

Description

Title of the invention: Bell-shaped leak detection device for a sealing membrane

Technical field

- 5 [0001] The invention relates to a bell-shaped leak detection device for detecting leaks in a sealing membrane, in particular a corrugated sealing membrane, for example, in a sealed tank. These sealed tanks can be, for example, sealed and thermally insulating tanks for storing and/or transporting a fluid, such as a cryogenic fluid.

Technological background

- 10 [0002] Document KR 1020100050128 discloses a method for testing the seal of a membrane of a sealed and thermally insulating tank for storing LNG. The tank comprises a multilayer structure and successively has, from the outside to the inside, a secondary insulating space, a secondary sealing membrane, a primary insulating space and a primary sealing membrane intended to be in contact with the liquefied natural gas contained in the tank.
- 15 The method more particularly aims to detect leaks through weld beads that allow the metal sheets of the primary sealing membrane to be sealably connected together. The method stipulates injecting a tracer gas into the primary insulating space, then moving detection equipment equipped with a tracer gas analyzer, inside the tank, along the weld beads of the primary sealing membrane. Thus, if the detection equipment detects the presence of
- 20 the tracer gas, it can infer that there is a sealing fault in the primary sealing membrane. In such a method, injecting the tracer gas into the primary insulating space is critical, since the detection method can only guarantee reliable results if the tracer gas has been homogeneously distributed throughout the whole of the primary insulating space.

- [0003] Furthermore, the detection equipment is made up of a tracer gas suction unit and a
- 25 tracer gas detector. The suction unit is moved along the entire length of the weld bead using a carriage, with the carriage being located on a bottom wall of the tank and the suction unit being fixed to the carriage so as to be located on a weld bead of a wall adjacent to the bottom wall. However, it is difficult, using this equipment, to check all the weld beads of the tank, since the equipment is bulky and needs to be connected to the carriage on the
- 30 bottom wall. This equipment is also very slow, since the equipment only checks a small portion of the weld bead at a time and the assembly of the equipment on the carriage needs to be modified in order to change weld bead.

Summary of the invention

[0004] One idea behind the invention is to propose a bell-shaped detection device or a leak detection device for testing the seal of a sealed membrane of a tank that is reliable and is easy to use in the tank.

5 [0005] Another idea behind the invention is to propose a bell-shaped detection device or a leak detection device that can be used quickly for testing the seal of a sealed membrane of a tank in a minimum amount of time.

[0006] Another idea behind the invention is to propose a method for testing the seal of a membrane that is reliable and quick to implement.

10 [0007] According to one embodiment, the invention provides a bell-shaped leak detection device for detecting a leak on a test zone of a sealing membrane of a tank, the bell-shaped detection device comprising:

- a main body intended to be arranged on the test zone;
- a seal connected to the main body and configured to define a detection chamber between the main body and the test zone, the seal comprising a peripheral sealing lip having a closed contour for surrounding the test zone;
- 15 - a mechanical pressure means supported by the main body and comprising at least one pressure element configured to exert a pressure, on a portion of the sealing lip, directed toward the membrane when the main body is arranged on the test zone.

20 [0008] By virtue of these features, the bell-shaped detection device can be quickly placed on a test zone so that the seal can form a detection chamber over the entire test zone. Furthermore, the mechanical pressure means allows the sealing lip to be pressed onto one or more portions, particularly where there is a risk of the seal detaching from the sealing membrane, in order to increase the reliability of detecting a possible leak by the bell-shaped detection device.

25 [0009] Advantageously, the bell-shaped detection device is able to detect a tracer gas. According to one possibility provided by the invention, this tracer gas is not necessarily injected into the zone where the seal is tested, it can be introduced into the zone in another way.

30 [0010] Furthermore, by virtue of the bell-shaped leak detection device according to the invention, it is now possible to easily obtain a depression of less than 100 Pa in the detection chamber, for example, of the order of 50 to 60 Pa (0.5-0.6 mbar).

[0011] According to other advantageous embodiments, such a bell-shaped device can have one or more of the following features.

[0012] According to one embodiment, the pressure element is a resiliently deformable element that exerts a pressure on the portion of the sealing lip by resilient deformation.

[0013] Thus, the elasticity of the pressure element allows, during the resilient deformation thereof, a return force to be exerted on the sealing lip toward the sealing membrane.

5 [0014] According to one embodiment, the pressure element is oriented perpendicular to the contour of the peripheral sealing lip.

[0015] According to one embodiment, the sealing lip has a service state, when a depression is applied in the detection chamber, wherein a portion of the sealing lip is held between the main body and the sealing membrane over at least part of the periphery of the detection
10 chamber, advantageously over the entire periphery of said chamber.

[0016] According to one embodiment, the bell-shaped leak detection device has an elongated shape, the length of which is greater than or equal to 0.5 m, preferably greater than or equal to 1 m, more preferably greater than or equal to 2 m.

[0017] According to one embodiment, the mechanical pressure means comprise a plurality of
15 pressure elements configured to exert a pressure on a plurality of portions of the sealing lip, with portions being located at the two ends of the sealing lip in a longitudinal direction.

[0018] According to one embodiment of the invention, portions of the sealing lip pressed by the mechanical pressure means are located at the two ends of the sealing lip in a longitudinal direction, that is at the two ends of the bell-shaped device, given that said
20 device has a general longitudinal shape.

[0019] Thus, the mechanical pressure means apply a pressure on various zones where there is a risk of the seal detaching, namely the ends of the seal.

[0020] According to one embodiment, the sealing lip comprises at least one indentation, the shape of which corresponds to that of a corrugation of the membrane, the indentation
25 being intended to straddle the corrugation.

[0021] According to one embodiment, the sealing lip comprises at least two indentations, for example, three indentations.

[0022] By virtue of these features, it is possible to place the bell-shaped detection device on a sealing membrane comprising corrugated sheets, with the one or more indentations
30 allowing the bell-shaped device to straddle the corrugations.

[0023] According to one embodiment, the portion of the sealing lip pressed by the mechanical pressure means is located at a base of the indentation.

[0024] By virtue of this feature, the bell-shaped detection device can be placed on a sealing membrane comprising corrugated sheets, with the one or more indentations allowing the bell-shaped device to straddle the corrugations.

5 [0025] Thus, the mechanical pressure means apply a pressure on a zone where there are risks of the seal detaching due to the change of slope of the indentation.

[0026] According to one embodiment, the mechanical pressure means comprise a plurality of pressure elements configured to exert a pressure on a plurality of portions of the sealing lip, with portions being located at the bases of the indentation or indentations.

10 [0027] Thus, the mechanical pressure means apply a pressure on various zones where there is a risk of the seal detaching, namely the base of one or more indentations.

[0028] According to one embodiment, the portion of the sealing lip is located on an apex of the indentation.

15 [0029] According to one embodiment of the invention, all the portions of the sealing lip located at the bases of the indentation are pressed by the plurality of pressure elements of the mechanical means.

[0030] According to one embodiment, at least one, part of or the pressure elements comprise a curved strip, at least one of the ends of which comes into abutment on the base of an indentation.

20 [0031] Advantageously, at least one, part of or the pressure elements comprise a curved strip, the two ends of which come into abutment on the base of two contiguous indentations.

25 [0032] By virtue of this feature, it is easier to position the bell-shaped leak detection device, since the curved strip will allow correct pressure placement of the indentations of the sealing lip on the two contiguous ridges of the membrane, irrespective of any slight variations of the distance between these two contiguous ridges or the approximate positioning of the bell-shaped leak detection device on the ridged membrane by one or more operators.

[0033] According to one embodiment, the mechanical pressure means comprise a support element extending over the entire length of the main body, above said main body and fixed thereto.

30 [0034] According to one embodiment, the curved strips are distributed over the sealing lip and are fixed to the support element by fixing means.

[0035] According to one embodiment, the curved strips are resiliently deformable so as to, when they are deformed, exert a resilient return force on the sealing lip.

[0036] According to one embodiment, the fixing means comprise a plurality of pins, the pins each comprising a rod freely mounted on a body, the rod comprising an end in abutment against one of the curved strips, the body being fixed to the support element, and also comprising a spring connecting the rod to the body, the spring acting between the body and the rod in order to position the end of the rod in abutment against the curved strip and the spring being configured to exert a return force on the curved strip, so that the curved strip urges the sealing lip against the base of a corrugation.

[0037] According to one embodiment, the mechanical pressure means comprise a plurality of end pressure elements, the end pressure elements being located at the two ends of the sealing lip in a longitudinal direction, that is at the two ends of the bell-shaped device, given that said device has a longitudinal shape.

[0038] Thus, the length of the bell-shaped device according to the invention can be at least one (1) meter and between 10 and 20 centimeters (cm) wide, preferably between 14 cm and 16 cm.

[0039] The bell-shaped leak detection device according to the invention is able, when it is used on a membrane zone comprising ridges, to test a plurality of ridges (the one or more weld points present on said ridge or on said ridges), that is at least three (3) ridges and up to nearly ten ridges. It is also possible to contemplate connecting a plurality of bell-shaped detection devices one next to the other, or one after the other, in order to form a greater/more substantial test zone length, with only one vacuum pump then being able to be used to generate the required vacuum in these bell-shaped leak detection devices that are connected together.

[0040] Such a bell-shaped detection device can weigh between 3 kilos and 25 kilos, preferably between 5 and 10 kilos, particularly as a function of the materials used, its length and its width.

[0041] According to one embodiment, at least one or the end pressure elements comprise an end pin, the end pin comprising a rod freely mounted on a body, with an elongated bearing element being fixed to an end of the rod, the elongated bearing element coming into abutment against the sealing lip, and the body being fixed to the support element, the end pin also comprising a spring connecting the rod to the body, the spring acting between the body and the rod in order to position the elongated bearing element against the sealing lip, the spring being configured to exert a return force on the elongated bearing element, so that the elongated bearing element urges the sealing lip against the zone to be tested.

[0042] According to one embodiment, the second end is equipped with an elongated bearing element, the elongated bearing element being configured to transfer the resilient return

force onto a zone of the sealing lip corresponding to a length of the elongated bearing element.

5 [0043] According to one embodiment, the second end of a first end pin and the second end of a second end pin adjacent to the first end pin are fixed together using an elongated bearing element.

[0044] According to one embodiment, at least one or the end pressure elements comprise a plurality of adjustment elements forming a row of elements, the adjustment element comprising a rod extending toward the sealing lip and an adjustable end in a longitudinal direction of the rod, so as to come into contact with the sealing lip following adjustment.

10 [0045] According to one embodiment, the pressure element comprises a curved strip comprising, at one of the ends thereof that is in contact with the sealing lip, a cylindrical sleeve.

[0046] Thus, the cylindrical sleeve allows the pressure of the mechanical pressure means to be evenly applied on part of the sealing lip.

15 [0047] According to one embodiment, the seal comprises a casing, which at least partially covers the main body and which is fixed to the main body, the peripheral sealing lip being connected to the casing so as to extend said casing and being curved opposite the main body.

20 [0048] According to one embodiment, the cylindrical sleeve comprises a length direction, the length direction of the cylindrical sleeve being substantially orthogonal to the casing, so that the cylindrical sleeve extends from the casing at one end of the sealing lip.

[0049] According to one embodiment, the sealing lip comprises a curved part substantially orthogonal to the casing, the curved part having a transverse section dimension that is greater than or equal to 1 cm, preferably greater than or equal to 1.5 cm, more preferably
25 greater than or equal to 2 cm.

[0050] According to one embodiment, the seal is made from an elastomer material, the hardness of which is between 20 and 50 Shore A.

[0051] By virtue of these features, the seal is made up of a material that is flexible enough to be deformed by the mechanical pressure means.

30 [0052] According to one embodiment, the elastomer material of the seal is selected from polyurethane elastomer and ethylene-propylene-diene monomer (EPDM) rubber. The elastomer material of the seal also can be made of silicon, nitrile or Viton®.

[0053] According to one embodiment, the main body comprises a rigid core, and the seal comprises a casing hermetically applied against a peripheral wall of the rigid core.

[0054] According to one embodiment, the rigid core comprises a recess on a lower surface that is intended to be rotated toward the test zone.

5 [0055] According to one embodiment, the rigid core comprises a channel connecting the recess to an upper surface of the rigid core for connecting a vacuum pump.

[0056] According to one embodiment, the invention provides a leak detection device for testing the seal of a sealed and thermally insulating tank, the leak detection device comprising:

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- a bell-shaped leak detection device as described above;
 - a vacuum pump connected to the detection chamber;
 - analysis equipment connected to the detection chamber for analyzing an amount of gas present in the detection chamber.

[0057] According to one embodiment, the invention provides a leak detection assembly on a test zone of a sealing membrane of a tank, the assembly comprising:

- 15
- a bell-shaped leak detection device as described above or a leak detection device as described above;
 - a sealing membrane comprising a test zone;

20 wherein the bell-shaped leak detection device is located on the test zone so that the sealing lip surrounds the test zone.

[0058] According to one embodiment, the invention provides a method for operating a leak detection device as described above on a test zone of a sealing membrane of a tank, wherein the method comprises the following steps:

- 25
- placing the bell-shaped detection device on the test zone so that the sealing lip completely surrounds the test zone;
 - applying a pressure onto the sealing lip using the mechanical pressure means in order to press the sealing lip against the sealing membrane;
 - depressurizing the detection chamber by means of the vacuum pump;
 - conveying the gases present in the detection chamber toward the analysis equipment;
- 30 and

- analyzing, by means of the analysis equipment, the gases originating from the detection chamber and delivering a variable representing the gases present in the detection chamber.

[0059] According to one embodiment, the bell-shaped leak detection device is oriented on the test zone so that a length of the bell-shaped leak detection device is superposed with the test zone.

5 [0060] According to one embodiment, the test zone is part of a weld bead of the sealing membrane.

[0061] Thus, the bell-shaped leak detection device is used to verify that there is no fault on the weld bead that could generate a leak in the sealing membrane.

[0062] According to one embodiment, the test zone is located on a corrugated sealing membrane.

10 [0063] According to one embodiment, the invention provides a method for testing the seal of a membrane of a sealed and thermally insulating tank, the sealed and thermally insulating tank having a polyhedral shape defined by a plurality of tank walls that are fixed on a support structure, each of the tank walls comprising a thermally insulating barrier comprising insulating elements anchored to the support structure and a membrane resting
15 against the insulating elements of the thermally insulating barrier, the thermally insulating barriers of the tank walls being connected together and together defining the thermally insulating space; the seal testing method comprising the following steps:

- injecting tracer gas into the thermally insulating space;
- providing a leak detection device comprising a bell-shaped detection device configured
20 to define a sealed detection chamber with the membrane, and a vacuum pump, which is, on the one and, connected to the detection chamber and, on the other hand, to analysis equipment;
- arranging the bell-shaped detection device against a face of the membrane opposite the thermally insulating space, the bell-shaped detection device being arranged so that the
25 detection chamber is arranged facing a portion of a weld bead to be tested;
- depressurizing the detection chamber using the vacuum pump;
- conveying the gaseous phase contained in the detection chamber toward the analysis equipment; and
- analyzing, by means of the analysis equipment, said gaseous phase and delivering a
30 variable representing a concentration of tracer gas in said gaseous phase.

[0064] It is clearly understood that the pressure applied on the sealing lip, before depressurizing the detection chamber, is exerted on the surface of said lip from outside the detection chamber. In this way, the sealing lip, which can be a single element, defines a sealed or hermetic volume intended to become, once depressurization is implemented,
35 the depressurization chamber.

- [0065] According to one embodiment, the invention provides a leak detection device for testing the seal of a membrane of a sealed and thermally insulating tank; the leak detection device comprising a bell-shaped detection device configured to define a sealed detection chamber with the membrane, and a vacuum pump, which is, on the one hand, connected to the detection chamber and, on the other hand, to analysis equipment.
- [0066] According to embodiments, the method for testing the seal of a membrane and/or the leak detection device can comprise one or more of the following features.
- [0067] According to one embodiment, the tracer gas is injected into the thermally insulating space by means of the aforementioned tracer gas injection method. However, according to another embodiment, the tracer gas also can be injected into the thermally insulating space using another method.
- [0068] According to one embodiment, the analysis equipment is a mass spectrometer.
- [0069] According to one embodiment, the bell-shaped detection device has an elongated shape.
- [0070] According to one embodiment, the bell-shaped detection device comprises a rigid core and a seal, which are fixed together and are arranged to define the detection chamber with the membrane to be tested.
- [0071] According to one embodiment, the seal comprises a casing fixed to the rigid core and a peripheral sealing lip that extends the casing.
- [0072] According to one embodiment, the casing of the seal has a base, which covers the upper surface of the rigid core and a peripheral wall, which conforms to the periphery of the rigid core.
- [0073] According to one embodiment, the peripheral sealing lip is curved toward the outside of the bell-shaped detection device and is configured to bend and to be urged against the membrane when the detection chamber is depressurized.
- [0074] According to one embodiment, the portion of the weld bead is traversed by at least one corrugation of the membrane.
- [0075] According to one embodiment, the peripheral sealing lip is shaped to adapt to the geometry of said at least one corrugation.
- [0076] According to one embodiment, the portion of the weld bead is traversed by at least two parallel corrugations, for example, three corrugations, of the membrane and the peripheral sealing lip is shaped to adapt to the geometry of said corrugations.

[0077] According to one embodiment, the peripheral sealing lip comprises at least two indentations, the shape of which corresponds to that of a corrugation of the membrane projecting toward the inside of the tank, said indentations being intended to straddle said corrugation.

5 [0078] According to one embodiment, at least one corrugation of the membrane projects toward the inside of the tank, the bell-shaped detection device being arranged against the membrane so that the indentations straddle the corrugation.

[0079] According to one embodiment, the peripheral sealing lip comprises at least two projecting zones, the shape of which corresponds to that of a corrugation of the membrane
10 projecting toward the outside of the tank.

[0080] According to one embodiment, the bell-shaped detection device is arranged against the membrane so that the projecting zones are inserted into the corrugation.

[0081] According to one embodiment, the seal is made from an elastomer material, the hardness of which is between 20 and 50 Shore A.

15 [0082] According to one embodiment, the elastomer material of the seal is selected from polyurethane elastomer, silicon, nitrile and Viton®.

[0083] According to one embodiment, the bell-shaped detection device is equipped with a clamping system able to urge the peripheral sealing lip against the membrane to be tested.

[0084] According to one embodiment, before depressurizing the detection chamber, the
20 clamping system is activated so as to ensure that the detection chamber is sealed.

[0085] According to one embodiment, when the seal comprises at least two indentations with a shape that corresponds to that of a corrugation of the membrane projecting toward the outside of the tank and passing through the portion of the weld bead, the clamping system comprises a clip on each of the indentations, each clip comprising two branches,
25 respectively arranged on either side of the indentation and configured to apply a clamping force from the peripheral sealing lip against the corrugation of the membrane.

[0086] According to one embodiment, the detection chamber is depressurized up to an absolute pressure value ranging between 10 and 1,000 Pa, preferably below 100 Pa absolute.

30 [0087] According to one embodiment, the gaseous phase is analyzed for a duration that is greater than or equal to 5 seconds.

[0088] According to one embodiment, the variable representing a concentration of tracer gas in said gaseous phase is compared to a threshold and the seal of the portion of the weld

bead is considered to be defective when the variable representing a concentration of tracer gas in said gaseous phase is above said threshold.

[0089] According to one embodiment, the leak detection device further comprises a homogenization chamber, which is arranged between the detection chamber and the analysis equipment, the bell-shaped detection device comprising a gas intake equipped with a tap, the homogenization chamber and the gas intake being connected at two opposite ends of the detection chamber.

[0090] According to one embodiment, the tap of the gas intake is closed when the detection chamber is depressurized, with the step of conveying the gaseous phase contained in the detection chamber comprising:

- opening the tap of the gas intake and conveying the gaseous phase contained in the detection chamber toward the homogenization chamber; and
- conveying the gaseous phase from the homogenization chamber toward the analysis equipment.

[0091] According to one embodiment, the invention provides a method for controlling the diffusion of the tracer gas in the thermally insulating space.

[0092] According to one embodiment, the method for controlling the diffusion of the tracer gas is implemented during the aforementioned seal testing method. However, in another embodiment, it also can be implemented independently.

[0093] According to one embodiment, controlling the diffusion of the tracer gas in the thermally insulating space comprises:

- sampling the gas contained in the thermally insulating space by means of a plurality of sampling devices each passing through the membrane of one of the tank walls; and
- conveying the sampled gas toward analysis equipment, such as a mass spectrometer, for example.

[0094] According to one embodiment, the sampling devices advantageously are arranged in the vicinity of corner zones formed at the junction between two or three tank walls.

[0095] According to one embodiment, each gas sampling device comprises a cover plate, which is connected to a membrane by means of a mastic bead surrounding a zone of the membrane devoid of a weld, at the junction between two elements of the membrane, the cover plate having a hole and a connector intended to be connected to a duct connected to the analysis equipment, said connector being sealably welded on the periphery of the hole of the cover plate.

[0096] According to one embodiment, the gas sampling device comprises a connection component, which has an end fitting intended to be sealably connected to a duct connected to the analysis equipment, a shoulder and a threaded lower rod, which projects from the shoulder, passes through the secondary membrane and is screwed into a threaded bore provided in a plate fixed on the thermally insulating barrier; the gas sampling device further comprising an annular seal, which is threaded onto the lower rod and which is sandwiched between the secondary membrane and the shoulder, the connection component having a perforation, which emerges, on the one hand, at the end fitting and, on the other hand, in the thermally insulating space.

10 **Brief description of the drawings**

[0097] The invention will be better understood, and further aims, details, features and advantages thereof will become more clearly apparent throughout the following description of a plurality of particular embodiments of the invention, which are provided solely by way of a non-limiting illustration, with reference to the accompanying drawings, in which:

15 [0098] [Fig.1] is a schematic view of a leak detection device according to a first embodiment;

[0099] [Fig.2] is a transverse section view along the plane II-II of the bell-shaped detection device of the leak detection device of figure 1;

[0100] [Fig.3] is a perspective view of a seal according to a first embodiment;

20 [0101] [Fig.4] is a schematic view of an alternative embodiment of a leak detection device, in which the bell-shaped detection device is equipped with a clamping system;

[0102] [Fig.5] is a perspective view of a seal according to a second embodiment;

[0103] [Fig.6] schematically illustrates the position of the bell-shaped detection device facing a portion of a weld bead providing the seal between two adjacent corrugated metal sheets of a membrane;

25 [0104] [Fig.7] is a schematic view of a leak detection device according to a second embodiment;

[0105] [Fig.8] is a perspective view of a bell-shaped leak detection device according to a third embodiment;

30 [0106] [Fig.9] is a schematic, transverse section view of the bell-shaped detection device of figure 8, before the depressurization of the detection chamber;

[0107] [Fig.10] is a transverse, schematic section view of the bell-shaped detection device of figure 8, following the depressurization of the detection chamber;

[0108] [Fig.11] is a schematic illustration of a multilayer structure of a wall of a membrane tank;

[0109] [Fig.12] is a partial schematic view of a sealed and thermally insulating tank illustrating tracer gas injection devices positioned through a membrane of the bottom wall of the tank;

5 [0110] [Fig.13] is a perspective view of a bell-shaped leak detection device according to a fourth embodiment;

[0111] [Fig.14] is an exploded view of the detail XIV of figure 13 illustrating a pressure element of the bell-shaped leak detection device;

10 [0112] [Fig.15] shows an exploded view of the detail XV of figure 13 illustrating a first end of the bell-shaped leak detection device;

[0113] [Fig.16] shows an exploded view of the detail XVI of figure 13 illustrating a second end of the bell-shaped leak detection device;

[0114] [Fig.17] shows an exploded view of the detail XVI of figure 13 from another viewing angle.

15 **Description of embodiments**

[0115] A leak detection device will be described hereafter that can be used for detecting leaks in various sealed assemblies, for example, a welded assembly. In the following examples, the welded assembly is a sealing membrane for a fluid tank.

20 [0116] During the step of testing the seal for checking the seal of the weld beads of a membrane 5, 8, a leak detection device 54 is used, as shown in figure 1.

[0117] The leak detection device 54 comprises a bell-shaped detection device 55, which is intended to be arranged against the internal face of the membrane 5, 8 facing a portion of the weld bead to be tested.

25 [0118] The bell-shaped detection device 55 has an elongated shape and is between 0.5 and 4 m long, for example, of the order of 1 m. The length of the bell-shaped detection device 55 advantageously is as long as possible in order to check the seal of a larger zone during the one and the same test. However, the selection of this length of the bell-shaped device can be adapted as a function of, on the one hand, the dimensions of the membrane 5, 8, and therefore of the tank, to be tested and, on the other hand, as a function of its
30 maneuverability for a minimum number of operator(s).

[0119] As shown in figure 2, the bell-shaped detection device 55 comprises a rigid main body 100 and a flexible seal 60, which are fixed together and which are arranged to define a

sealed detection chamber 61 with the membrane 5, 8 to be tested, which chamber is arranged facing the portion of the weld bead 62 to be tested.

[0120] With further reference to figure 1, it can be seen that the leak detection device 54 also comprises analysis equipment 56, which is connected to the detection chamber 61 and allows the tracer gas to be detected. Once the analysis equipment 56 detects an amount of tracer gas that is above a threshold, it can infer that there is a sealing fault in the portion of the tested weld bead 62. According to one embodiment, the analysis equipment 56 is a mass spectrometer.

[0121] The leak detection device 54 also comprises a vacuum pump 57, which is connected to said analysis equipment 56. The vacuum pump 57 is connected, on the one hand, to the detection chamber of the bell-shaped detection device 55, so as to allow the detection chamber to be depressurized and, on the other hand, to the analysis equipment 56, so as to convey the gas contained in the detection chamber 61 toward the analysis equipment 56.

[0122] The vacuum pump 57 is connected to the bell-shaped detection device 55 via a pipe 58, which preferably is flexible. The pipe 58 is connected to a channel, which is provided in the main body 100 and emerges in the detection chamber 61.

[0123] As shown in figures 2 and 3, the main body 100 comprises a rigid core 59 and the seal 60 comprises a casing 63 conforming to the shape of the rigid core 59 and a peripheral sealing lip 64, which extends the casing 63 downward. The casing has a bottom 63, which covers the upper surface of the rigid core 59 and a peripheral wall 74, which conforms to the periphery of the rigid core 59. The bottom 63 has at least one hole, not shown, which is sealably connected to the pipe 58 connected to the vacuum pump 57. The rigid core 59 comprises a recess 79 on its lower surface 80 over the entire length of the rigid core 59. The recess 79 allows, during the depressurization of the detection chamber 61, despite the rigid core 59 lowering toward the membrane 5, 8 due to a deformation of the sealing lip 64, the test zone 62 to always be in fluid contact with the detection chamber 62. Furthermore, the rigid core 59 also comprises a channel 82, not shown in figure 2 since it is only present in a plane passing in the vicinity of the pipe 58, allowing the recess 79 to be connected to an upper surface 81 of the rigid core 59. The channel 82 allows the detection chamber 61 to be connected with the vacuum pump 57 and the analysis equipment 56 via the pipe 58.

[0124] The peripheral sealing lip 64 is curved toward the outside of the bell-shaped detection device 55 and is thus configured to bend and be urged against the membrane 5, 8 when

the sealed chamber 61 is depressurized. In other words, the peripheral sealing lip 64 has a section having a general L-shape.

[0125] The width of the portion curved toward the outside of the peripheral sealing lip 64 is of the order of 15 to 40 mm. The peripheral sealing lip 64 is shaped to adapt to the geometry of the membrane 5, 8 along the weld bead to be tested. Furthermore, in figure 3, the peripheral sealing lip 64 comprises indentations 65, the shape of which corresponds to that of the corrugations of the membrane 5, 8 that the bell-shaped detection device 55 is intended to straddle when it is in position against the portion of the weld bead 62 to be tested.

[0126] The seal 60 advantageously is made from an elastomer material, the hardness of which is between 20 and 50 Shore A. For example, the seal is made from polyurethane elastomer, EPDM rubber, silicon, nitrile or Viton®.

[0127] In one embodiment, schematically illustrated in figure 4, the bell-shaped detection device 55 is also equipped with a mechanical pressure means 66, which in this embodiment is a clamping system 66, able to press the peripheral sealing lip 64 against the membrane 8 to be tested, so as to ensure that the detection chamber 61 is sealed. The clamping system 66 in this case comprises a clip 67 on each of the indentations 65 of the peripheral sealing lip 64. Each clip 67 comprises two branches, respectively arranged on either side of the indentation 65 and configured to apply a clamping force from the peripheral sealing lip 64 against the membrane 8. Advantageously, the branches are configured to clamp the peripheral sealing lip 64 against the sealing membrane, in the vicinity of the base of the corrugation.

[0128] Furthermore, in the embodiment that is shown, the clamping system 66 further comprises, on each of the longitudinal ends of the bell-shaped detection device 55, a movable finger 68, which is configured to urge one of the longitudinal ends of the peripheral sealing lip 64 against the membrane 8.

[0129] Figure 5 illustrates a seal 60 according to an alternative embodiment. This seal 60 is shaped to adapt to a membrane 5, in which the corrugations project toward the outside of the tank. Such a membrane is, for example, a secondary membrane 5 using Mark V technology. Furthermore, the peripheral sealing lip 64 comprises projecting zones 69 intended to be inserted inside corrugations of the membrane 5.

[0130] The procedure for detecting a sealing fault of a weld bead is as follows.

[0131] Initially, the bell-shaped detection device 55 is arranged facing the portion of the weld bead 62 to be tested, as shown in figure 6.

[0132] The bell-shaped detection device 55 must be checked to ensure that it is properly centered relative to the weld bead 62, so that the two lateral parts of the curved portion of the peripheral sealing lip 64 are arranged on either side of the weld bead 62.

[0133] The vacuum pump 57 is then started in order to depressurize the detection chamber 61 and to promote the migration of the tracer gas through the defective zones of the weld bead 62.

[0134] Once the pressure inside the detection chamber 61 drops below a pressure threshold P_s , a gas flow is conveyed from the detection chamber 61 toward the analysis equipment 56 and a tracer gas leak rate ϕ is measured for a minimum duration T_m . The leak rate ϕ is then compared to a threshold ϕ_s .

[0135] If the leak rate ϕ is less than the threshold ϕ_s , then it is inferred that the tested portion of the weld bead 62 does not have a sealing fault. In this case, the bell-shaped detection device 55 is then arranged facing an adjacent portion of the weld bead 62 by providing a covering between the two successively tested portions, so as to ensure that the seal of the weld bead 62 has been tested over the entire length of said weld bead 62.

[0136] Otherwise, if the leak rate ϕ is greater than or equal to the threshold ϕ_s , then it is inferred that the tested portion of the weld bead 62 has a sealing fault. Corrective welding measures are then implemented in order to correct the fault.

[0137] By way of an example, for a helium concentration in the thermally insulating space of the order of 20%, the pressure threshold below which the leak rate is measured is between 10 and 1,000 Pa absolute, preferably less than 100 Pa absolute. By way of an example, the minimum measuring duration of the leak rate is 5 seconds and the threshold ϕ_s is of the order of $1.0 \cdot 10^{-6} \text{ Pa} \cdot \text{m}^3 \cdot \text{s}^{-1}$.

[0138] Figure 7 shows a leak detection device 54 according to another embodiment. This embodiment differs from the previously described embodiment in that it further comprises a homogenization chamber 70, which is disposed between the detection chamber 61 and the analysis equipment 56 and in that the bell-shaped detection device 55 comprises a gas intake 71.

[0139] The gas intake 71 is equipped with a tap for establishing or interrupting an ambient air flow toward the detection chamber 61. The homogenization chamber 70 is connected at one end of the detection chamber 61, whereas the gas intake 71 is connected at the opposite end of the detection chamber 61.

[0140] The operating mode of the leak detection device 54 is as follows.

[0141] When the bell-shaped detection device 55 is arranged facing the portion of the weld bead 62 to be tested, the tap of the gas intake 71 is closed and the vacuum pump 57 is started in order to depressurize the detection chamber 61. As soon as the pressure inside the detection chamber 61 drops below a pressure threshold P_s , the tap of the gas intake 5 71 is opened and all the gas previously contained in the sealed chamber is transferred to the homogenization chamber 70. The volume of the homogenization chamber 70 is greater than that of the detection chamber 61 and it comprises, for example, a piston system for precisely sucking in all the gas contained in the detection chamber 61.

[0142] The gas contained in the homogenization chamber 70 is subsequently transferred 10 toward the analysis equipment 56 in order to determine a tracer gas leak rate ϕ .

[0143] Such an embodiment is advantageous in that it allows the tracer gas diffusion time inside the bell-shaped detection device 55 to be reduced and thus allows the minimum measuring duration to be reduced. This is particularly advantageous when the time required for the tracer gas to migrate from one end to the other of the bell-shaped detection 15 device 55 is likely to be long due to the significant length of the bell-shaped detection device 55 and/or when the depression prevailing inside the detection chamber 61 is insufficient.

[0144] Figure 8 shows a bell-shaped detection device 55 according to a third embodiment. The bell-shaped detection device 55 of figure 8 is designed similar to the bell-shaped 20 detection device 55 of figure 4, but particularly differs with respect to the mechanical pressure means 66. Indeed, the bell-shaped detection device 55 comprises a main body 100 extending in a longitudinal direction, a flexible seal 60 fixed on the main body 100 and a mechanical pressure means 66 supported by the main body and configured to exert a pressure directed toward the membrane 5, 8 on the seal 60. The main body 100 comprises 25 a rigid core 59. The rigid core 59 comprises a channel 82 allowing a lower surface 80 to be connected to an upper surface 81 of the rigid core 59. The channel 82 allows the detection chamber 61 to be connected to the gas outlet 78.

[0145] The seal 60 comprises a casing 63 fixed to the rigid core 59 by fixing means 110, for example, involving a hoop surrounding the entire circumference of the rigid core 59 and 30 the seal 60 and fixing these two elements 59/60 together by means of a mechanical fixing element, such as screws. The seal 60 also comprises a peripheral sealing lip 64 connected to the casing 63 and having a closed contour for surrounding the part of the weld bead 62 to be tested. The peripheral lip 64 is also curved in the opposite direction to the main body 100, so as to have part of the peripheral lip 64 substantially parallel to the membrane 5, 8. 35 The peripheral sealing lip 64 also has a plurality of indentations 65 spaced apart over its

circumference, with the indentations 65 assuming the shape of the corrugations of the membrane 5, 8 to be tested. Thus, when the bell-shaped detection device 55 is placed on the membrane 5, 8, the indentations 55 allow the bell-shaped detection device 55 to adapt to the corrugated shape of the membrane 5, 8. The main body 100 and the support element 73 are particularly traversed by a gas outlet 78, allowing the gas to be discharged when the detection chamber 61 is depressurized.

[0146] The mechanical pressure means comprise a support element 73 extending over the entire length of the main body 100 above said main body 100 and fixed thereto. Handles 76 are fixed at the two longitudinal ends of the support element 73, so as to allow the bell-shaped detection device 55 to be handled by an operator and optionally allow the mechanical pressure means to be activated by a force of the operator.

[0147] The mechanical pressure means 66 is made up of a plurality of pressure elements 72, which are in the form of curved strips 72 distributed over the sealing lip 64 and which are fixed to the support element 73 by fixing means 77. The curved strips 72 are resiliently deformable so as to, when they are deformed, exert a resilient return force on the sealing lip 64, in order to urge it onto the membrane 5, 8. In order to increase the reliability of the seal of the detection chamber 61, it seems advisable to urge the sealing lip 64 into the zones where the risk of detachment is greatest. For this reason, curved strips 72 are particularly located at the bases of the indentations 64 of the sealing lip 64 and at the longitudinal ends of the bell-shaped detection device 55 on the sealing lip 64.

[0148] A plurality of curved strips 72 is fixed at one of the ends thereof to the support element 73, whereas the other end is placed on the sealing lip 64. These strips 72 are particularly placed on the ends of the bell-shaped detection device 55. Other curved strips 72 for their part are fixed at their centers to the support element 73, whereas the two ends thereof are placed on the sealing lip 64, so as to apply a pressure onto two different zones, with these strips 72 particularly being placed between two indentations 65.

[0149] The curved strips 72 have a cylindrical sleeve 75 at each of the ends thereof in contact with the sealing lip 64. The cylindrical sleeve 75 particularly allows an even pressure to be applied on the sealing lip 64, whilst avoiding any punching that could degrade the integrity of the sealing lip 64. The cylindrical sleeve 75 extends in a direction orthogonal to the longitudinal direction of the main body 100. The length of a cylindrical sleeve 75 is also substantially equal to the dimension of the part of the sealing lip 64 projecting from the main body 100, toward where the cylindrical sleeve 75 extends. Thus, the cylindrical sleeve 75 allows the mechanical pressure means 66 to exert an effective pressure on the sealing lip.

[0150] When placing the bell-shaped leak detection device 55 on the zone to be tested, the mechanical pressure means 66 needs to be checked to ensure that it is properly sealably urged against the seal 60 in order to be able to properly test the seal of the weld. Therefore, one problem involves ensuring that the mechanical pressure means 66 properly fulfills its role around the peripheral sealing lip 64. However, the zone to be tested, and in particular at the ends of the bell-shaped detection device 55, can be a junction zone between a plurality of corrugated metal sheets, for example, four corrugated metal sheets, so that the zone is not completely flat, but comprises steps making it difficult to urge the seal 60.

[0151] Figure 13 shows a bell-shaped detection device 55 according to a fourth embodiment, where the mechanical pressure means 66 has been reinforced at the ends of the bell-shaped detection device 55 to overcome the unevenness of the zone. The bell-shaped detection device 55 of figure 13 is designed similar to the bell-shaped detection device 55 of figure 8, but particularly differs with respect to the mechanical pressure means 66. Indeed, the bell-shaped detection device 55 of figure 13 also comprises a main body 100 extending in a longitudinal direction, a flexible seal 60 fixed on the main body 100 and a mechanical pressure means 66 supported by the main body and configured to exert a pressure directed toward the membrane 5, 8 on the seal 60. However, the mechanical pressure means 66 in this case comprise pressure elements 72 and end pressure elements 87.

[0152] The pressure elements 72 each comprise a curved strip 72, at least one end of which comes into abutment on the base of an indentation 62. The curved strips 72 located between two contiguous indentations for their part have one end located against the base of one of the indentations 65, and the other end located against the base of the other one of the indentations 65. The pressure elements 72 in this case are, as illustrated in figure 14, fixed by fixing means 77, each comprising a pin 83. The pins 83 each comprise a rod 85 freely mounted on a body 84. The rod 85 comprises an end in abutment against one of the curved strips 72. The body 84 is fixed to the support element 73. The pin 83 also comprises a spring 86 connecting the rod 85 to the body 84, with the spring 86 acting between the body 84 and the rod 85, in order to position the end of the rod 85 in abutment against the curved strip 72. Thus, the spring 86 is configured to exert a return force on the curved strip 72, so that the curved strip 72 urges the sealing lip 64 against the base of the corrugation.

[0153] The end pressure elements 87 are located at the two ends of the sealing lip 64 in a longitudinal direction, that is at the two ends of the bell-shaped leak detection device 55 given that said device assumes a general longitudinal shape. The end pressure elements 87 can be designed in accordance with a plurality of distinct alternative embodiments that

may or may not be able to be combined on the same bell-shaped leak detection device 55. For the sake of brevity, three alternative embodiments of the end pressure elements 87 are illustrated in figure 13 on the same bell-shaped leak detection device 55.

[0154] Figures 15 to 17 show the three alternative embodiments of the end pressure elements 87. As shown in figure 15 according to the first alternative embodiment, the end pressure element 87 comprises an end pin 88. The end pins 88 each comprise a rod 90 freely mounted on a body 89. An elongated bearing element 91 is fixed at one end of the rod 90, with the elongated bearing element 91 coming into abutment against the sealing lip 64. The body 89 is fixed to the support element 73. The end pin 88 also comprises a spring 86 connecting the rod 90 to the body 89, with the spring 86 acting between the body 89 and the rod 90 in order to position the elongated bearing element 91 against the sealing lip 64. Thus, the spring 86 is configured to exert a return force on the elongated bearing element 91, so that the elongated bearing element 91 urges the sealing lip 64 against the zone to be tested. In this way, the return force is exerted on the sealing lip 64 over the entire length of the elongated bearing element 91. In the case of the first alternative embodiment of figure 15, each elongated bearing element 91 is fixed to only one rod 90 of an end pin 88.

[0155] A second alternative embodiment of the end pressure elements 87 is illustrated in figure 16. The second alternative embodiment differs from the first alternative embodiment with respect to the elongated bearing element 91 of the end pins 88, the other features of the end pressure elements 87 are maintained. In this alternative embodiment, the elongated bearing element 91 is fixed at one end of a rod 90 of a first end pin 88 and at one end of a rod 90 of a second end pin 88 adjacent to the first end pin 88. The elongated bearing element 91 in this case therefore is longer than in the first alternative embodiment and is thus urged by two end pins 88 distributed over the length thereof so as to form a longer bearing surface on the sealing lip 64.

[0156] A third alternative embodiment of the end pressure elements 87 is illustrated in figure 17. In this alternative embodiment, the end pressure element 87 comprises a plurality of adjustment elements 92 forming a row of elements. The adjustment element 92 comprises a rod 93 extending toward the sealing lip 64 and perpendicular to the zone to be tested and an adjustable end 94 in a longitudinal direction of the rod, so as to come into contact with the sealing lip 64 after adjusting the rod 93. Thus, the end pressure element 87 can be more precisely adjusted using the adjustment elements 92, in order to more precisely conform to the zone to be tested and therefore improve the seal of the detection chamber 61.

[0157] A method for operating a bell-shaped leak detection device 65 as illustrated in figure 8 in a leak detection device 54 comprising said bell-shaped device 65, a vacuum pump 57 connected to the detection chamber 61 via the gas outlet 78 and analysis equipment 56 will be described hereafter. The operation of such a detection device 54 allows the seal of a weld bead 62 to be controlled between two corrugated sheets of a sealing membrane 5, 8.

[0158] Firstly, the bell-shaped detection device 55 is placed on the zone in which the seal is to be tested, in this case part of the weld bead 62, for example, by one or more operators via the handles 76. To this end, the main body 100 of the bell-shaped detection device 55 is placed above the weld bead 62, so that the length of the main body 100 is aligned and centered with the weld bead 62. Thus, the sealing lip 64 is located on either side of the weld bead 62 and completely surrounds the zone of the weld bead 62 to be tested in order to form, with the main body 100 and the membrane 5, 8, a sealed detection chamber 61, as shown in figure 9.

[0159] After the bell-shaped detection device 55 has been placed on the weld bead 62, the bell-shaped detection device 55 is spontaneously fixed on the membrane 5, 8 by virtue of the depression force activated by the vacuum pump 57. This depression force then activates the mechanical pressure means 66, so that it redirects the pressure in order to press the sealing lip 64 onto the membrane 5, 8 in certain well-defined zones.

[0160] When the mechanical pressure means 66 experience a force on the support element 73, the support element 73 retransfers the force to the curved strips 72 via their respective fixings, which tends to resiliently deform the curved strips 72. For this reason, and through resilient return, the curved strips 72 transfer the force to the sealing lip 64 via the cylindrical sleeves 75 at the zones where detachment of the sealing lip is most likely, namely the longitudinal ends of the main body 100 and the bases of the indentations 65.

[0161] The vacuum pump 57 is then activated so as to create a depression in the detection chamber 61 via the channel 82 and the gas outlet 78. The flexibility of the sealing lip 64 causes the deformation thereof during the depressurization of the detection chamber 61, tending to reduce the volume of the detection chamber 61. Indeed, the sealing lip 64 thus approaches on either side of the weld bead 62, as shown in figure 10. Once the pressure inside the detection chamber 61 drops below a pressure threshold P_s , the gases present in the detection chamber 61 are conveyed toward the analysis equipment 56.

[0162] Thus, advantageously, the sealing lip 64 assumes two positions depending on whether it is located in its initial state, that is without the application of a depression in the detection chamber 61, or in a service state, when such a depression is applied.

- [0163] In its initial state, the sealing lip 64 rests on the surface of a sealing membrane 5, 8 without any pressure, whereas in its service state at least one end portion of the sealing lip 64 is pressed under the main body 100 so as to perfectly seal the contour or the periphery of the detection chamber 61. Indeed, by virtue of the flexibility of the sealing lip 64, said lip is pinched between the main body 100 and the membrane 5, 8 when the depression is applied. This positioning of the sealing lip 64 between the main body 100, crushed or compressed thereby, and the sealing membrane 5, 8 effectively helps to obtain a perfect seal for the detection chamber 61, thus allowing a vacuum of at least 100 Pa (1 mbar) to be obtained and maintained, and even having a much lower pressure.
- [0164] Thus, according to a preferred embodiment of the invention, the sealing lip 64 has a service state, when a depression is applied in the detection chamber 61, in which a portion of the sealing lip 64 is held between the main body 100 and the sealing membrane 5, 8 over at least part of the periphery of the detection chamber 61, even over the entire periphery of said chamber 61.
- [0165] The analysis equipment 56 then analyses, over a minimum time period T_m , the gas concentration of the gases present in the detection chamber 61, so as to obtain a value representing the evolution of the concentration. This representative value is then compared to a threshold value, so as to determine whether or not the part of the tested weld bead 62 has a sealing fault.
- [0166] If the measured value is below the threshold value, then it is inferred that the tested part does not have a sealing fault and, in this case, the bell-shaped detection device 55 is then arranged facing an adjacent portion of the weld bead 62, by providing a cover between the two successively tested portions, so as to ensure that the seal of the weld bead 62 has been tested over the entire length of said weld bead 62.
- [0167] If the measured value is greater than or equal to the threshold value, then it is inferred that the tested part of the weld bead 62 has a sealing fault. Corrective welding measures are then implemented in order to correct the fault. Measures using an additional detection tool also can be contemplated in order to more precisely locate the site of the sealing fault.
- [0168] In another embodiment, not shown, the various features of the preceding embodiments can be combined together. Indeed, for example, the mechanical pressure means 66 of figure 8 can be adapted to a seal 60 of figure 5 by modifying the arrangement of the curved strips 72.
- [0169] The bell-shaped detection device, the detection device and the method for operating the device described above are particularly intended to test the seal of a membrane of a

sealed and thermally insulating membrane tank. By way of an example, such membrane tanks are particularly disclosed in patent applications WO 14057221, FR 2691520.

[0170] The membrane tanks have a plurality of walls, which have a multilayer structure, as shown in figure 11. Each wall 1 comprises, from the outside to the inside of the tank, a secondary thermally insulating barrier 2 comprising secondary insulating panels 3 anchored to a support structure 4, a secondary membrane 5 that rests against the secondary thermally insulating barrier 2, a primary thermally insulating barrier 6 comprising primary insulating panels 7 that rest against the secondary membrane 2 and are anchored to the support structure 4 or to the secondary insulating panels 3 and a primary membrane 8 that rests against the primary thermally insulating barrier 6 and that is intended to be in contact with the liquefied gas contained in the tank.

[0171] The tank has a general polyhedral shape. In the embodiment illustrated in figure 12, the tank has a front wall 9 and a rear wall, not shown, which in this case are octagon shaped. The tank also comprises a ceiling wall 10, a bottom wall 11 and side walls 11, 12, 13, 14, 15, 16, 17 that extend in the longitudinal direction of the tank between the front wall 9 and the rear wall.

[0172] The secondary thermally insulating barriers 2 of the tank walls are connected together so as to form, between the support structure 4 and the secondary membrane 5, a secondary, sealed thermally insulating space. Similarly, the primary thermally insulating barriers 6 of the tank walls are connected together so as to form, between the secondary membrane 5 and the primary membrane 8, a sealed, primary thermally insulating space.

[0173] At least one of the primary 8 and secondary 5 membranes comprises a plurality of metal sheets that are welded together. The seal testing method that will be described hereafter more specifically intends to test the seal of the welds for connecting the metal sheets together. According to one embodiment, the membrane to be tested has corrugations, which allow it to deform under the effect of the thermal and mechanical stresses generated by the fluid stored in the tank. To this end, as shown, for example, in figure 8, each metal sheet comprises two series of corrugations that are perpendicular to each other.

[0174] In one embodiment, the seal testing method comprises three steps, namely:

- the diffusion of a tracer gas in a thermally insulating space covered by the membrane 5, 8 for which the seal is to be tested;
- controlling the diffusion of the tracer gas in the thermally insulating space; and
- checking the seal of the welds of the membrane 5, 8.

[0175] In another embodiment, the seal testing method only comprises checking the seal of the welds of the membrane 5, 8 without using a tracer gas.

[0176] The step of diffusing a tracer gas involves injecting a tracer gas into the thermally insulating space that is covered by the membrane 5, 8 for which the seal is to be checked.

5 When intending to check the seal of the secondary membrane 5, the tracer gas is injected into the secondary thermally insulating space. In this case, the seal testing method is implemented before the primary thermally insulating barrier 7 and the primary membrane 8 are installed. When intending to check the seal of the primary membrane 8, the tracer gas is injected into the primary thermally insulating space.

10 [0177] Figure 12 schematically illustrates a sealed and thermally insulating tank, as well as a system for injecting tracer gas into a thermally insulating space.

[0178] The injection system comprises a plurality of ducts 18, which are, on the one hand, connected to a tracer gas source, not illustrated, and, on the other hand, connected to tracer gas injection devices 19 providing a passage for injecting the tracer gas through the membrane 5, 8 for which the seal must be tested. More specifically, the tracer gas injection devices 19 provide tracer gas passages through the membrane of the bottom wall 11. Such an arrangement is particularly advantageous since the vapor density of the tracer gas is lower than that of air, so that it tends to rise in the thermally insulating space. Hence, injecting the tracer gas from below, through the membrane 5, 8 to be tested of the bottom wall 11, allows the tracer gas to be quickly and homogeneously diffused in the thermally insulating space.

[0179] In the embodiment shown in figure 12, the bottom wall 11 is equipped with at least four tracer gas injection devices 19, which are evenly distributed over the surface of the bottom wall 11. The bottom wall 11 has a rectangular shape and thus can be divided into four surface zones that are equal on the two axes of symmetry x and y thereof. Each of the four tracer gas injection devices 19 is arranged in one of the four aforementioned zones. In the illustrated particular embodiment, each tracer gas injection device 19 is arranged in the vicinity of the center of its respective zone. In a particular embodiment, each of the four tracer gas injection devices is arranged at a distance $\frac{1}{4} L$ from the adjacent longitudinal edge and at a distance $\frac{1}{4} B$ from the adjacent transverse edge, with L being the longitudinal dimension of the bottom wall 11 and B being the transverse dimension of the bottom wall 11.

[0180] The step of controlling the diffusion of tracer gas involves, when the tracer gas has diffused through the thermally insulating space, controlling the diffusion of the tracer gas in the thermally insulating space.

[0181] To this end, a plurality of gas sampling devices is used to take a sample of the gas contained in the thermally insulating space where the tracer gas was injected, which sampling devices are provided through the membrane covering said thermally insulating space. Each sampling device is connected to analysis equipment, such as a mass spectrometer, which allows the presence and the concentration of the tracer gas in the corresponding zone of the thermally insulating space to be checked.

[0182] The step of checking welds involves using the previously described leak detection device 54 on one of the membranes 5, 8 of the sealed and thermally insulating tank.

[0183] Even though the invention has been described in relation to a plurality of specific embodiments, it is obvious that it is by no means limited thereto and that it comprises all the technical equivalents of the means described, as well as their combinations if they fall within the scope of the invention.

[0184] The use of the verb “comprise” or “include” and of its conjugated forms does not exclude the presence of other elements or other steps than those stated in a claim.

[0185] In the claims, any reference sign between brackets cannot be interpreted as a limitation of the claim.

Claims

[Claim 1] A bell-shaped leak detection device (55) for detecting a leak on a test zone (62) of a sealing membrane (5, 8) of a tank, the bell-shaped leak detection device (55) comprising:

- a main body (100) intended to be arranged on the test zone (62);
- a seal (60) connected to the main body (100) and configured to define a detection chamber (61) between the main body (100) and the test zone (62), the seal (60) comprising a peripheral sealing lip (64) having a closed contour for surrounding the test zone (62);
- a mechanical pressure means (66) supported by the main body (100) and comprising at least one pressure element (72) configured to exert a pressure, on a portion of the sealing lip (64), directed toward the membrane (5, 8) when the main body (100) is arranged on the test zone (62)

wherein the sealing lip (64) comprises at least one indentation (65), the shape of which corresponds to that of a corrugation of the membrane (5, 8), the indentation (65) being intended to straddle the corrugation

wherein the pressure element (72) is adapted to locally press the sealing lip into a portion of said sealing lip (64) which is located at a base of the indentation (65).

[Claim 2] The bell-shaped leak detection device (55) as claimed in claim 1, wherein the pressure element (72) is a resiliently deformable element that exerts a pressure on the portion of the sealing lip (64) by resilient deformation.

[Claim 3] The bell-shaped leak detection device (55) as claimed in claim 1 or claim 2, wherein the pressure element (72) is oriented perpendicular to the contour of the peripheral sealing lip (64).

[Claim 4] The bell-shaped leak detection device (55) as claimed in any one of the preceding claims, wherein the sealing lip (64) is configured such that, in a service state when a depression is applied in the detection chamber (61), a portion of said sealing lip (64) is held between the main body (100) and the sealing membrane (5, 8) over at least part of the periphery of the detection chamber (61), advantageously over the entire periphery of said chamber (61).

[Claim 5] The bell-shaped leak detection device (55) as claimed in any one of the preceding claims, wherein the bell-shaped leak detection device (55) has an elongated shape, the length of which is greater than or equal to 0.5 m.

[Claim 6] The bell-shaped leak detection device (55) as claimed in claim 5, wherein the mechanical pressure means (66) comprise a plurality of pressure elements (72) configured to exert a pressure on a plurality of portions of the sealing lip (64), with portions being located at the two ends of the sealing lip (64) in a longitudinal direction.

[Claim 7] The bell-shaped leak detection device (55) as claimed in any one of claims 1 to 6, wherein the mechanical pressure means (66) comprise a plurality of pressure elements (72) configured to exert a pressure on a plurality of portions of the sealing lip (64), with portions being located at the bases of the indentation (65).

5 [Claim 8] The bell-shaped leak detection device (55) as claimed in any one of claims 1 to 7, wherein all the portions of the sealing lip (64) located at the bases of the indentation (65) are pressed by the plurality of pressure elements (72) of the mechanical means (66).

[Claim 9] The bell-shaped leak detection device (55) as claimed in any one of claims 1 to 8, wherein the sealing lip (64) comprises at least two indentations (65), and the pressure
10 elements (72) comprise a curved strip, the two ends of which come into abutment on the base of two contiguous indentations (65).

[Claim 10] The bell-shaped leak detection device (55) as claimed in any one of the preceding claims, wherein the pressure element (72) comprises a curved strip comprising, at one of the ends thereof that is in contact with the sealing lip (64), a cylindrical sleeve
15 (75).

[Claim 11] The bell-shaped leak detection device (55) as claimed in any one of the preceding claims, wherein the seal (60) is made from an elastomer material, the hardness of which is between 20 and 50 Shore A.

[Claim 12] The bell-shaped leak detection device (55) as claimed in claim 11, wherein the
20 elastomer material of the seal (60) is selected from polyurethane elastomer and EPDM rubber.

[Claim 13] The bell-shaped leak detection device (55) as claimed in any one of the preceding claims, wherein the main body (100) comprises a rigid core (59), and wherein the seal (60) comprises a casing (63) hermetically applied against a peripheral wall of the
25 rigid core (59).

[Claim 14] The bell-shaped leak detection device (55) as claimed in claim 13, wherein the rigid core (59) comprises a recess (79) on a lower surface (80) that is intended to be rotated toward the test zone (62).

[Claim 15] The bell-shaped leak detection device (55) as claimed in claim 14, wherein the
30 rigid core (59) comprises a channel (82) connecting the recess (79) to an upper surface (81) of the rigid core (59) for connecting a vacuum pump (57).

[Claim 16] A leak detection device (54) for testing the seal of a membrane (5, 8) of a sealed and thermally insulating tank, the leak detection device (54) comprising:

- a bell-shaped leak detection device (55) as claimed in any one of claims 1 to 15;
- 35 - a vacuum pump (57) connected to the detection chamber (61);

- analysis equipment (56) connected to the detection chamber (61) for analyzing an amount of gas present in the detection chamber (61).

[Claim 17] A method for operating a leak detection device (54) as claimed in claim 16 on a test zone (62) of a sealing membrane (5, 8) of a tank, wherein the method comprises the following steps:

- placing the bell-shaped leak detection device (55) on the test zone (62) so that the sealing lip (64) completely surrounds the test zone (62);
- applying a pressure onto the sealing lip (64) using the mechanical pressure means (66) in order to press the sealing lip (64) against the sealing membrane (5, 8);
- depressurizing the detection chamber (61) by means of the vacuum pump (57);
- conveying the gases present in the detection chamber (61) toward the analysis equipment (56); and
- analyzing, by means of the analysis equipment (56), the gases originating from the detection chamber (61) and delivering a variable representing the gases present in the detection chamber (61).

[Claim 18] The operating method as claimed in claim 17, wherein the bell-shaped leak detection device (55) is oriented on the test zone (62) so that a length of the bell-shaped leak detection device (55) is superposed with the test zone (62).

[Claim 19] The operating method as claimed in claim 17 or claim 18, wherein the test zone (62) is part of a weld bead (62) of the sealing membrane (5, 8).

[Claim 20] The operating method as claimed in any one of claims 17 to 19, wherein the test zone (62) is located on a corrugated sealing membrane (5, 8).