

## Description

### Title of the invention: Method for testing the seal of a sealed membrane

#### Technical field

- 5 [1] The invention relates to the field of sealed and thermally insulating membrane tanks. The invention relates in particular to the field of sealed and thermally insulating tanks for the storage and/or the transport of liquefied gas at low temperature, such as tanks for the transport of liquefied petroleum gas (LPG) at for example a temperature between -50°C and 0°C inclusive or for the transport of liquefied natural gas (LNG) at approximately  
10 -162°C at atmospheric pressure. These tanks may be installed on land or on a floating structure. In the case of a floating structure, the tank may be intended for the transport of liquefied gas or to receive liquefied gas serving a fuel for the propulsion of the floating structure.
- [2] In one embodiment the liquefied gas is LNG, namely a mixture with a high content of  
15 methane stored at a temperature of approximately -162°C at atmospheric pressure. Other liquefied gases may also be envisaged, in particular ethane, propane, butane or ethylene but also hydrogen. Liquefied gases may also be stored under pressure, for example at a relative pressure between 2 and 20 bar inclusive, and in particular at a relative pressure close to 2 bar. The tank may be constructed using various techniques, in particular in the  
20 form of an integrated membrane tank.

#### Technological background

- [3] A sealed and thermally insulating tank for storage of liquefied natural gas arranged in a supporting structure has a multilayer structure, namely, from the exterior toward the interior of the tank, a secondary thermally insulating barrier anchored against the supporting  
25 structure, a secondary sealing membrane that rests on the secondary thermally insulating barrier, a primary thermally insulating barrier that rests on the secondary sealing membrane, and a primary sealing membrane that rests on the primary thermally insulating barrier and that is intended to be in contact with the liquefied natural gas stored in the tank.
- [4] The document FR2903165 describes a sealed and thermally insulating tank in which  
30 prefabricated elements are anchored in the internal space of the supporting structure in order to form the tank. Each prefabricated element includes a secondary thermally insulating barrier portion, a secondary sealing membrane portion, and a primary thermally

insulating barrier portion. These prefabricated elements are anchored to the supporting structure in accordance with a regular mesh.

- 5 [5] The primary thermally insulating barrier portion of a prefabricated block covers the secondary sealing membrane only partially. Accordingly, a peripheral portion of the secondary sealing membrane of said prefabricated blocks can be seen. A flexible sealed film is fixed to said peripheral portion of the secondary sealing membrane of two adjacent prefabricated elements in order to assure the continuity of the secondary sealing membrane.
- 10 [6] During the construction of the tank, tests are carried out in order to be sure of the seal of the secondary sealing membrane. In some cases these seal tests must be carried out only on tank portions.
- 15 [7] For example, in the context of a tank of small size such as a ship fuel supply tank, the lower part of the tank is assembled initially from prefabricated blocks after which scaffolding is installed to finalize the construction of the tank. It is then necessary to test the seal of the secondary sealing membrane over the lower part of the tank when the tank has been only partially constructed.
- 20 [8] Likewise, during the construction of a methane tanker ship tank, a lateral opening is blocked at the end of construction of the tank by adding a supporting structure portion on which a tank portion is mounted. It is then necessary to check independently the seal of the secondary sealing membrane of the added tank portion.
- [9] However, this kind of test of the seal of the secondary sealing membrane of a tank portion is complex and necessitates numerous manipulations and checks. In particular, because this test is carried out only on an unfinished tank portion, the secondary sealing membrane does not form a sealed enclosed space enabling a simple and direct seal test.
- 25 [10] The document WO2014076424 describes a method of construction of a sealed and thermally insulated tank wall in which welded structures are used to form an enclosed space between a secondary sealing membrane and the supporting structure in such a manner as to test the seal of the secondary sealing membrane. Such welded structures are complex to implement.

## 30 **Summary**

- [11] One idea behind the invention is to provide a sealing membrane seal test method that is simple to use. In particular, one idea behind the invention is to provide a seal test method of this kind making it possible to check the seal of the sealing membrane of an unfinished tank portion, that is to say a tank portion intended to be associated with one or more other

tank portions in order to finalize the construction of said tank. One idea behind the invention is to enable a reliable and rapid seal test.

[12] To this end, the invention provides a method for testing the seal of a sealing membrane, the sealing membrane being fixed to a thermally insulating barrier, the thermally insulating barrier resting on a sealed supporting surface, the method comprising:

- applying a first strip of sealing compound to the sealing membrane;
- applying a second strip of sealing compound to the supporting surface around the sealing membrane,
- disposing a sealed cover on the first strip of sealed mastic and on the second strip of sealed mastic so that on the one hand the sealed cover is connected in sealed manner to the sealing membrane by the first strip of sealed mastic and, on the other hand, the sealed cover is connected in sealed manner to the supporting surface by the second strip of sealing compound, the sealed cover, the supporting surface, the first strip of sealing compound, the second strip of sealing compound and the sealing membrane together defining an enclosed space,
- depressurizing the enclosed space with respect to an environment outside said enclosed space; and
- measuring a parameter representing the variation of the pressure inside the enclosed space after said enclosed space has been depressurized.

[13] Thanks to these features it is possible to test the seal of the sealing membrane of a tank portion under construction in a simple and reliable manner. In particular, the application of strips of sealing compound and the arranging of the sealed cover in sealed manner on the sealing membrane and on the supporting surface by means of the strips of sealing compound enables an enclosed space to be produced in a simple and rapid manner without necessitating complex manipulations. In particular, this enclosed space is obtained without necessitating welding of metal parts to the sealing membrane and/or to the supporting surface.

[14] Embodiments of a seal test method of this kind may have one or more of the following features.

[15] A strip of sealing compound may take various forms. It is advantageously furnished in the form of a roll that is unrolled to apply the strip of sealing compound onto the required surface but may equally, for example, be produced from cartridges employed with a sealing compound gun or be produced from a bulk material. A strip of sealing compound of this kind has an elongate shape and is applied in such a manner as to surround a portion of the sealing membrane the seal of which must be tested.

- [16] In accordance with one embodiment, a strip of sealing compound is for example an adhesive tape. In accordance with one embodiment, the first strip of sealing compound and/or the second strip of sealing compound include(s) a film and a layer of sealing compound on one face of said film. In accordance with one embodiment, the layer of sealing compound is a layer of rubber, preferably a layer of synthetic rubber. In accordance with one embodiment, the layer of sealing compound has a thickness between 1 and 4 mm inclusive, for example 3 mm. In accordance with one embodiment, the first strip of sealing compound and/or the second strip of sealing compound is or are produced by a superposition of layers of sealing compound.
- [17] In accordance with one embodiment, the strip of sealing compound is a strip of butyl sealing compound, that is to say a plastic sealing compound based on polyisobutylene.
- [18] The rigid secondary barrier (RSB) or Triplex® preferably has a shear strength determined at -170°C in accordance with the ISO4587 standard between 17 and 30 MPa inclusive and preferably greater than 22 MPa.
- [19] In accordance with one embodiment, the strip of sealing compound is a strip of adhesive sealing compound, for example sealing compound applied with the aid of a sealing compound gun or any other device enabling a bead of sealing compound to be applied over the required length having the required dimensions of length, thickness, section and so on. In accordance with one embodiment, the first strip of sealing compound and/or the second strip of sealing compound is or are produced from a bead of sealing compound having a thickness between 1 mm and 15 mm inclusive, preferably between 2 mm and 10 mm inclusive. A bead of sealing compound of this kind advantageously enables compensation of flatness defects of the supporting surface.
- [20] In accordance with one embodiment, the first strip of sealing compound is fixed onto a peripheral portion of the sealing membrane, said peripheral portion of the sealing membrane surrounding a central portion of the sealing membrane the seal of which must be tested.
- [21] In accordance with one embodiment, the sealing membrane includes at least one composite sealed film portion, the method further including a step of application of an adhesive layer to a face of said at least one composite film portion in such a manner that said adhesive layer is impregnated in the composite film portion, the first strip of sealing compound being applied to said face of said at least one composite film portion.
- [22] An adhesive layer of this kind impregnating the composite sealed film portion enables good cooperation between the first strip of sealing compound and the sealing membrane,

including at the level of the composite sealed film portion, in particular when that composite sealed film is a flexible composite film as described hereinafter. In fact, a composite sealed film of this kind may feature irregularities, for example linked to the presence of visible fibers. These irregularities can degrade the sealed cooperation between the first strip of sealing compound and the sealing membrane at the level of the composite sealed film. An adhesive layer of this kind impregnated in the composite sealed film therefore adheres in a satisfactory manner to the composite sealed film portion whilst offering a satisfactory area of adhesion and of cooperation to the first strip of sealing compound. This is of particular interest when the sealed flexible composite film portion includes layers of glass fibers with no resin to which the first strip of sealing compound does not adhere correctly.

[23] In accordance with one embodiment, the adhesive layer is a layer of polyurethane glue.

[24] In accordance with one embodiment, the first strip of sealing compound is adhesive. In accordance with one embodiment the second strip of sealing compound is adhesive.

[25] Strips of adhesive sealing compound of this kind facilitate the seal test method. In fact, strips of adhesive sealing compound of this kind assure a sealed connection in a simple and reliable manner between said strips of adhesive sealing compound and on the one hand the sealing membrane or the supporting surface and, on the other hand, the sealed cover. Moreover, strips of adhesive sealing compound of this kind may be fixed in a rapid, reliable and sealed manner to the sealing membrane, likewise to the supporting surface.

[26] According to one embodiment, the first strip of sealing compound is made of synthetic rubber. According to one embodiment, the second strip of sealing compound is made of synthetic rubber.

[27] In accordance with one embodiment, the sealed cover is a polymer film tarpaulin.

[28] In accordance with one embodiment, the polymer film tarpaulin is made of a material chosen from vinyl, nylon and polyethylene.

[29] A polymer film tarpaulin of this kind is simple and rapid to produce and to form to size to form the sealed cover. Moreover, a polymer film tarpaulin of this kind is simple to install whilst offering satisfactory seal and strength properties upon depressurization of the enclosed space.

[30] In accordance with one embodiment, the method further includes a step of positioning a screen covering an interstice between the thermally insulating barrier and the supporting surface in order to prevent the polymer film tarpaulin from being positioned in said interstice during the depressurization of the enclosed space.

- [31] A screen of this kind enables blocking of an interstice between the thermally insulating barrier and the supporting surface. In fact, in the context of a tank integrated into a supporting structure such as a ship's double hull, beads of mastic are generally interleaved between the thermally insulating barrier and the supporting surface formed by the internal hull of the ship in order to compensate flatness defects of the supporting structure. A gap can therefore separate the thermally insulating barrier from the supporting surface. A screen of this kind makes it possible to prevent the polymer film tarpaulin being damaged when inserted into this space during depressurization of the enclosed space.
- [32] In accordance with one embodiment, the screen is a plate of for example plastic material.
- [33] In accordance with one embodiment, the method includes a step of positioning a protection angle-iron including a first plane flange and a second plane flange so that the first plane flange is disposed against the sealing membrane and the second plane flange extends along an edge of the thermally insulating barrier and projects in the direction of the supporting surface.
- [34] In accordance with one embodiment, the screen extends in the direction of thickness of the tank wall, in the direction of the interior of the tank, beyond the edge of the second plane flange of the protection angle-iron. This makes it possible to prevent the polymer film tarpaulin coming into contact against an insulating packing of the thermally insulating barrier.
- [35] In accordance with one embodiment, the screen includes an angle-iron resting on the one hand against the thermally insulating barrier and, on the other hand, against the supporting surface in such a manner as to form a plane bearing surface between the thermally insulating barrier and the supporting surface, the second strip of sealing compound being applied to the supporting surface in such a manner as to surround the angle-iron so that said angle-iron is accommodated in the enclosed space, the polymer film tarpaulin being caused to come to bear against said plane bearing surface during the depressurization of said enclosed space.
- [36] In accordance with one embodiment, a reinforcing fabric is fixed to the polymer film tarpaulin, the tarpaulin being fixed in such a manner that the reinforcing fabric is positioned in the enclosed space at the level of a corner formed by the thermally insulating barrier.
- [37] A reinforcing fabric of this kind makes it possible to prevent the polymer film tarpaulin being damaged during depressurization of the enclosed space. In fact, a polymer film tarpaulin of this kind is relatively thin and may be damaged during depressurization of the

enclosed space, said depressurization of the enclosed space bringing the polymer film tarpaulin into contact with projecting corners formed by the thermally insulating barrier. Moreover, the lateral face of the thermally insulating barrier may have some roughness, for example if that lateral face of the thermally insulating barrier is formed by an insulating packing including reinforcing fibers. Such roughness is also liable to damage the polymer film tarpaulin during depressurization of the enclosed space. This reinforcing fabric therefore enables protection of the polymer film tarpaulin during depressurization of the enclosed space.

[38] In accordance with one embodiment, the thermally insulating barrier includes a plurality of prefabricated blocks juxtaposed in accordance with a regular pattern. In accordance with one embodiment, the sealing membrane includes a plurality of rigid sealed film portions, each rigid sealed film portion being integrated into a corresponding prefabricated block. In accordance with one embodiment, a rigid sealed film portion, and preferably each rigid sealed film portion, includes a sheet of aluminum interleaved between two layers of glass fibers and resin, a rigid sealed film of this kind being in particular sold under the product name rigid Triplex®. In accordance with one embodiment, the sealing membrane includes one or more flexible and composite sealed film portions. In accordance with one embodiment, said flexible composite film portion or portions is or are fixed in sealed manner, for example glued, to rigid sealed film portions of two adjacent prefabricated blocks. In accordance with one embodiment, the flexible composite film portion or portions include(s) a sheet of aluminum interleaved between two layers of glass fibers without resin, a flexible composite film portion of this kind being in particular sold under the product name flexible Triplex®. In accordance with one embodiment, the composite sealed film portion to which the adhesive layer is applied is a flexible composite film portion.

[39] In accordance with one embodiment, the first strip of sealing compound is applied to the sealing membrane after the sealing membrane has been fixed to the thermally insulating barrier.

[40] In accordance with one embodiment, the first strip of sealing compound is applied directly against the rigid sealed film.

[41] In accordance with one embodiment, the first strip of sealing compound is applied indirectly by means of an adhesive layer on the flexible sealed film.

[42] In accordance with one embodiment, the method further includes steps of removing the sealed cover, removing the first strip of sealing compound and removing the second strip of sealing compound after the step of measuring the parameter representing the evolution of the pressure in the enclosed space. In accordance with one embodiment, the

method further includes a step of buffing the adhesive layer. This buffing of the adhesive layer enables removal of any pollution resulting from the application of the adhesive layer to the sealing membrane.

[43] In accordance with one embodiment, the sealed cover includes a sealed metal structure.

[44] A metal structure of this kind offers good reliability during the seal test whilst enabling simple and rapid sealing of the enclosed space by arranging said metal structure on the strips of sealing compound. Moreover, a metal structure of this kind has a weight enabling its cooperation in sealed manner with the strips of sealing compound in a simple and effective manner.

[45] In accordance with one embodiment, the metal structure includes

- a central portion,
- a plane internal rim, and
- a plane external rim,

and the plane internal rim is developed in a first plane parallel to the sealing membrane and the plane external rim is developed in a second plane parallel to the supporting surface,

and the sealed cover is arranged so that the first strip of sealing compound is interleaved in sealed manner between the plane internal rim and the sealing membrane and so that the second strip of sealing compound is interleaved in sealed manner between the plane external rim and the supporting surface.

[46] In accordance with one embodiment, the metal structure is made of stainless steel.

[47] In accordance with one embodiment, the central portion is plane. In accordance with one embodiment, the central portion is developed in a plane parallel to the direction of thickness of the tank wall.

[48] In accordance with one embodiment, the internal rim is developed in a first plane and the external rim is developed in a second plane, the first plane and the second plane forming an angle corresponding to the angle between the sealing membrane and the supporting surface.

[49] In accordance with one embodiment, the plane internal rim is developed perpendicularly to the plane central portion. In accordance with one embodiment, the plane external rim is developed perpendicularly to the plane central portion. In accordance with one embodiment, the plane internal rim is developed from a first edge of the plane central portion of a first side of said plane central portion and the plane external rim is developed

from a second edge of the plane central portion of a second side of the plane central portion, the first edge of the plane central portion being opposite the second edge of the plane central portion, the first side of the plane central portion being opposite the second side of the plane central portion.

5 [50] In accordance with one embodiment, a plurality of the aforementioned metal structures are arranged between the sealing membrane and the supporting surface, supplementary strips of sealing compound being arranged in sealed manner between two successive metal structures of the sealed cover.

10 [51] In accordance with one embodiment, the metal structure includes an internal part and an external part, the internal part including the plane internal rim and a first part of the central portion, the external part including the plane external rim and a second part of the central portion,

and the step of disposing the sealed cover includes the steps of:

- 15 - arranging the first part of the metal structure so that the plane internal rim rests on the first strip of sealing compound,
- arranging the second part of the metal structure so that the plane external rim rests on the second strip of sealing compound, and
- connecting in sealed manner the first part of the metal structure and the second part of the metal structure.

20 [52] A metal structure in two parts of this kind advantageously enables compensation of discrepancies linked to the manufacturing tolerances of the tank portion and/or of the parts of the metal structure. In particular, the first part and the second part of the central portion can overlap to a greater or lesser degree to form the central portion and thereby to compensate discrepancies resulting from the manufacturing tolerances of the metal structure or of the thermally insulating barrier or again flatness defects of the supporting surface.

30 [53] The first part of the metal structure and the second part of the metal structure may be connected in sealed manner in numerous ways. In accordance with one embodiment, the first part of the metal structure and the second part of the metal structure are connected in sealed manner by welding. In accordance with one embodiment, the first part of the metal structure and the second part of the metal structure are connected in sealed manner by a strip of sealing compound.

35 [54] In accordance with one embodiment, the method further includes a step of application of a bearing force in the direction of the supporting surface to the sealed cover in line with the first strip of sealing compound and in line with the second strip of sealing compound.

- [55] The application of a bearing force of this kind to the sealed cover in line with the strips of sealing compound assures good cooperation and a good seal between the sealed cover and the sealing membrane and/or the supporting surface.
- [56] In accordance with one embodiment, the method further includes a step of fixing a caul sheet at the level of a corner of the thermally insulating barrier so that said caul sheet covers said corner, the caul sheet being connected in sealed manner on the one hand to the supporting surface and, on the other hand, to the secondary sealing membrane.
- [57] In accordance with one embodiment, the sealed cover includes the caul sheet. In accordance with one embodiment, the caul sheet is accommodated in the enclosed space.
- [58] In accordance with one embodiment, the caul sheet is a metal part, for example a stainless steel part. The caul sheet may be fixed in numerous ways to the sealing membrane or to the supporting surface. In accordance with one embodiment, the caul sheet is welded to the supporting surface. In accordance with one embodiment, the caul sheet is connected in sealed manner to the supporting surface and/or to the sealing membrane by means of a strip of sealing compound like the first strip of sealing compound and/or, respectively, the second strip of sealing compound.
- [59] In accordance with one embodiment, the corner covered by the caul sheet is a projecting corner of the thermally insulating barrier.
- [60] In accordance with one embodiment, the corner has an edge that is developed in a direction of thickness of the tank, the caul sheet having a first plane flange covering a portion of a first lateral face of the thermally insulating barrier and a second plane flange covering a portion of a second lateral face of the thermally insulating barrier, said portions of the first lateral face and of the second lateral face of the thermally insulating barrier forming said corner of the thermally insulating barrier. In accordance with one embodiment, the caul sheet includes a third flange that is developed in a plane perpendicular to the direction of thickness of the tank, said third flange being connected in sealed manner to the sealing membrane.
- [61] In accordance with one embodiment, the caul sheet is produced by molding it in situ at the corner of the thermally insulating barrier.
- [62] In accordance with one embodiment, the method includes a step of positioning a connecting device including a connecting angle-iron and a connecting flange disposed facing an orifice formed in said connecting angle-iron, said connecting angle-iron being connected in sealed manner to the supporting surface, to the sealing membrane and to

the sealed cover and the connecting flange being connected in sealed manner to a means for depressurizing the enclosed space.

[63] In accordance with one embodiment, the connecting angle-iron is made by molding it in situ on the thermally insulating barrier, the connecting flange being embedded in the mass of the connecting angle-iron during molding thereof.

[64] In accordance with one embodiment, the invention also provides a sealing device for closing an enclosed space defined between a sealing membrane fixed to a thermally insulating barrier anchored to a supporting surface and said supporting surface, the sealing device including

- a sealed cover connected in sealed manner to, on the one hand, the sealing membrane by means of a first strip of sealing compound and, on the other hand, to the supporting surface by means of a second strip of sealing compound, and
- a vacuum pump connected to the enclosed space and able to depressurize said enclosed space.

[65] A sealing device of this kind enables simple, rapid and reliable testing of the seal of a tank portion.

[66] Embodiments of a sealing device of this kind may have one or more of the above features or the following features.

[67] In accordance with one embodiment, the sealed cover includes a polymer film tarpaulin, the sealing device further including a screen covering an interstice between the thermally insulating barrier and the supporting surface in such a manner as to block said interstice and to prevent the insertion of the polymer film tarpaulin in said interstice in the presence of depressurization of the enclosed space.

[68] In accordance with one embodiment, the sealing device further includes a clamping device adapted to exert a bearing force in the direction of the supporting surface on the sealed cover in line with the first and second strips of sealing compound.

[69] The application of a bearing force of this kind to the sealed cover in line with the strips of sealing compound assures good cooperation and a good seal of the fixing of the sealed cover to the strips of sealing compound.

[70] In accordance with one embodiment, the clamping device includes a fixing member fixed to the supporting surface and a bearing plate, the bearing plate being mounted to be mobile in a direction of thickness of the tank on the fixing member in such a manner as to be able to be brought to bear on the sealed cover in line with the second strip of sealing compound.

- [71] In accordance with one embodiment, the prefabricated blocks include a primary thermally insulating barrier portion resting on the rigid sealed film. In accordance with one embodiment, said thermally insulating barrier portions have dimensions less than the dimensions of the rigid sealed film so that a periphery of said rigid sealed film is apparent.
- 5 [72] In accordance with one embodiment, the clamping device includes a bearing member fixed to the primary thermally insulating barrier portion of a prefabricated block.
- [73] In accordance with one embodiment, the sealing membrane is a corrugated sealing membrane including a first series of parallel corrugations and a second series of parallel corrugations, the corrugations of the first series of parallel corrugations and the corrugations of the second series of parallel corrugations intersecting, the sealing  
10 membrane including a plurality of nodes formed at the level of the intersections between the corrugations of the first series of parallel corrugations and the corrugations of the second series of parallel corrugations. In accordance with one embodiment, the clamping device includes a bearing member fixed to the sealing membrane, for example by clipping  
15 it onto undercuts formed by the nodes of the sealing membrane.
- [74] In accordance with one embodiment said bearing member has a base fixed to said primary thermally insulating barrier portion, for example to one of said nodes of the sealing membrane, a spacer that is developed from said base in the direction of the rigid sealed film, and a bearing plate mounted to be mobile in the direction of thickness of the tank on  
20 the spacer so as to be able to exert a bearing force on the sealed cover in line with the first strip of sealing compound.
- [75] In accordance with one embodiment, the supporting surface is formed by a supporting structure intended to receive a sealed and thermally insulating tank including the sealing membrane the seal of which it is wished to test, for example by the internal hull of a ship  
25 including said tank.
- [76] In accordance with one embodiment, the supporting surface is formed by the secondary sealing membrane of a sealed and thermally insulating tank, the sealing membrane to be tested then being a primary sealing membrane.
- [77] A seal test method of the above kind or a sealing device of the above kind may be  
30 used in a tank that may be part of a terrestrial storage installation, for example for storing LNG, or installed in a coastal water or deep water floating structure, in particular a methane tanker ship, a floating storage and regassification unit (FSRU), a floating production storage and offloading (FPSO) unit and so on. A tank of this kind may also serve as a fuel tank in any type of ship.

## Brief description of the figures

- [78] The invention will be better understood and other objects, details, features and advantages thereof will become more clearly apparent in the course of the following description of particular embodiments of the invention given by way of nonlimiting illustration only and with reference to the appended drawings.
- [79] [fig.1] figure 1 is a schematic perspective view of a sealed and thermally insulating tank portion.
- [80] [fig.2] figure 2 is a view in section of the sealed and thermally insulating tank portion from figure 1 in which is installed a sealing device in accordance with a first embodiment.
- 10 [81] [fig.3] figure 3 is a view in section of the sealed and thermally insulating tank portion from figure 1 on which is installed a sealing device in accordance with a first variant of the first embodiment illustrated in figure 2.
- [82] [fig.4] figure 4 is a view in section of the sealed and thermally insulating tank portion from figure 1 on which is installed a sealing device in accordance with a second variant of the first embodiment illustrated in figure 2.
- 15 [83] [fig.5] figure 5 is a schematic view in perspective of a sealed and thermally insulating tank portion the seal of the sealing membrane of which must be tested.
- [84] [fig.6] figure 6 is a schematic detail view in perspective of the tank portion illustrated in figure 5 during a first step of executing a seal test method by means of a sealing device in accordance with a second embodiment.
- 20 [85] [fig.7] figure 7 is a schematic detail view in perspective of the tank portion illustrated in figure 5 during a second step of execution of the seal test method by means of the sealing device in accordance with the second embodiment.
- [86] [fig.8] figure 8 is a schematic detail view in perspective of the tank portion illustrated in figure 5 during a third step of execution of the seal test method by means of the sealing device in accordance with the second embodiment.
- 25 [87] [fig.9] figure 9 is a schematic detail view in perspective of the tank portion illustrated in figure 5 during a fourth step of execution of the seal test method by means of the sealing device in accordance with the second embodiment.
- 30 [88] [fig.10] figure 10 is a schematic detail view in perspective of the tank portion illustrated in figure 5 during a fifth step of execution of the seal test method by means of the sealing device in accordance with the second embodiment.

[89] [fig.11] figure 11 is a schematic detail view in perspective of the tank portion illustrated in figure 5 on which is installed the sealing device in accordance with the second embodiment.

[90] [fig.12] figure 12 is a view in section of the sealed and thermally insulating tank portion from figure 1 on which is installed a sealing device in accordance with another variant of the first embodiment illustrated in figure 2.

[91] [fig.13] figure 13 is a view in perspective of a connecting device during its production by molding it in-situ on the secondary thermally insulating barrier.

## Description of the embodiments

[92] In the remainder of the description the terms “external” and “internal” will be used to designate, in accordance with the definitions given in the description, the relative position of one element with respect to another, with reference to the interior of the tank. Thus an element close to or facing toward the interior of the tank is described as internal as opposed to an external element situated close to or facing toward the exterior of the tank.

[93] Referring to figure 1, there is seen a sealed and thermally insulating tank portion anchored onto a support structure 13. A tank portion of this kind includes, from the exterior of the tank toward the interior of the tank, a secondary thermally insulating barrier 1, a secondary sealing membrane 2, a primary thermally insulating barrier 3, and a primary sealing membrane (not illustrated in figure 1).

[94] The tank is constructed from prefabricated blocks 4 each including a secondary thermally insulating barrier portion, a secondary sealing membrane portion and a primary thermally insulating barrier portion. To be more specific, each prefabricated block 4 includes, from the exterior of the tank to the interior of the tank, a bottom plate 5, a secondary insulating packing 6, a rigid sealed film 7, a primary insulating packing 8, and a cover plate 9. The bottom plate 5 and the secondary insulating packing 6 form a first block of substantially parallelepiped shape covered by the rigid sealed film 7 and the primary insulating packing 8 and the cover plate 9 form a second block of substantially parallelepiped shape resting on the rigid sealed film 7.

[95] The bottom plate 5 and the cover plate 9 are for example made of plywood. The secondary insulating packing 6 and the primary insulating packing 8 are for example made of polyurethane foam, possibly reinforced by fibers. The rigid sealed film 7 is for example made of rigid Triplex®, that is to say constituted of a sheet of aluminum interleaved between two layers of glass fibers and of resin.

[96] In a prefabricated block 4 of this kind the bottom plate 5, the secondary insulating packing 6 and the rigid sealed film 7 have dimensions in a plane perpendicular to the direction of thickness of the tank greater than the dimensions of the primary insulating packing 8 and of the cover plate 9 so that a peripheral border 10 of the rigid sealed film is not covered by the primary insulating packing 8.

[97] During the construction of the tank prefabricated blocks 4 of this kind are anchored to the supporting structure 13, for example the internal wall of a ship's double hull, in a juxtaposed manner. A flexible sealed film 11 is applied to the peripheral border 10 of the rigid sealed film 7 of two juxtaposed prefabricated blocks 4 in such a manner as to ensure continuity of the seal between the rigid sealed films 7 of two adjacent prefabricated blocks 4. This flexible sealed film 11 is for example made of flexible Triplex®, that is to say constituted of a sheet of aluminum between two layers of glass fibers with no resin. The secondary sealing membrane 2 is formed by the rigid sealed film 7 of these two prefabricated blocks 4 and a flexible sealed film portion 11 connecting the adjacent peripheral border portions 10 of said two prefabricated blocks 4. Other details of prefabricated blocks 4 of this kind, the arrangement thereof, or again other constituent elements of the tank are for example described in the document FR2903165.

[98] During the construction of the tanks it is necessary to test the seal of the secondary sealing membrane 2 being constructed.

[99] This is for example the case in tanks of small size such as the tanks intended to serve as fuel tanks supplying a propulsion system. In fact, these tanks are likely to be assembled in two stages, a lower part of the tank being mounted on the supporting structure 13 initially after which, in a second time period and after the installation of scaffolding, the upper part of the tank is mounted on the supporting structure 13. It is necessary to test the seal of the secondary sealing membrane 2 before installing the upper part of the tank. Now, when only the lower part of the tank has been assembled the secondary sealing membrane 2 is only partially formed and the peripheral border 10 can be seen on the prefabricated blocks that constitute the edges of said lower part of the tank.

[100] This is also the case on closing the tank in the context of a methane tanker ship tank. In fact, during the construction of a methane tanker ship tank, a lateral portion of the supporting structure 13 and therefore of the corresponding tank is left open in order to allow the passage of the tooling necessary for the construction of the tank. This opening, generally referred to as the plating breach, is closed to finalize the construction of the tank by mounting a supporting structure 13 portion on which is mounted a corresponding portion of the tank. The portion of the tank mounted on the added portion of the supporting

structure 13 includes prefabricated blocks 4 and has a visible secondary sealing membrane 2 peripheral border 10. The seal of the secondary sealing membrane 2 formed by this assembled tank portion must also be tested before finalizing the construction of the tank.

5 [101] A seal test device is provided in order to test the seal of the secondary sealing membrane 2 in a tank under construction. Figures 2 to 4 illustrate a first embodiment of a seal test device of this kind.

[102] In the example illustrated in figure 1, only two prefabricated blocks 4 are illustrated. The remainder of the description of this first embodiment of the seal test device is given in  
10 the context of a tank portion formed by these two prefabricated blocks 4 and the flexible sealed film portion 11 connecting said prefabricated blocks 4. However, this description applies by way of analogy to any assembly of prefabricated blocks 4 anchored to the supporting structure and connected at the level of their adjacent edges by portions of flexible sealed film 11.

15 [103] A tank portion of this kind includes a secondary sealing membrane 2 central portion 14 the seal of which must be tested. The central portion 14 is formed by the rigid sealed films 7 of the adjacent prefabricated blocks 4 and the flexible sealed film 11 portions connecting said prefabricated blocks 4. The central portion 14 is surrounded by a secondary sealing membrane 2 peripheral portion 15. This peripheral portion 15 is formed on the one hand  
20 by the peripheral border portions 10 situated at the face level of prefabricated blocks 4 with no facing prefabricated block 4 and, on the other hand, by extremity portions 16 of the flexible sealed film portions 11 connecting said peripheral border portions 10.

[104] Figure 2 illustrates a view in section of a tank portion under construction on which is installed a device for testing the seal of the secondary sealing membrane in accordance  
25 within the first embodiment. This figure 2 typically illustrates a view in section of the prefabricated blocks 4 at the level of the section plane A-A in figure 1. The function of this seal test device is to enable testing of the seal of the central portion 14 of the secondary sealing membrane 2 formed by the two prefabricated blocks 4 and by the flexible sealed film portion 11 connecting in sealed manner the facing portions of the peripheral borders  
30 10 of the two prefabricated blocks 4.

[105] In accordance with this first embodiment, the seal test device includes a polymer film tarpaulin 12 fixed in sealed manner on the one hand to the secondary sealing membrane 2 and on the other hand to the supporting structure 13 by means of strips of sealing compound.

[106] A first strip of adhesive sealing compound 17 is applied to the rigid sealed film 7. To be more specific, this first strip of adhesive sealing compound 17 is applied in sealed manner to the peripheral portion 15 of the sealing membrane 2, that is to say to all the periphery of the secondary sealing membrane 2 entirely surrounding the central portion 14 of the secondary sealing membrane 2 to be tested.

[107] A second strip of adhesive sealing compound 18 is applied directly to the supporting structure 13. To be more specific, this second strip of adhesive sealing compound 18 is applied in sealed manner to the supporting structure 13 in such a manner as to surround entirely the tank portion the seal of the secondary sealing membrane 2 of which must be tested.

[108] The polymer film tarpaulin 12 is applied in sealed manner to the first strip of adhesive sealing compound 17. Similarly, the polymer film tarpaulin 12 is applied in sealed manner to the second strip of adhesive sealing compound 18. The polymer film tarpaulin 12 connects in sealed manner the secondary sealing membrane 2 covered by the first strip of sealing compound 17 and the supporting structure 13 at the level of the second strip of sealing compound 18. An enclosed space 19 is therefore delimited conjointly by the supporting structure 13 portion 20 surrounded by the second strip of sealing compound 18, the polymer film tarpaulin 12 and the central portion 14 of the secondary sealing membrane 2 surrounded by the first strip of sealing compound 17.

[109] The first strip of sealing compound 17 and the second strip of sealing compound 18 are preferably made of synthetic rubber. For example, the strips of sealing compound 17, 18 take the form of strips of adhesive sealing compound having a thickness of adhesive synthetic rubber between 1 and 4 mm inclusive, for example 3 mm, carried by a polyester PTFE or other film, the strip being unwound on applying the face bearing the sealing compound to the application surface and removing the film once the sealing compound has been applied to said surface. Strips of sealing compound 17, 18 based on synthetic rubber adhesive of this kind are for example produced by the company Airtech®, for example under the product name AT-200Y. The sealing compound is for example a butyl sealing compound, that is to say a plastic sealing compound based on polyisobutylene. A sealing compound of this kind has a viscosity at rest and at 25°C between 735 000 and 805 000 Pa.s. inclusive, for example of the order of 770 000 Pa.s, and a viscosity at 25°C between 180 000 and 250 000 Pa.s inclusive, for example of the order of 215 000 Pa.s when it is loaded at a shear rate of  $0.6 \text{ s}^{-1}$ . Moreover, a sealing compound of this kind has a shear strength determined at -170°C in accordance with the ISO4587 standard between

17 and 30 MPa inclusive and preferably greater than 22 MPa. Finally, it has been observed that a sealing compound of this kind has excellent adhesion properties.

[110] The polymer film tarpaulin 12 is for example made of vinyl film or of nylon, such as for example a tarpaulin produced by the company Airtech® under the product name Wrightlon®. A nylon tarpaulin of this type has for example a thickness between 50 and 100 µm inclusive, for example of the order of 70 µm. In accordance with another embodiment, the polymer film tarpaulin 12 is made of polyethylene and preferably has a thickness between 150 and 240 µm inclusive, for example of the order of 190 µm. A polymer film tarpaulin 12 of this kind is sealed and may be reliably and simply fixed in sealed manner by means of a strip of adhesive sealing compound 17, 18 such as described hereinabove. Moreover, a polymer film tarpaulin 12 of this kind may easily be sized as a function of the dimensions of the tank portion for which the seal of the secondary sealing membrane 2 must be tested.

[111] To verify the seal of the fixing of the first strip of sealing compound 17 to the secondary sealing membrane 2, of the second strip of sealing compound 18 to the supporting structure 13, and of the polymer film tarpaulin 12 to said strips of adhesive sealing compound 17, 18 it is for example possible to use an acoustic leak detection system, such as for example an ultrasound leak detection system, after first depressurizing the enclosed space 19. One such ultrasound leak detection system is for example the Vacleak LEQ-70® system produced by the company Airtech®.

[112] In order to test the seal of the secondary sealing membrane 2 to be tested, that is to say the central portion 14 surrounded by the first strip of sealing compound 17, the polymer film tarpaulin 12 is connected to a depressurizing means. One such depressurizing means is for example a vacuum pump 31 connected to the enclosed space 19 or any other depressurization means capable of reducing the pressure in the enclosed space 19.

[113] Activation of the depressurization means enables the pressure in the enclosed space 19 to be reduced relative to the environment external to said enclosed space 19. This depressurization is for example of the order of -500 to -600 mbar.

[114] In order to detect any seal defect of the secondary sealing membrane 2, the evolution of a parameter representing the pressure in the enclosed space 19 is then monitored by means of an ad hoc sensor, for example a sensor integrated into the vacuum pump 31. This parameter may for example be the pressure measured in the enclosed space by a pressure sensor 32, a tension parameter of the polymer film tarpaulin 12 under the depressurization in the enclosed space 19, an acoustic parameter or any other parameter enabling measurement of the evolution of the pressure in the enclosed space 19. A seal

defect of the secondary sealing membrane 2 under test is detected in the event of an increase in the pressure in the enclosed space 19 relative to the environment external to said enclosed space 19.

5 [115] The flexible sealed film 11 portion has a greater roughness than the rigid sealed film portion 7. In fact, the flexible Triplex® type flexible sealed film portion 11 includes visible fibers that compromise the sealed adhesion of the first strip of adhesive sealing compound 17 to said flexible sealed film 11 portion.

10 [116] In order to assure sealed cooperation between the flexible sealed film 11 portion and the first strip of sealing compound 17, a layer of polyurethane glue 21 is applied to the edge portions 16 of the flexible sealed film portion 11 intended to receive the first strip of sealing compound 17. This layer of polyurethane glue 21 penetrates the flexible sealed film 11 portion, thus assuring good cooperation between said layer of polyurethane glue 21 and the flexible sealed film portion 11. This layer of polyurethane glue 21 moreover offers a good adhesion surface for the first strip of sealing compound 17, thus assuring the  
15 sealed and reliable fixing of said first strip of sealing compound 17 to the flexible sealed film 11 portion. In order to assure good impregnation of the polyurethane layer 21 in the flexible sealed film 11, the layer of polyurethane glue 21 is advantageously heated and pressed. After the seal test the layer of polyurethane glue 21 is preferably buffed in order to prevent the presence of polyurethane glue residues on the flexible sealed film 11 portion.  
20 Similarly, after the seal test there preferably follows verification, for example simple visual inspection by an operative, of the absence of residues on the first strip of sealing compound 17 and where applicable the second strip of sealing compound 18.

25 [117] Figure 3 illustrates a first variant of the first embodiment of the seal test device. This first variant differs from that described with reference to figure 2 in that the seal test device further includes an angle-iron 22 forming a screen and a reinforcing fabric 23.

[118] When the enclosed space 19 is depressurized the polymer film tarpaulin 12 is caused by the depressurization to come into contact with and to press against the secondary thermally insulating barrier 1. In particular, the polymer film tarpaulin 12 is brought into contact with the projecting corner formed by the secondary thermally insulating barrier 1.  
30 A relatively thin polymer film tarpaulin 12 could therefore be damaged in contact with the projecting corner formed by the secondary thermally insulating barrier 1.

[119] In this first variant the reinforcing fabric 23 is positioned in such a manner as to cover the projecting corner formed by the secondary thermally insulating barrier 1 and therefore to protect the polymer film tarpaulin 12 when the enclosed space 19 is depressurized.

[120] Similarly, the insulating packing 6 of the secondary thermally insulating barrier 1 may have a high roughness, in particular when this insulating packing 6 is formed of foam reinforced by fibers. This roughness of the insulating packing 6 can also damage the polymer film tarpaulin 12 when the enclosed space 19 is depressurized, said depressurization of the enclosed space bringing the polymer film tarpaulin into contact with the secondary insulating packing 6. The reinforcing fabric 23 therefore advantageously covers the lateral faces of the prefabricated blocks 4 in such a manner as to protect the polymer film tarpaulin 12 when the enclosed space 19 is depressurized.

[121] A reinforcing fabric 23 of this kind is installed, for example fixed to or deposited on the secondary thermally insulating barrier 1, at the locations liable to damage the polymer film tarpaulin 12. This reinforcing fabric may equally be integrated directly into the polymer film tarpaulin 12, for example by gluing it thereto, and the polymer film tarpaulin is then fixed to form the enclosed space in such a manner that this reinforcing fabric 23 is arranged at the required locations of the secondary thermally insulating barrier 1 when the enclosed space 19 is depressurized. A reinforcing fabric 23 of this kind may be made of numerous materials such as cardboard, wood, plastic and so on enabling protection of the polymer film tarpaulin 12.

[122] Moreover, when the prefabricated blocks 4 are anchored to the supporting structure 13, an interstice 24 remains present between the bottom plate 5 of said prefabricated blocks 4 and the supporting structure 13. This interstice is the result of the presence of beads of sealing compound between the bottom plate 5 of the prefabricated blocks 4 and the supporting structure 13. Beads of sealing compound of this kind enable compensation of flatness defects of the supporting structure 13 and offer a plane bearing surface for anchoring the prefabricated blocks 4.

[123] The angle-iron 22 is installed around the tank portion for which the seal of the secondary sealing membrane 2 must be tested. The angle-iron 22 is positioned along the secondary thermally insulating barrier 1 in such a manner as to block the interstice separating the prefabricated blocks 4 and the supporting structure 13. This angle-iron 22 typically features a plane plate that is developed from the supporting structure 13 toward the interior of the tank at least as far as the bottom plate 5 of the prefabricated blocks 4. This plane plate therefore offers a continuous and plane bearing surface around the tank portion for which the seal of the secondary sealing membrane 2 must be tested. When the enclosed space 19 is depressurized the polymer film tarpaulin 12 is caused by the depressurization of the enclosed space 19 to come to bear against this plane surface formed by the angle-iron 22 and cannot be inserted into the interstices separating the

prefabricated blocks 4 and the supporting structure 13, as such insertion could damage the polymer film tarpaulin 12.

[124] In an analogous manner that is not represented, a blocking means may be provided between two lateral faces of adjacent prefabricated blocks 4 to prevent the polymer film tarpaulin 12 being damaged by the reduction of pressure in the enclosed space 19. This blocking means is for example produced by covering the spaces between the adjacent prefabricated blocks 4 with the reinforcing fabric 23, a plane plate or any other suitable means. This blocking means can therefore also be produced with the aid of insulating packing plugs inserted between the prefabricated blocks.

[125] In another variant embodiment represented in figure 12, the sealing device includes a plate 34, for example made of plastic material, such as PVC, that enables protection of the polymer film tarpaulin 12 during depressurization, preventing the latter from coming into contact against the insulating packing 6 and insertion thereof into the interstices separating the prefabricated blocks 4 and the supporting structure 13.

[126] Moreover, in this embodiment the sealing device includes a protection angle-iron 35 that is positioned along the secondary thermally insulating barrier 1. The protection angle-iron 35 includes a first plane flange that extends parallel to the supporting structure 13 and is fixed against the rigid sealed film 7 and a second plane flange that extends in the direction of thickness of the tank wall, in the direction of the supporting structure 13, and is positioned against the lateral faces of the prefabricated blocks 4. The protection angle-iron 4 is for example made of cardboard and enables protection of the polymer film tarpaulin 12 from the projecting corners of the secondary thermally insulating barrier 1.

[127] The plate 34 advantageously extends in the direction of thickness of the tank wall, in the direction of the interior of the tank, beyond the edge of the second plane flange of the protection angle-iron 35, which makes it possible to prevent the polymer film tarpaulin 12 coming into contact against the insulating packing 6.

[128] Figure 4 illustrates a second variant of the first embodiment of the seal test device. This second variant differs from that described with reference to figure 2 in that the seal test device further includes a complementary clamping device 25 for sealed fixing of the polymer film tarpaulin 12 to the supporting structure 13 and to the secondary sealing membrane 2.

[129] A clamping device 25 of this kind includes pins 26 fixed to the supporting structure 13. Bearing plates 27 are mounted on these pins 26 by any appropriate means. For example, a pin 26 of this kind includes a rod the end of which is threaded. The bearing plate 27 has

an orifice passing through it and is mounted on the pin 26 so that the shank of said pin passes through the orifice that passes through the bearing plate 27. A nut (not illustrated) is screwed onto the threaded end of the rod in such a manner as to press the bearing plate 27 in the direction of the supporting structure 13. A bearing plate 27 of this kind is for example a wood batten and is positioned so as to be brought to bear against the polymer film tarpaulin 12 in line with the second strip of sealing compound 18 when screwing down the nut.

[130] The clamping device 25 further includes a bearing member including a base 28, a spacer 29 and a bearing plate 30. The base 28 is fixed to the primary thermally insulating barrier 3. For example, the base 28 is fixed to the fixing points that are usually employed to fix complement panels used to complete the primary thermally insulating barrier 3 during construction of the tank. The spacer 29 is developed from the base 28 in the direction of the secondary sealing membrane 2. An edge of the spacer 29 opposite the base 28 carries the bearing plate 30 that is arranged in line with the first strip of sealing compound 17 and presses on the polymer film tarpaulin 12 in line with the first strip of sealing compound 17. The pressure of said bearing plate 30 is adjustable by any appropriate means; for example, the spacer 29 may be telescopic with an immobilizing system enabling adjustment of the size of the spacer 29 or the spacer 29 may include a thread cooperating with a nut that when it is screwed on brings the bearing plate 30 to bear on the polymer film tarpaulin 12 and so on.

[131] At the level of the corners of the tank portion for which the seal of the secondary sealing membrane 2 must be tested, for example at the level of the corners of the finalized tank, the polymer film tarpaulin 12 may incorporate pleats in order to follow the geometry of the tank portion at the level of said corner.

[132] An alternative is for a plurality of polymer film tarpaulin 12 pieces to be assembled by means of a strip of adhesive sealing compound providing an additional seal (not illustrated).

[133] In accordance with another alternative, a caul sheet 33 illustrated in figure 1 may be fixed in sealed manner to cover the corner. This caul sheet 33 includes a first plane flange, a second plane flange and a third plane flange. The first plane flange is developed in a plane parallel to the direction of thickness of the tank and covers an extremity portion of a first lateral face of the secondary thermally insulating barrier 1. The second plane flange is developed in a plane parallel to the direction of thickness of the tank and covers an edge portion of a second lateral face of the secondary thermally insulating barrier 1, the first edge portion and the second edge together form a projecting corner of the secondary thermally insulating barrier 1. The third flange is developed in a plane perpendicular to the

direction of thickness of the tank and covers a secondary sealing membrane portion vertically in line with said edge portions of the first and second lateral faces of the secondary thermally insulating barrier 1. This caul sheet 33 is for example made of stainless steel and is fixed in sealed manner by strips of adhesive sealing compound as described hereinabove applied between the third flange and the secondary sealing membrane 2 and between the first and second flanges and the supporting structure 13.

[134] In this alternative the polymer film tarpaulin 12 is able to cover the caul sheet 33 at the corner or to be fixed in sealed manner to said caul sheet 33 by one or more strips of adhesive sealing compound analogous to the first and/or second strip of adhesive sealing compound.

[135] In accordance with another alternative, not illustrated, the caul sheet 33 is produced by molding it in situ at the level of the corners of the thermally insulating barrier which enables a made-to-measure caul sheet 33 to be obtained. The caul sheet 33 is for example produced by molding polyurethane glue. To this end, the corner zone intended to receive the caul sheet molded in situ is covered beforehand with an adhesive protection strip making it possible to prevent the polyurethane glue coming into direct contact against the secondary sealing membrane 2 or the secondary thermally insulating barrier 1. The protection adhesive tape preferably consists of silicone and acrylic where the adhesive part is concerned while the strip part (non-adhesive function, but adhesive support and mechanical strength function) is made of polyester, with a thickness between 150 and 200  $\mu\text{m}$  inclusive, preferably between 155 and 170  $\mu\text{m}$  inclusive (Flash tape 5<sup>®</sup> from the company SOLVAY). Thereafter, a mat of glass fibers is positioned against the corner of the thermally insulating barrier before being covered with polyurethane glue. In accordance with one advantageous embodiment the polyurethane glue may be deposited in two stages. After polymerization of the caul sheet 33 the adhesive tape is removed and the caul sheet 33 is fixed by one or more additional strips of adhesive sealing compound analogous to the first and/or second strip of adhesive sealing compound, as in the previous embodiment.

[136] Moreover, in accordance with an embodiment illustrated in figure 13, the vacuum pump 31 is connected to the enclosed space by means of a connecting device such as illustrated in figure 13. The connecting device includes a connecting angle-iron 36 that is advantageously produced by molding it in situ in accordance with a process similar to that described hereinabove with reference to the caul sheet 33. A connecting flange 37 intended to be connected to the vacuum pump 31 is here embedded in the mass of the connecting angle-iron 36 when molding it. After polymerization of the connecting angle-

iron 36 the connecting angle-iron 36 is pierced facing the connecting flange 37 in order to enable depressurization of the enclosed space 19.

[137] The connecting angle-iron 36 is then fixed in a similar manner to the caul sheet 33, that is to say by one or more supplementary strips of adhesive sealing compound analogous to the first and/or second strip of adhesive sealing compound.

[138] As represented in figure 13, the connecting angle-iron 36 is advantageously disposed to straddle two adjacent prefabricated blocks 4 so that the connecting flange 37 is situated facing the space formed between two adjacent prefabricated blocks 4. This facilitates the depressurization of the enclosed space 19.

[139] Figures 5 to 11 illustrate the various steps of installation of a seal test device in accordance with a second embodiment. In those figures identical elements or elements having the same function as elements described hereinabove with reference to figures 1 to 4 have the same reference increased by 100. This second embodiment of the sealing device differs mainly in that the polymer film tarpaulin 12 is replaced by metal structures 112 as explained hereinafter.

[140] Figure 5 represents a plurality of adjacent prefabricated blocks 104 the rigid sealed films 107 of which are interconnected by flexible sealed film portions 111. In an analogous manner to the first embodiment described hereinabove, a first step of the installation of the seal test device in accordance with the second embodiment consists in applying a layer of polyurethane glue 121 to edge portions 116 of the flexible sealed film portions 111 intended to receive a first strip of sealing compound 117, as illustrated in figure 6. These layers of polyurethane glue 121 enable good cooperation between the first strip of sealing compound 117 and said edge portions 116 of the flexible sealed film portions 111.

[141] During a second step of installation of the sealing device, as illustrated in figure 7, the first strip of sealing compound 117 is applied in sealed manner to the peripheral portion 115 of the secondary sealing membrane 2. Similarly, the second strip of sealing compound 118 is applied in sealed manner to the supporting structure 113 around the tank portion for which the seal of the secondary sealing membrane 102 must be tested.

[142] During a third step a caul sheet 133 is installed at the level of a corner 134 formed by the secondary thermally insulating barrier 101. This caul sheet 33 is for example made of stainless steel.

[143] The caul sheet 133 includes a first plane flange 135 and a second plane flange 136. The caul sheet 133 is installed at the level of the corner 134 so that the first plane flange 135 is developed in a plane parallel to the direction of thickness of the tank and covers an

edge portion 137 of a first lateral face 138 of the secondary thermally insulating barrier 101. The caul sheet 133 is installed at the level of the corner 134 so that the second plane flange 136 is developed in a plane parallel to the direction of thickness of the tank and covers an edge portion 139 of a second lateral face 140 of the secondary thermally insulating barrier 101, said first edge portion 137 and said second edge portion 139 conjointly forming the corner 134 of the secondary thermally insulating barrier 101.

[144] The caul sheet 133 further includes a third plane flange 141 and a fourth plane flange 142. The third flange 141 is developed perpendicularly to the first and second plane flanges 135, 136 from the internal edges of said first and second plane flanges 135, 136. Similarly, the fourth plane flange is developed perpendicularly to the first and second plane flanges 135, 136 from the external edges of said first and second plane flanges 135, 136. The third plane flange 141 and the fourth plane flange 142 are therefore parallel and are developed in opposite directions from opposite edges of the first and second plane flanges 135, 136. The caul sheet 133 is installed at the level of the corner 134 so that the third flange 141 is applied in sealed manner to the first strip of sealing compound 117 and the fourth flange 142 is applied in sealed manner to the second strip of sealing compound 118. Thus the caul sheet 133 is fixed in sealed manner by means of the strips of sealing compound 117 and 118 to the secondary sealing membrane 102 and to the supporting structure 113.

[145] During a fourth step illustrated in figure 9 complementary strips of adhesive sealing compound 143 are applied to the edges of the caul sheet 133 that do not cooperate with the first strip of sealing compound 117 or the second strip of sealing compound 118.

[146] During a fifth step illustrated in figure 10 a metal structure 144 is arranged in sealed manner between the secondary sealing membrane 102 and the supporting structure 113. A metal structure 144 of this kind includes a plane central portion 145, a plane internal rim 146 and a plane external rim 147. The internal rim 146 and the external rim 147 are developed perpendicularly to the plane central portion 145. The internal rim 146 and the external rim 147 are developed from opposite edges of the plane central portion 145 and in opposite directions relative to said plane central portion 145. This metal structure 144 is arranged on the tank portion so that the internal rim 146 rests in sealed manner on the first strip of sealing compound 117 and the external rim 147 rests in sealed manner on the second strip of sealing compound 118, the plane central portion 145 covering the lateral face 138 of the thermally insulating barrier. The metal structure 144 is moreover arranged on the tank portion so that one extremity of said metal structure cooperates in sealed manner with one of the complementary strips of sealing compound 143 arranged on the

caul sheet 133. Typically the internal rim 146 of the metal structure 144 cooperates in sealed manner with the complementary strip of sealing compound 143 applied to the third flange 141 of the caul sheet 133, the plane central portion 145 of the metal structure 144 cooperates in sealed manner with the complementary strip of sealing compound applied to the first flange 135 of the caul sheet 133, and the external rim 147 of the metal structure 144 cooperates in sealed manner with the complementary strip of sealing compound 143 applied to the fourth flange 142 of the caul sheet 133. The metal structure 144 and the caul sheet 133 are therefore connected in sealed manner by the complementary strip of sealing compound 143.

[147] Caul sheets 133 and metal structures 144 of the above kind are arranged in an analogous manner over all the periphery of the tank portion for which the seal of the secondary sealing membrane 102 must be tested in order to form the enclosed space 119 as illustrated in figure 11.

[148] This second embodiment of the seal test device offers good reliability, the caul sheets 133 and the metal structures 144 being solid and there being no risk of them being damaged. Moreover, the seal of the enclosed space 119 is obtained simply and reliably thanks to the strips of sealing compound 117, 118 and 143. Moreover, this seal test device is very simple to remove since it is sufficient simply to remove the structures 144 and caul sheets 133 and then the strips of sealing compound 117 and 118, and possibly to buff the layers of polyurethane glue 121.

[149] In order to assure good cooperation between on the one hand the structures 144 and the caul sheets 133 and, on the other hand, the first strip of sealing compound 117 and the second strip of sealing compound, it is equally possible to apply a force to said structures 144 and caul sheets 133 by means of a clamping device analogous to that described hereinabove with reference to figure 4.

[150] Moreover, in order to compensate discrepancies linked to the manufacturing tolerances of the tank portion it is possible to provide structures 144 and caul sheets 133 in two parts. An internal part of a structure 144 then includes the internal rim 146 and an internal part of the central portion 145 and an external part of the structure 144 includes the external rim 147 and an external part of the central portion 145. The step of installation of the structure 144 then includes a first step consisting in installing the lower part or the upper part of the structure, applying a complementary strip of sealing compound to the central portion of said part, and installing the straddling other part of the structure so that the lower part and the upper part of the central portion 145 are connected in sealed manner by a complementary strip of sealing compound or by welding. By modifying the overlap

between the internal part and the external part of the central portion 145, this variant embodiment enables adaptation of the size of the central portion 145 to compensate discrepancies linked to the manufacturing tolerances of the tank.

5 [151] Similarly, it is possible to compensate flatness defects of the supporting structure 13, 113 by applying a plurality of layers of sealing compound to form the second strip of sealing compound 18, 118. In particular, in the second embodiment of the seal test device, flatness defects of the supporting structure 113 may generate a discrepancy that can vary between 4 mm and 30 mm with the metal structures 144 or the caul sheets 133. The application of a plurality of superposed layers of sealing compound enables the second strip of sealing  
10 compound 118 to be formed with a thickness sufficient to fill these discrepancies linked to flatness defects of the supporting structure 113.

[152] The description hereinabove is indicated for testing the seal of a secondary sealing membrane 2, 102 but the above sealing devices may be installed in an analogous manner to test a primary sealing membrane seal.

15 [153] In the context of testing the seal of a primary sealing membrane, the secondary sealing membrane 2, 102 forms a plane and sealed supporting surface to which the second strip of sealing compound 18, 118 is applied. In a variant, this plane and sealed supporting surface is formed by a seal test device for testing the seal of the secondary sealing membrane 2, 102. In another variant, the second strip of sealing compound 18, 118 is  
20 applied to the supporting structure 13, 113 and the secondary sealing membrane 2, 102 is equally accommodated in the enclosed space 19, 119. The first strip of sealing compound 17, 117 is then applied to the primary sealing membrane.

[154] Moreover, a clamping device 25 may then be adapted so that the base 28 includes a clamp, for example of the spring clip type, capable of being clipped onto a primary sealing  
25 membrane portion the seal of which must be tested. In the context of a primary sealing membrane including a first series of parallel corrugations and a second series of parallel corrugations forming nodes at the level of the intersections between the corrugations of the first series of corrugations and the corrugations of the second series of corrugations, the base 28 can then be clipped onto the nodes of said primary sealing membrane.

30 [155] Although the invention has been described with reference to a plurality of particular embodiments, it is obvious that it is in no way limited to them and that it encompasses all technical equivalents of the means described and combinations thereof if the latter enter within the scope of the invention as defined by the claims.

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

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

## Claims

- [Claim 1] A method for testing the seal of a sealing membrane (2, 102), the sealing membrane (2, 102) being fixed to a thermally insulating barrier (1, 101), the thermally insulating barrier (1, 101) resting on a sealed supporting surface (13, 113), the method comprising:
- applying a first strip of sealing compound (17, 117) to the sealing membrane (2, 102);
  - applying a second strip of sealing compound (18, 118) to the supporting surface (13, 113) around the sealing membrane (2, 102),
  - disposing a sealed cover (12, 144, 133) on the first strip of sealed mastic (17, 117) and on the second strip of sealed mastic (18, 118) so that on the one hand the sealed cover (12, 144, 133) is connected in sealed manner to the sealing membrane (2, 102) by the first strip of sealed mastic (17, 117) and, on the other hand, the sealed cover (12, 144, 133) is connected in sealed manner to the supporting surface (13, 113) by the second strip of sealing compound (18, 118), the sealed cover (12, 144, 133), the supporting surface (13, 113), the first strip of sealing compound (17, 117), the second strip of sealing compound (18, 118) and the sealing membrane (2, 102) together defining an enclosed space (19, 119),
  - depressurizing the enclosed space (19, 119) with respect to an environment outside said enclosed space (19, 119); and
  - measuring a parameter representing the variation of the pressure inside the enclosed space (19, 119) after said enclosed space (19, 119) has been depressurized.
- [Claim 2] The seal test method as claimed in claim 1, in which the sealing membrane (2, 102) includes at least one composite sealed film portion (11, 111), the method further including a step of application of an adhesive layer (21, 121) to a face of said at least one composite film portion (11, 11) in such a manner that said adhesive layer (21, 121) is impregnated in the composite film portion (11, 111), the first strip of sealing compound (17, 117) being applied to said face of said at least one composite film portion (11, 111).

[Claim 3] The seal test method as claimed in claim 2, in which the adhesive layer (21, 121) is a layer of polyurethane glue.

5 [Claim 4] The seal test method as claimed in any one of claims 1 to 3, in which the first strip of sealing compound (17, 117) is adhesive and in which the second strip of sealing compound (18, 118) is adhesive.

[Claim 5] The seal test method as claimed in any one of claims 1 to 4, in which first strip of sealing compound (17, 117) is made of synthetic rubber and in which the second strip of sealing compound (18, 118) is made of synthetic rubber.

10 [Claim 6] The seal test method as claimed in any one of claims 1 to 5, in which the sealed cover is a polymer film tarpaulin (12).

[Claim 7] The seal test method as claimed in claim 6, in which the polymer film tarpaulin (12) is made of a material chosen from vinyl, nylon and polyethylene.

15 [Claim 8] The seal test method as claimed in either one of claims 6 or 7, further including a step of positioning a screen (22, 34) covering an interstice between the thermally insulating barrier (1) and the supporting surface (13) in order to prevent the polymer film tarpaulin (12) from being positioned in said interstice during the depressurization of the enclosed space (19).

20 [Claim 9] The seal test method as claimed in claim 6 or 7, further including a step of positioning a protection angle-iron (35) including a first plane flange and a second plane flange so that the first plane flange is disposed against the sealing membrane (2) and the second plane flange extends along an edge of the thermally insulating barrier (1) and projects in the direction of the supporting surface (13).

25 [Claim 10] The seal test method as claimed in any one of claims 6 to 9, in which a reinforcing fabric (23) is fixed to the polymer film tarpaulin (12), the tarpaulin being fixed in such a manner that the reinforcing fabric (23) is positioned in the enclosed space (19) at the level of a corner formed by the thermally insulating barrier (1).

30 [Claim 11] The seal test method as claimed in any one of claims 1 to 5, in which the sealed cover includes a sealed metal structure (144).

[Claim 12] The seal test method as claimed in claim 11, in which the metal structure (144) includes

- a central portion (145),
- a plane internal rim (146), and
- 5 - a plane external rim (147),

and in which the plane internal rim (146) is developed in a first plane parallel to the sealing membrane (102) and the plane external rim (147) is developed in a second plane parallel to the supporting surface (113),

and in which the sealed cover is arranged so that the first strip of sealing compound (117) is interleaved in sealed manner between the plane internal rim (146) and the sealing membrane (102) and so that the second strip of sealing compound (118) is interleaved in sealed manner between the plane external rim (147) and the supporting surface (113).

[Claim 13] The seal test method as claimed in claim 12, in which the metal structure (144) includes an internal part and an external part, the internal part including the plane internal rim (146) and a first part of the central portion (145), the external part including the plane external rim (147) and a second part of the central portion (145),

and in which the step of disposing the sealed cover includes the steps of:

- 20 - arranging the first part of the metal structure (144) so that the plane internal rim (146) rests on the first strip of sealing compound (117),
- arranging the second part of the metal structure (144) so that the plane external rim (147) rests on the second strip of sealing compound (118), and
- 25 - connecting in sealed manner the first part of the metal structure (144) and the second part of the metal structure (144).

[Claim 14] The seal test method as claimed in any one of claims 1 to 13 further including a step of application of a bearing force in the direction of the supporting surface (13, 113) to the sealed cover (12, 133, 144) in line with the first strip of sealing compound (17, 117) and in line with the second strip of sealing compound (18, 118).

[Claim 15] The seal test method as claimed in any one of claims 1 to 14, further including a step of fixing a caul sheet (33, 133) at the level of a corner

of the thermally insulating barrier (1, 101) so that said caul sheet (33, 133) covers said corner, the caul sheet (33, 133) being connected in sealed manner on the one hand to the supporting surface (13, 113) and, on the other hand, to the sealing membrane (2, 102).

5 [Claim 16] The seal test method as claimed in claim 15, in which the caul sheet (33) is made by molding in situ in the corner of the thermally insulating barrier (1).

[Claim 17] The seal test method as claimed in any one of claims 1 to 16, including a step of positioning a connecting device including a connecting  
10 angle-iron (36) and a connecting flange (37) disposed facing an orifice formed in said connecting angle-iron (36), said connecting angle-iron (36) being connected in sealed manner to the supporting surface (13), to the sealing membrane (2) and to the sealed cover (2) and the connecting flange (36) being connected in sealed manner to a means (31) for depressurizing the  
15 enclosed space (19).

[Claim 18] The seal test method as claimed in claim 15, in which the connecting angle-iron (36) is made by molding it in situ on the thermally insulating barrier (1), the connecting flange (37) being embedded in the mass of the connecting angle-iron (36) during molding thereof.

20 [Claim 19] A sealing device for closing an enclosed space (19, 119) defined between a sealing membrane (2, 102) fixed to a thermally insulating barrier (1, 101) anchored to a supporting surface (13, 113) and said supporting surface (13, 113); the sealing device including  
- a sealed cover (12, 133, 144) connected in sealed manner too, on the one  
25 hand, the sealing membrane (2, 102) by means of a first strip of sealing compound (17, 117) and, on the other hand, to the supporting surface (13, 113) by means of a second strip of sealing compound (18, 118), and  
- a vacuum pump connected to the enclosed space (19, 119) and able to depressurize said enclosed space (19, 119).

30 [Claim 20] The sealing device as claimed in claim 19, in which the sealed cover includes a polymer film tarpaulin (12), the sealing device further including a screen (22) covering an interstice between the thermally insulating

barrier (1) and the supporting surface (13) in such a manner as to block said interstice and to prevent the insertion of the polymer film tarpaulin (12) in said interstice in the presence of depressurization of the enclosed space (19).

5 [Claim 21] The sealing device as claimed in claim 19 or 20, further including a clamping device (25) adapted to exert a bearing force in the direction of the supporting surface (13, 113) on the sealed cover (12, 133, 144) in line with the first and second strips of sealing compound.