimed in claim 11 or 12, wherein the cover (14) is attached against the first and second insulating panels (1, 2) via an attachment means.

[Claim 14] The method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank as claimed in one of claims 1 to 13, wherein the expanding foam comprises polyurethane.

[Claim 15] The method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank as claimed in one of claims 1 to 14, wherein the insert element is a compressible insulating element (10).

[Claim 16] The method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank as claimed in claim 15, wherein the compressible insulating element comprises glass wool, the glass wool being compressed during the expansion of the expanding foam.

[Claim 17] The method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank as claimed in one of claims 1 to 14, wherein the insert element comprises kraft paper, a non-stick stretch film or a mold release agent, preferably kraft paper.

[Claim 18] The method for insulating an inter-panel space of a wall of a sealed and thermally insulating tank as claimed in one of claims 2 to 17, wherein the first insulating panel (1) and the second insulating panel (2) each comprise an insulating foam (3) sandwiched between a first plywood plate (5) intended to carry a sealed membrane and a second plywood plate (5) intended to be placed on a support, wherein the step of compartmentalization comprises:

- laying a first bead of mastic (42) on an outer face of the second plywood plate (5) of the first insulating panel (1), the first bead of mastic (42) extending continuously along the inter-panel space (7);
- laying a second bead of mastic (43) on an outer face of the second plywood plate (5) of the second insulating panel (2), the second bead of mastic (43) extending continuously along the inter-panel space (7).