

Description

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

Technical field

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

10 Technological background

[0002] The document KR1020100050128 discloses a seal test method for a membrane of a sealed and thermally-insulating tank for storing liquefied natural gas (LNG). The tank has a multilayer structure and features successively, from the exterior to the interior, a secondary thermally-insulating barrier, a secondary
15 sealing membrane, a primary thermally-insulating barrier and a primary sealing membrane intended to be in contact with the LNG contained in the tank. The method is more particularly directed to detecting leaks via weld beads for connecting in sealed manner the metal plates of the primary sealing membrane. The method injects a tracer gas such as helium into the primary thermally-insulating barrier and then moves detection equipment equipped with a tracer gas
20 analyser inside the tank along the weld beads of the primary sealing membrane. Thus if the detection equipment detects the presence of the tracer gas it may be concluded that there is a sealing defect in the primary sealing membrane.

[0003] Also known is the document WO2019224479, filed in the name of the applicant,
25 which describes a leak detection device using a tracer gas and having an elongate shape intended to follow the weld line the seal of which said device aims to test.

[0004] A leak detection device of this kind must preferably be able to be manipulated by a single operative, while reducing the time to test numerous weld lines, also designated hereinafter by the expression "weld beads" or more simply "beads", it
30 being understood that its primary characteristic must be the most precise and finest possible detection of any leak.

[0005] This is why it is desirable to have available a leak detection device of elongate shape to track a long weld line optimally whilst being as light as possible.

[0006] However, after multiple tests the applicant has found that the leak detection device may have certain deficiencies or a reduced leak detection capability because of this aim of reducing the weight of the device associated with a very elongate shape of the device and thus its detection chamber.

[0007] Such deficiencies or inaccuracies of the leak detection device occur in particular when the membranes on which said device rests have a mediocre surface state (poor flatness), when the weld line is locally thicker or wider than usual or because the vacuum pump suffers from poor performance.

[0008] In fact, the analysis equipment of the leak detection device functions correctly when a minimum level of vacuum is achieved homogeneously over all the length of the detection chamber. To this end it is imperative to guarantee a perfect seal of the detection chamber.

Summary of the invention

[0009] One idea behind the invention is to propose a bell-shaped detection and a leak detection device enabling reliable and easy testing of the seal of a sealed membrane of a tank that can be used in the tank.

[0010] The present invention more particularly aims to propose a leak detection device that functions perfectly regardless of all these equipment and dimension constraints and the multiple random features of the environment. It must be noted here that a classic sealed and thermally-insulating tank, for example that equipping a liquid natural gas carrier (LNGC), comprises more than one thousand membranes welded together, i.e. the equivalent of several kilometres of weld lines, or beads, the seal of which it is imperative to verify.

[0011] The applicant intends to remedy the shortcomings of current detection methods and equipment by proposing a device for testing the seal of a membrane that is perfectly reliable, simple and rapid to use.

[0012] Following diverse experiments and trials, the applicant has therefore developed a bell-shaped leak detection device for detecting a leak in a test zone of a sealing membrane of a sealed and thermally-insulating tank, the bell-shaped leak detection

device being configured to evolve between an initial state and a service state, the bell-shaped leak detection device including:

- a main body extending along a longitudinal axis L and rising along a vertical axis V perpendicular to the longitudinal axis L, intended to be disposed on the test zone;
- a seal connected to the main body and configured, in its service state, to define a detection chamber between the main body and the test zone, the seal including a peripheral sealing lip having a closed outline to surround the test zone;

the bell-shaped leak detection device being characterised in that it includes a first retaining element, said first retaining element being disposed on the seal and forming a surface-to-surface contact with a portion of the seal placed around the main body.

[0013] According to the invention the terms “longitudinal”, “transverse” and “vertical” refer to the orientation of the detection cloche. A longitudinal axis L of a system of axes L, V, T corresponds to a main lengthwise axis of the bell-shaped detection device. A transverse axis T of the system of axes L, V, T corresponds to an axis perpendicular to the longitudinal axis L. Finally, a vertical axis V of the system of axes L, V, T corresponds to an axis perpendicular to the longitudinal axis L and the transverse axis T.

[0014] In accordance with one embodiment of the invention the bell-shaped leak detection device includes at least one second retaining element, each second retaining element being situated at one end of the seal along the longitudinal axis L.

[0015] The bell-shaped detection device typically includes two second retaining elements, said two second retaining elements each being situated at a distinct end of the detection cloche.

[0016] The seal advantageously includes notches spaced from one another along the longitudinal axis L and the bell-shaped leak detection device advantageously includes at least one third retaining element, each third retaining element being disposed on a portion of the seal placed around the main body on one of said notches and forming a surface-to-surface contact with said portion of the seal placed around the main body on one of said notches.

[0017] In accordance with one feature of the invention the bell-shaped leak detection device includes a first and/or a second and/or a third bearing element configured to be moved in translation along an axis parallel to the vertical axis V when the bell-shaped detection device evolves between the initial state and the service state so as to come to abut against the sealing lip in the service state.

[0018] The first bearing element advantageously includes two blades situated on either side of the main body between the first retaining element and the sealing lip.

[0019] In accordance with one feature the bell-shaped leak detection device includes at least one second bearing element fixed to the second retaining element and situated at one end of the seal along the longitudinal axis L.

[0020] In accordance with a preferred embodiment the bell-shaped detection device according to the invention includes two second bearing elements each situated at a distinct end of the bell-shaped leak detection device.

[0021] In accordance with another embodiment the at least one second bearing element is formed of a block fixed to the end of the bell-shaped detection device and extending all around the rounded portion of the main body and a fixing portion directly fixed to the second retaining element.

[0022] In accordance with one feature the bell-shaped leak detection device includes at least one third bearing element and the third bearing element includes a first set of two fingers situated on one side of the third retaining element and a second set of two fingers situated on the other side of the third retaining element relative to a transverse axis T perpendicular to the longitudinal axis L and the vertical axis V and in each set of two fingers the two fingers are disposed on either side of the third retaining element along the longitudinal axis L.

[0023] In accordance with another embodiment the first and second sets of two fingers are secured to the third retaining element.

[0024] In accordance with another embodiment each finger includes an upper part and a lower part, the upper part being mobile in rotation relative to the third retaining element about a first axis I parallel to a transverse axis T and the lower part being mobile in rotation relative to the upper part about a second axis II parallel to the transverse axis T and distinct from the first axis I.

[0025] Each finger advantageously includes at least one compression element connecting the upper part to the lower part.

[0026] In the bell-shaped leak detection device the seal is advantageously made of an elastomer material having a Shore A hardness between 20 and 50 inclusive.

5 [0027] In the bell-shaped leak detection device the main body advantageously includes a rigid core and the seal includes an enclosure applied in hermetically sealed manner against a peripheral wall of the rigid core.

[0028] In the bell-shaped leak detection device the rigid core advantageously includes a recess on a lower surface intended to face toward the test zone.

10 [0029] In the bell-shaped leak detection device the rigid core advantageously includes a channel extending from the recess and discharging onto an opening in an upper surface of the rigid core, the opening being intended to be connected to at least one vacuum pump.

[0030] The invention also relates to a leak detection device for detecting a leak in a
15 test zone of a sealing membrane of a sealed and thermally-insulating tank. According to the invention the leak detection device includes:

- a bell-shaped leak detection device of the above kind;
- at least one vacuum pump connected to the detection chamber configured to depressurise the detection chamber when the bell-shaped detection device is in
20 the service state and the at least one vacuum pump is activated;
- analysis equipment connected to the detection chamber configured to analyse a gas present in the detection chamber.

[0031] The gas detected as present in the detection chamber is preferably a tracer gas different from any of the significant components of atmospheric air.

25 [0032] The invention will be better understood and other aims, details, features and advantages thereof will become more clearly apparent in the course of the following description of a plurality of particular embodiments of the invention given by way of non-limiting illustration only with reference to the appended drawings.

Brief description of the drawings

[0033] The invention will be better understood and other aims, details, features and advantages thereof will become more clearly apparent in the course of the following description of a plurality of particular embodiments of the invention given by way of non-limiting illustration only with reference to the appended drawings.

5 [0034] [Fig. 1] is a diagrammatic view of a leak detection device in accordance with a first embodiment.

[0035] [Fig.2] is a view in cross section on the plane II-II of the detection cloche of the leak detection device from figure 1.

10 [0036] [Fig.3] is a perspective view of a seal of a bell-shaped leak detection device of the leak detection device.

[0037] [Fig.4] is a perspective view of a bell-shaped leak detection device of the leak detection device.

[0038] [Fig.5] is an exploded view of the bell-shaped detection device of the leak detection device from figure 1.

15 [0039] [Fig.6] is a diagrammatic view of a third retaining element in accordance with a first embodiment.

[0040] [Fig.7] is a diagrammatic view of a third retaining element in accordance with a second embodiment.

20 [0041] [Fig.8] is a diagrammatic functional view of a leak detection device employing the bell-shaped leak detection device from figure 1 in accordance with a second embodiment.

[0042] [Fig.9] is a diagrammatic illustration of a multilayer structure of a wall of a membrane tank.

25 [0043] [Fig.10] is a diagrammatic partial view of a sealed and thermally-insulating tank depicting tracer gas injection devices positioned through a membrane of the bottom wall of the tank.

Description of embodiments

30 [0044] The features, variants and embodiments of the invention may be associated with one another in diverse combinations if they are not incompatible or mutually exclusive. There may in particular be conceived variants of the invention

comprising only a selection of the features described hereinafter separately from the other features described if that selection is characteristic and sufficient to confer a technical advantage and/or to distinguish the invention from the prior art.

[0045] In the figures elements common to more than one figure retain the same reference number.

[0046] There is described hereinafter a leak detection device that may be used to detect leaks in various sealed assemblies, for example a welded assembly. In the examples hereinafter the welded assembly is a sealing membrane for a fluid tank.

[0047] During the step of the seal test for verifying the seal of the weld beads of a membrane 5, 8 a leak detection device 54 as represented in figure 1 and in figure 2 in cross section on the plane II-II of the bell-shaped detection device of the leak detection device from figure 1 is used.

[0048] The leak detection device 54 includes a bell-shaped detection device 55 that is intended to be disposed against the internal face of the membrane 5, 8 facing a portion of the weld bead to be tested.

[0049] The bell-shaped detection device 55 has an elongate shape and generally has a length between 0.5 and 4 m inclusive, for example of the order of 1 m. The bell-shaped detection device 55 is advantageously as long as possible so as to verify the seal of a larger zone in a single test. Nevertheless, the length of the bell-shaped device could be adapted as a function on the one hand of the dimensions of the membrane 5, 8 to be tested and on the other hand with a view to its manoeuvrability by a minimum of operatives, preferably by only one operative. The elongate shape is particularly suitable for testing an assembly of rectangular metal plates in which the weld beads essentially follow the rectilinear edges of the plates.

[0050] Because of its length, the bell-shaped detection device 55 advantageously includes notches 65 so as to fit over the corrugations on the membrane 5, 8. These notches 65 are at a distance from 15 to 50 cm from one another.

[0051] The bell-shaped detection device 55 according to the invention is configured to detect a leak in a test zone 62 of a sealing membrane of a sealed and thermally-insulating tank. It is configured to evolve between an initial state and a service state. It includes:

- a main body 100 extending along a longitudinal axis L and up a vertical axis V perpendicular to the longitudinal axis L, intended to be disposed on the test zone 62;

- a seal 60 connected to the main body 100 and configured, in its service state, to define a detection chamber between the main body 100 and the test zone 62, the seal 60 including a peripheral sealing lip 64 having a closed outline to surround the test zone 62.

[0052] The bell-shaped leak detection device 55 includes a first retaining element 73, said first retaining element 73 being disposed on the seal 60 and forming a surface-to-surface contact with a portion of the seal 60 placed around the main body 100.

[0053] The invention also relates to a leak detection device for detecting a leak in a test zone 62 of a sealing membrane of a sealed and thermally-insulating tank. This device is depicted diagrammatically in figure 1. The leak detection device includes a bell-shaped leak detection device, various embodiments of which are described hereinafter, at least one vacuum pump connected to the detection chamber configured to depressurise the detection chamber when the bell-shaped detection device is in the service state and the at least one vacuum is activated, and analysis equipment connected to the detection chamber configured to analyse a gas present in the detection chamber.

[0054] The vacuum pump 57 is associated with the 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 enable depressurisation of the detection chamber and on the other hand to the analysis equipment 56 so as to convey the gas contained in the detection chamber 61 to the analysis equipment 56.

[0055] The vacuum pump 57 is connected to the bell-shaped detection device 55 via a pipe 58 that is preferably flexible. The pipe 58 is connected to a channel in the main body 100 that discharges into the detection chamber 61.

[0056] As represented in figure 1 the analysis equipment 56 is connected to the bell-shaped leak detection device 55 and enables detection of a predefined gas, for example a tracer gas or a gas of the surrounding air present on the other side of the welded assembly to be tested. As soon as the analysis equipment 56 detects the predefined gas in a quantity above a threshold it may be concluded that there

is a sealing defect in the tested portion of the weld bead 62. In accordance with one embodiment the analysis equipment 56 is a mass spectrometer.

[0057] Figure 2 is a view in cross section on the plane II-II of the bell-shaped detection device. As represented in figure 2 the rigid main body 100, the flexible seal 60 and a first retaining element 73 of the bell-shaped detection device 55 are fixed to one another and arranged to define with the membrane 5, 8 to be tested a sealed detection chamber 61 disposed facing the portion of the weld bead 62 to be tested. These elements are fixed together by fixing means 77, for example a screw, as represented in figure 4.

[0058] As represented in figures 2 and 3 the main body 100 advantageously includes a rigid core 59 and the seal 60 includes an enclosure 63 applied in a hermetically-sealed manner against a peripheral wall of the rigid core 59. The seal 60 includes an enclosure 63 espousing the shape of the rigid core 59 and a peripheral sealing lip 64 that extends the enclosure 63 in the lower part of the bell-shaped device along the vertical axis V and is extended along the transverse axis T on each side of the bell-shaped device. The enclosure has a bottom 63 that covers the upper surface of the rigid core 59 and a peripheral wall 68 that espouses the periphery of the rigid core 59. The bottom 63 includes at least one hole, not represented, to which may be connected in sealed manner the pipe 58 connected to the at least one vacuum pump 57. The rigid core 59 includes on its lower surface 80 a recess 79 along all the length of the rigid core 59. The recess 79 makes it possible, during depressurisation of the detection chamber 61, to ensure that, despite a downward movement of the rigid core 59 toward the membrane 5, 8 caused by deformation of the sealing lip 64, the test zone 62 is still in fluidic contact with the detection chamber 62. Furthermore, the rigid core 59 also includes a channel 82, not represented in figure 2 because present only in a plane at the level of the tube 58, for connecting the recess 79 to an upper surface 81 of the rigid core 59. The channel 82 enables communication of the detection chamber 61 with the at least one vacuum pump 57 and the analysis equipment 56 via the pipe 58.

[0059] The peripheral sealing lip 64 is curved toward the exterior of the bell-shaped detection device 55 and is thus configured to bend and to be pressed against the membrane 5, 8 when the sealed chamber 61 is depressurised. In other words, the peripheral sealing lip 64 has a section in the general shape of an L.

[0060] The outwardly curved portion of the peripheral sealing lip 64 typically has a width of the order of 15 to 40 mm. The peripheral sealing lip 64 is shaped to match the geometry of the membrane 5, 8 along the weld bead to be tested. Also, as shown in figure 3, the peripheral sealing lip 64 includes notches 65 having a shape corresponding to that of the corrugations of the membrane 5, 8 that the bell-shaped detection device 55 is intended to straddle when it is positioned against the portion of the weld bead 62 to be tested.

[0061] The seal 60 is advantageously made of an elastomer material having a Shore A hardness between 20 and 50 inclusive. The seal is for example made of polyurethane elastomer, EPDM rubber, silicone, nitrile or Viton ®.

[0062] Figure 4 is a perspective view of a bell-shaped leak detection device of the leak detection device. In this embodiment the first retaining elements 73 are positioned on either side of each notch 65, along the bell-shaped detection device and along the longitudinal axis L, to hold the seal 60 against the main body 100 and thus guarantee that the bell-shaped detection device 55 of the detection device 54 is sealed.

[0063] As indicated in figure 2 the first retaining elements 73 each have an upper face 92 that applies mechanical pressure to an upper part of the enclosure 63 of the seal 60 and two lateral faces 91 situated on either side of the main body 100 relative to the longitudinal axis L and applying mechanical pressure to the seal along the peripheral wall 68 and along the vertical axis V, coming to abut against the sealing lip 64 so as to exert pressure on the membrane 5, 8. Such mechanical pressure applied by these first retaining elements 73 enables prevention of deformation of the seal 60 and thus guarantees a better seal of the bell-shaped detection device 55.

[0064] In accordance with one embodiment the bell-shaped detection device 55 includes a first and/or a second and/or a third bearing element 90, 87, 85 configured to move in translation along an axis parallel to the vertical axis V when the bell-shaped detection device 55 evolves between the initial state and the service state so as to come to abut against the sealing lip 64 in the service state.

[0065] In one embodiment the first retaining elements 73 of the bell-shaped detection device of the leak detection device include a first bearing element 90. The first

bearing element 90 includes two blades 93 situated on either side of the main body 100, between the first retaining element 73 and the sealing lip 64.

[0066] In accordance with an embodiment that can be seen in figure 2 the two blades 93 come into contact with the sealing lip 64 in order to press that sealing lip 64 against the membrane 5, 8. The blades 93 may be L-shaped, for example.

[0067] In accordance with one embodiment, as represented in figure 2, the two blades 93 are mounted independently of the first retaining elements 73, allowing rectilinear movement in translation along the vertical axis V. The blades 93 are preferably disposed on the internal face of the lateral faces 91 of the first retaining elements 73.

[0068] In accordance with another variant of this embodiment the two blades 93 are mounted independently and may be fixed, for example screwed or glued, to the lateral faces 91 of the first retaining elements 73.

[0069] In accordance with another variant of this embodiment, as represented in figure 4, the two blades 93 are extensions of the first retaining elements 73.

[0070] As represented in figure 4 and in accordance with another embodiment the bell-shaped device 55 includes at least one second retaining element 74, each retaining element 74 being situated at one end of the seal 60 along the longitudinal axis L.

[0071] Two second retaining elements 74 are preferably situated at respective ends of the bell-shaped leak detection device 55, given that the latter has a longitudinal general shape. The second retaining elements 74 enable application of mechanical pressure against the seal along the vertical axis V in order to press the seal 60 onto and hold it against the main body 100. This enables prevention of deformation of the seal 60 and therefore guaranteed improved sealing of the bell-shaped detection device 55.

[0072] In another embodiment and as represented in figure 5 the bell-shaped device 55 includes at least one second bearing element 87 fixed to the second retaining element 74 and situated at one end of the seal 60 along the longitudinal axis L. Two second bearing elements 87 are preferably situated at respective ends of the bell-shaped leak detection device 55, given that the latter has a longitudinal general shape. The second bearing elements 87 may be designed in accordance with a

plurality of distinct variants in terms of shape and material, combinable or not on the same bell-shaped leak detection device 55.

[0073] In accordance with one embodiment the at least one second bearing element 87 takes the form of a block 99 fixed to the end of the bell-shaped detection device and extending all around the rounded portion of the main body 100 and a fixing portion 98 fixed directly to the second retaining element 74. The block 99 may be of rounded shape and have a lower face bearing against the sealing lip 64 and an upper face coming into contact with the fixing portion 98. The block 99 has the advantage of being a lightweight structure reducing the weight of the structure of the bell-shaped detection device. Furthermore, here the block 99 has a spring element function. In fact, when the operative bears down on the handling handles 51, 52 the block 99 is deformed elastically and comes to apply a homogeneous elastic return force over all of its lower surface that is in contact with the sealing lip 64 in order to ensure that this sealing lip 64 is pressed against the zone to be tested.

[0074] The block 99 is advantageously made of an elastomer material having a Shore A hardness between 35 and 50 inclusive, such as polyurethane.

[0075] In accordance with one embodiment handles 51, 52 are mounted on the second retaining elements 74 in order to facilitate handling the bell-shaped device.

[0076] As represented in figures 4 and 5 the bell-shaped device 55 may include at least one third retaining element 72 of the seal situated at a notch 65 of the bell-shaped detection device 55, the or each element being disposed on a portion of the seal placed around the main body 100 on one of said notches 65 and forming a surface-to-surface contact with said portion of the seal 60. The third retaining elements 72 are U-shaped, matching the notch 65 and enabling mechanical pressure to be applied to the seal 60 in order to press and retain the enclosure 63 of the seal 60 against the main body 100. This mechanical pressure enables prevention of deformation of the seal 60 and therefore guaranteed improved sealing of the bell-shaped detection device 55.

[0077] The first, second and third retaining elements 72, 73, 74 may be made of a material having a Shore D hardness greater than 50. The first, second and third retaining elements 72, 73, 74 are for example made of polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), acrylonitrile-

butadiene-styrene (ABS), polyamide 6 (PA6). The first, second and third retaining elements 72, 73, 74 may for example also be made of carbon fibre or aluminium.

[0078] As represented in figure 4 the bell-shaped detection device 55 may include at least one third bearing element 85 with a notch 65.

5 [0079] Figures 6 and 7 represent two different embodiments of a third bearing element 85. The third bearing element 85 includes a first set of two fingers 851 situated on one side of the third retaining element 72 and a second set of two fingers 851 situated on the other side of the third retaining element 72 relative to a transverse axis T perpendicular to the longitudinal axis L and the vertical axis V. In each set of
10 two fingers 851 the two fingers 851 are disposed on either side of the third retaining element 72 along the longitudinal axis L.

[0080] The two sets of two fingers 851 are in contact with the sealing lip 64 in order to press this sealing lip 64 against the base of the corrugation of the membrane 5, 8.

15 [0081] In accordance with an embodiment represented in figure 6 the third retaining element 72 is secured to the third bearing element 85 to form a one-piece part.

[0082] In accordance with another embodiment the third bearing element 85 is situated on a lower part of the third retaining element 72. The third bearing element 85 is advantageously configured to clamp the peripheral sealing lip 64 against the sealing membrane in the vicinity of the base of the corrugation by means of the two
20 sets of two fingers 851.

[0083] In accordance with another embodiment represented in figure 7 each finger 851 has an upper part 85a and a lower part 85b, the upper part 85a being mobile in rotation relative to the third retaining element 72 about a first axis I parallel to the transverse axis T and the lower part 85b being mobile in rotation relative to the
25 upper part 85a about a second axis II parallel to the transverse axis T and distinct from the first axis I.

[0084] The third bearing element 85 may be rigidly fixed to the third retaining element 72 or connected to the third retaining element 72. In this case the upper part 85a is not secured to the third retaining element 72 and connected to said third retaining
30 element 72 by means of a first fixing element 86, for example a screw, situated on the upper part 85a.

[0085] In accordance with one embodiment the upper part 85a is connected to an upper zone of the third retaining element 72 along the vertical axis V.

[0086] In accordance with one embodiment the upper part 85a and the lower part 85b are not secured to one another and are fixed by means of at least one second fixing element 88, for example a screw.

[0087] In accordance with one embodiment the upper part 85a and the lower part 85b are configured so as to nest one within the other.

[0088] In accordance with one embodiment the bell-shaped device 55 includes at least one compression element. The upper part 85a and the lower part 85b are connected to one another by means of a compression element 852, for example a spring, enabling each set of two fingers 851 to effect a pinching movement. Thus the third bearing element 85 is configured to come to apply a force pinching the peripheral sealing lip 64 against the membrane 5, 8. The two sets of two fingers 851 are advantageously configured to clamp the peripheral sealing lip 64 against the sealing membrane in the vicinity of the base of the corrugation.

[0089] The third retaining element 72 advantageously includes an opening 831 situated in the upper zone of the pressure element 83 along the vertical axis V.

[0090] The opening 831 allows the passage of a tapping point 78 situated on the notch of the bell-shaped leak detection device 55 in order to connect the pipe 58.

[0091] As represented in figure 8 the leak detection device 54 includes the bell-shaped detection device 55, the analysis equipment 56 with the associated vacuum pump 57, a second vacuum pump 37 of higher power and/or a third vacuum pump 53, and a suction circuit connecting the detection chamber 61 to the analysis equipment 56, to the higher power second vacuum pump 37 and to the third vacuum pump 53 by means of at least one solenoid valve 48. The suction circuit preferably includes a relatively long flexible pipe 58 to favour the mobility of the bell-shaped detection device 55 over a relatively extensive working zone around the analysis equipment 56. This flexible pipe 58 is for example connected by connectors 39 on the one hand to an outlet of the detection chamber 61 and on the other hand to the analysis equipment 56. When a second and/or a third vacuum pump 37, 53 is employed branch connectors 38 may be provided for branch

connection of the analysis equipment 56 and the vacuum pump(s) 37, 53 to one another.

[0092] Where the solenoid valves 48 are concerned, different configurations of positioning in the circuit according to the invention may be envisaged, namely in particular a solenoid valve 48 for each vacuum pump or only for the bell-shaped detection device 55.

[0093] A control unit 36 is also provided to control the solenoid valve 48 and possibly other elements such as the analysis equipment 56 in response to actions of an operative on one or more control members of the bell-shaped detection device 55, disposed for example on one or more handles 51, 52 for handling the bell-shaped detection device 55.

[0094] For example, the two handling handles 51, 52 may each be provided with a pushbutton 761 that can be pressed with the thumb and respectively configured as an activation button and a deactivation button. Control members taking a form other than a pushbutton may be envisaged instead, for example a capacitive touch-sensitive button, a pivoting lever, or any other member that can be actuated manually.

[0095] In a preferred embodiment the vacuum pump(s) 37, 53 or other source of reduced pressure are activated beforehand and continuously depressurise the suction circuit. The solenoid valves 48 have a closed default state so that the detection chamber 61 is not initially subjected to the reduced pressure, which allows free movement of the bell-shaped detection device 55 over the membrane 5, 8.

[0096] The solenoid valve 48 may be positioned on the gas outlet of the bell-shaped detection device 55. It may equally be positioned at another location in the suction circuit.

[0097] The control signals between the control unit 36, the solenoid valves 48 and the activation and deactivation buttons are conveyed by wired or wireless communication links 35, for example taking the form of a flexible electrical cable or braided flexible cables to favour the mobility of the bell-shaped detection device 55.

[0098] In one embodiment the control unit 36 is configured to control the analysis equipment 56 as well. To this end a wired or wireless communication link 35 is also

provided between the control unit 36 and the analysis equipment 56. Furthermore, a pressure sensor 49 also connected to the control unit 36 is provided on the bell-shaped detection device 55 to measure the pressure in the detection chamber 61.

[0099] The source of reduced pressure being activated beforehand, the operative takes hold of the bell-shaped detection device 55 by the two handles 51, 52 and positions the bell-shaped detection device 55 on the selected test zone, where necessary with the assistance for example of aiming devices 762. The operative then presses the activation button.

[0100] The operative has only to press the deactivation button to position the bell-shaped detection device 55 on another test zone. The bell-shaped detection device 55 can therefore be employed without the operative having to interact with the vacuum pump 37, the control unit 36 or the analysis equipment 56 in all of a working zone defined by the length of the fluidic and electrical connections of the bell-shaped detection device 55 to those elements. To favour mobility of the leak detection device 54 on a larger scale, the vacuum pump 37, the control unit 36 and the analysis equipment 56 may be mounted on a trolley, not depicted.

[0101] The bell-shaped detection device, the leak detection device 54 and the method of using the device described hereinabove are more particularly aimed at testing the seal of a membrane of a sealed and thermally-insulating membrane tank. For example, such membrane tanks are described in particular in patent applications WO14057221, FR2691520.

[0102] Membrane tanks have a plurality of walls that have a multilayer structure, as represented in figure 9. Each wall 1 includes, from the exterior to the interior of the tank, a secondary thermally-insulating barrier 2 including secondary insulating panels 3 anchored to a supporting structure 4, a secondary membrane 5 resting against the secondary thermally-insulating barrier 2, a primary thermally-insulating barrier 6 including primary insulating panels 7 resting against the secondary membrane 2 and anchored to the supporting structure 4 or to the secondary insulating panels 3, and a primary membrane 8 that rests against the primary thermally-insulating barrier 6 and is intended to be in contact with the liquefied gas contained in the tank.

[0103] The tank has a polyhedral general shape. In the embodiment depicted in figure 10 the tank has a front wall 9 and a rear wall, not represented, which here are of octagonal shape. The tank also includes a ceiling wall 10, a bottom wall 11 and lateral walls 11, 12, 13, 14, 15, 16, 17 that extend in a longitudinal direction L of the tank between the front wall 9 and the rear wall.

[0104] The secondary thermally-insulating barriers 2 of the tank walls communicate with one another so as to form between the supporting structure 4 and the secondary membrane 5 a sealed secondary thermally-insulating space. Similarly, the primary thermally-insulating barriers 6 of the tank walls communicate with one another so as to form a sealed primary thermally-insulating space between the secondary membrane 5 and the primary membrane 8.

[0105] The primary membrane 8 and/or the secondary membrane 5 include(s) a plurality of metal plates that are welded to one another. The seal test method described hereinafter is more particularly aimed at testing the seal of the welds for connecting the metal plates to one another. In accordance with one embodiment the membrane to be tested features corrugations that allow it to be deformed by thermal and mechanical loads generated by the fluid stored in the tank. To this end and as represented for example in figure 7 each metal plate includes two mutually-perpendicular series of corrugations.

[0106] In one embodiment the seal test method includes three steps, namely:

- diffusing a tracer gas into a thermally-insulating space covered by the membrane 5, 8 the seal of which is to be tested;
- monitoring diffusion of the tracer gas into the thermally-insulating space; and
- verifying the seal of the welds in the membrane 5, 8.

[0107] In another embodiment the seal test method includes only verification of the seal of the welds of the membrane 5, 8 without using a tracer gas.

[0108] The step of diffusing a tracer gas consists in injecting a tracer gas into the thermally-insulating space that is covered by the membrane 5, 8 the seal of which is to be verified. When it is required to verify the seal of the secondary membrane 5 the tracer gas is injected into the secondary thermally-insulating space. In this case the seal-test method is executed before the primary thermally-insulating barrier 7 and the primary membrane 8 are installed. If it is required to verify the

seal of the primary membrane 8 the tracer gas is injected into the primary thermally-insulating space.

[0109] Figure 10 diagrammatically depicts a sealed and thermally-insulating tank and a system for injecting tracer gas into a thermally-insulating space.

[0110] The injection system includes a plurality of pipes 18 which are on the one hand connected to a source of tracer gas, not depicted, and on the other hand connected to devices 19 for injection of the tracer gas, forming a tracer gas injection passage through the membrane 5, 8 the seal of which must be tested. The tracer gas injection devices 19 more particularly form tracer gas passages through the membrane of the bottom wall 11. This kind of disposition is particularly advantageous because the tracer gas has a lower vapour density than air so that it tends to rise in the thermally-insulating space. Thus injecting the tracer gas at the bottom, through the membrane 5, 8 to be tested of the bottom wall 11, enables rapid and homogeneous diffusion of the tracer gas into the thermally-insulating space.

[0111] In the embodiment represented in figure 10 the bottom wall 11 is equipped with at least four tracer gas injection devices 19 that are regularly distributed over the surface of the bottom wall 11. The bottom wall 11 has a rectangular shape and can therefore be divided into four zones of equal area by its two axes of symmetry x and y. Each of the four tracer gas injection devices 19 is disposed in one of the aforementioned four zones. In the particular embodiment depicted each tracer gas injection device 19 is disposed in the vicinity of the centre of its respective zone. In one particular embodiment each of the tracer gas injection devices is disposed 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 where L is the longitudinal dimension of the bottom wall 11 and B is the transverse dimension of the bottom wall 11.

[0112] The tracer gas diffusion monitoring step consists, when the tracer gas has diffused through the thermally-insulating space, in monitoring the diffusion of the tracer gas into the thermally-insulating space.

[0113] To this end the gas contained in the thermally-insulated space into which the tracer gas has been injected is sampled by means of a plurality of gas sampling devices that pass through the membrane covering said thermally-insulating space.

Each sampling device is connected to an analysis equipment such as a mass spectrometer which enables verification of the presence and the concentration of the tracer gas in the corresponding zone of the thermally-insulating space.

[0114] The step of verifying the welds consists in using the leak detection device 54
5 described above on one of the membranes 5, 8 of the sealed and thermally-insulating tank.

[0115] Although the invention has been described in connection with a plurality of particular embodiments, it is obvious that it is no way limited to them and that it encompasses all technical equivalents of the means described and combinations
10 thereof if the latter fall within the scope of the invention.

[0116] Use of the verb “to include” or “to comprise” and conjugate forms thereof does not exclude the presence of elements or steps other than those stated in a claim.

[0117] In the claims any reference sign between parentheses should not be interpreted as a limitation of the claim.

Claims

[Claim 1] Bell-shaped leak detection device (55) for detecting a leak in a test zone (62) of a sealing membrane of a sealed and thermally-insulating tank, the bell-shaped leak detection device (55) being configured to evolve between an initial state and a service state, the bell-shaped leak detection device (55) including:

- a main body (100) extending along a longitudinal axis (L) and rising along a vertical axis (V) perpendicular to the longitudinal axis (L), intended to be disposed on the test zone (62);

- a seal (60) connected to the main body (100) and configured, in its service state, to define a detection chamber between the main body (100) and the test zone (62), the seal (60) including a peripheral sealing lip (64) having a closed outline to surround the test zone (62);

the bell-shaped leak detection device (55) being characterised in that it includes:

- a first retaining element (73), said first retaining element (73) being disposed on the seal (60) and forming a surface-to-surface contact with a portion of the seal (60) placed around the main body (100);

- a first and/or a second and/or a third bearing element (90, 87, 85) configured to be moved in translation along an axis parallel to the vertical axis (V) when the bell-shaped detection device (55) evolves between the initial state and the service state so as to come to abut against the sealing lip (64) in the service state;

the at least one bearing element (90, 87, 85) being in contact with the sealing lip (64) so as to press the sealing lip (64) against the membrane in the service state.

[Claim 2] The bell-shaped leak detection device (55) according to claim 1 including at least one second retaining element (74), each second retaining element (74) being situated at one end of the seal (60) along the longitudinal axis (L).

[Claim 3] The bell-shaped leak detection device (55) according to claim 1 or 2 in which the seal (60) includes notches (65) spaced from one another along the longitudinal axis (L), the bell-shaped leak detection device including at least one

third retaining element (72), each third retaining element (72) being disposed on a portion of the seal placed around the main body (100) on one of said notches (65) and forming a surface-to-surface contact with said portion of the seal (60).

[Claim 4] The bell-shaped leak detection device (55) according to any one of
 5 claims 1 to 3 in which the first bearing element (90) includes two blades (93) situated on either side of the main body (100) between the first retaining element (73) and the sealing lip (64).

[Claim 5] The bell-shaped leak detection device (55) according to any one of
 10 claims 1 to 4 in combination with claim 2 including at least one second bearing element (87) fixed to the second retaining element (74) and situated at one end of the seal (60) along the longitudinal axis (L).

[Claim 6] The bell-shaped leak detection device (55) according to any one of
 claims 1 to 5 in combination with claim 3 including at least one third bearing
 element (85), in which the third bearing element (85) includes:

- 15 - a first set of two fingers (851) situated on one side of the third retaining element (72); and
- a second set of two fingers (851) situated on the other side of the third retaining element (72) relative to a transverse axis (T) perpendicular to the longitudinal axis and the vertical axis;

20 and in which in each set of two fingers (851) the two fingers (851) are disposed on either side of the third retaining element (72) along the longitudinal axis (L).

[Claim 7] The bell-shaped leak detection device (55) according to claim 6 in which the first and second sets of two fingers (851) are secured to the third retaining element (72).

25 [Claim 8] The bell-shaped leak detection device (55) according to claim 6 in which each finger (851) includes an upper part (85a) and a lower part (85b), the upper part (85a) being mobile in rotation relative to the third retaining member (72) about a first axis (I) parallel to a transverse axis (T) and the lower part (85b) being mobile in rotation relative to the upper part (85a) about a second axis (II) parallel to the
 30 transverse axis (T) and distinct from the first axis (I).

[Claim 9] The bell-shaped leak detection device (55) according to claim 8 in which each finger (851) includes at least one compression element (852) connecting the upper part (85a) to the lower part (85b).

[Claim 10] The bell-shaped leak detection device (55) according to any one of claims 1 to 9 in which the main body (100) includes a rigid core (59) and the seal (60) includes an enclosure (63) applied in hermetically sealed manner against a peripheral wall of the rigid core (59).

5 [Claim 11] The bell-shaped leak detection device (55) according to claim 10 in which the rigid core (59) includes a recess (79) on a lower surface (80) intended to face toward the test zone (62).

[Claim 12] The bell-shaped leak detection device (55) according to claim 11 in which the rigid core (59) includes a channel (82) extending from the recess (79) and
10 discharging onto an opening in an upper surface (81) of the rigid core (59), the opening being intended to be connected to at least one vacuum pump (37, 53, 57).

[Claim 13] Leak detection device (54) for detecting a leak in a test zone of a sealing membrane of a sealed and thermally-insulating tank, the leak detection device (54) including:

- 15 - a bell-shaped leak detection device (55) according to any one of claims 1 to 12;
- at least one vacuum pump (37, 53, 57) connected to the detection chamber (61) configured to depressurise the detection chamber (61) when the bell-shaped detection device is in the service state and the at least one vacuum pump (37, 53, 57) is activated;
- 20 - analysis equipment (56) connected to the detection chamber (61) configured to analyse a gas present in the detection chamber (61). |