

WELDING A SEALING MEMBRANE OF A THERMAL INSULATION BODY OF A TANK

5 **Field of the invention**

The subject matter of the invention is the creation of sealed and thermally insulating tanks intended more particularly, although not exclusively, for transporting, by sea, liquefied gases or cryogenic liquids and, more specifically, for transporting liquefied
10 natural gases with a high methane content (LNG) or a high petroleum content (LPG). Such tanks may also be installed on land or on a floating structure intended for storage.

The invention here relates to the welding of a sealing membrane of such a tank, and more particularly the invention proposes a solution for the optimal welding together of two adjacent strakes of the membrane and two anchoring flanges, said two strakes having
15 turned-up edges and the welding-together of these two contiguous strakes being performed at the level of these turned-up edges.

In what follows, the expression “anchoring flange” and “welding support” will be used interchangeably to refer to the one same element the function of which is both to offer a means of anchoring the membrane (the strakes thereof) to the thermally insulating
20 body and to act as a welding support for fixing to each of the two adjacent strakes.

Prior art

Tanks for storing or transporting low-temperature liquefied gases in which the or
25 each sealing membrane, notably a primary sealing membrane in contact with the product contained in the tank, is made up thin metal sheets supported by a thermally insulating barrier are known, for example from FR 2798358, FR 2709725 and FR 2549575. These thin metal sheets are joined together in a fluidtight manner in order to ensure the fluidtight sealing of the tank.

30 Figure 1 illustrates a known method for fixing said metal sheets to the thermally insulating barrier of this type of tank. In this figure 1, an upper surface 101 of the thermally insulating barrier has a slot 102 extending into the thickness of the thermally

insulating barrier from the support surface 101. This slot 102 has, within the thickness of the thermally insulating barrier, a retaining zone formed of a groove 103 which extends parallel to the support surface 101. This groove 103 extends at one end of the slot 102 which is the opposite end to the support surface 101 in the thickness of the thermally insulating barrier, the slot 102 having, in sectional cross section, the shape of an inverted T of which the base is formed by the groove 103. An L-shaped anchoring flange 104 is inserted in the slot 102. This anchoring flange 104 has a base 105 housed in the groove 103 to hold the anchoring flange 104 on the thermally insulating barrier in a direction perpendicular to the support surface 101. The anchoring flange 104 also comprises an anchoring leg 106 of which a lower part 107 adjoins the base 105 and an upper part 108 projects above the support surface 101.

Two metal sheets 109 are arranged one on each side of the anchoring flange 104. These metal sheets 109 each have a planar median portion 110 resting against the support surface 101 (for the sake of the legibility of the figure, the support surface 101 and the metal sheets 109 are depicted in figure 1 with a separation between them). These metal sheets 109 also have turned-up lateral edges, hereinafter referred to as turned-up edges 111. A turned-up edge 111 of each of the two adjacent metal sheets 109 is welded on each side of the anchoring leg 106 of the anchoring flange 104.

The turned-up edges 111 thus form, with the anchoring flange 104, bellows able to absorb the forces associated with the contraction of the sealing membrane, for example as cryogenic liquid is being loaded into the tank.

However, such an anchoring flange 104 constitutes a fixed fixing point for each turned-up edge 111. Specifically, because the anchoring flange 104 is urged in two opposite directions by the turned-up edges 111, it remains substantially static in the tank. As a result, the anchorage of the turned-up edges 111 on the support surface 101 via the anchoring flanges 104 is substantially fixed in the direction perpendicular to the turned-up edges 111. This therefore limits the flexibility of the sealing membrane.

This is why FR 3054872 proposes the use of two anchoring flanges, each of these two anchoring flanges having the respective function of anchoring a respective one of two adjacent strakes.

However, the junction between the turned-up edges of two adjacent strakes then involves four thicknesses of material (two turned-up edges of strakes, and two anchoring flanges) that have to be welded together in a completely fluidtight manner. Now, given

in particular the thicknesses of the turned-up edges of the strakes and the thicknesses of the anchoring flanges, fixing the two strakes to the anchoring flanges becomes particularly difficult to achieve when it is also considered that there is the desire to maintain a significant degree of flexibility, or elasticity, at these sealed junctions so as to be able in particular to absorb thermal stress loadings. Welding methods described in FR1589316 and DE4411888 are also known.

At the present time there is no method that allows quick and effective welding, namely, as a minimum, welding that is entirely fluidtight along the entire length of the welds, at the level of two adjacent strakes, when these each have an anchoring flange for anchoring to the thermally insulating body.

Brief description of the invention

The present invention seeks to plug the gaps in the prior art by offering a particularly effective solution for creating the weld between two adjacent strakes, when each one has or comprises an anchoring flange connecting or fixing it to the thermally insulating body.

The applicant, after various studies and analyses, has discovered a solution that is technically simple to implement and allows the creation of a perfect weld, namely one that is entirely fluidtight and mechanically very strong, between two adjacent/contiguous strakes of a membrane, via their respective anchoring flanges, and that can be done quickly.

Thus, the present invention relates to a method for welding a membrane of a sealed and thermally insulating tank, in which method a sealed and thermally insulating tank comprises at least one metal sealing membrane and a thermally insulating body comprising at least one thermally insulating barrier adjacent to said membrane, in which method:

- at least two metal strakes of the sealing membrane, which are borne by a support surface of the thermally insulating barrier, take the form of a profiled component comprising a planar median portion resting on the support surface and two turned-up lateral edges projecting from the support surface, and

- at least two metal welding supports, borne by the thermally insulating barrier, project from the support surface between the two adjacent turned-up lateral edges of the two adjacent strakes,

5 the method according to the invention being characterized in that a conducting strip is inserted between the two aforesaid metal welding supports and in that, thereafter, electrode-wheel resistance-seam welding is used to weld together in pairs, in a fluidtight manner, each of the two turned-up lateral edges of the two adjacent metal strakes and a respective one of said metal welding supports which are interposed between said adjacent turned-up edges.

10 By virtue of this method according to the invention it is now possible to produce an optimum-quality weld automatically in such a way that the time taken to install the sealed and thermally insulating tank is thereby significantly reduced. This then results in a gain in productivity. Furthermore, the welding method according to the invention makes it possible to ensure the mechanical continuity and fluidtightness of the
15 welded seam, to weld along the length of the turned-up edges without stopping and without rework, thanks to the electrical continuity, and that makes it possible not to fuse the two welding supports at the level of the welds with the two turned-up edges. This method is also compatible with present-day welding machines and therefore allows existing equipment to be retained, limiting machine-pool management and investment.

20 Also, by virtue of the method according to the invention, each of the two assemblies made up of a turned-up edge and a welding support is welded simultaneously (at the same time).

Numerous tests have been carried out to assess the quality of the weld between each of the anchoring flanges and the strake (the turned-up edge thereof), and these tests
25 reveal an optimum weld quality (notably no trace of the material that forms the conducting strip) offering excellent mechanical qualities, particularly with regard to its resistance to shocks, its tensile/flexural/compressive strength and its ability to withstand thermal gradients (the junction between the anchoring flange and the strake always needing to remain fluidtight).

30 What is meant here by electrode-wheel resistance-seam welding is welding in which the workpieces are assembled by applying an electrical current (applying the current continuously or otherwise) and a pressure of the electrode wheels against the surface that is to be welded.

Further advantageous features of the invention are specified succinctly hereinbelow:

5 - advantageously, at least one of the welding supports, and preferably both, consists of an anchoring flange so as to anchor the sealing membrane to the thermally insulating barrier of the thermally insulating body;

 - according to one embodiment, the anchoring flange takes the form of an L and comprises a longitudinal portion and a lower portion engaging with the thermally insulating barrier;

10 - according to one embodiment, the lower portion of the anchoring flange extends, parallel to the median portion of the metal strakes, in a cavity of the thermally insulating barrier of the thermally insulating body;

 - as a preference, prior to each of said turned-up edges being welded to one of said welding supports, said welding supports have been fixed to one another in a fluidtight manner using welding.

15 Thus, as depicted in the attached figure 4, the junction between the two adjacent strakes and the two metal anchoring flanges exhibits, because of the various spots of welding, a W-shaped profile or cross section. In other words, such a junction offers a dual-bellows function which gives it significant properties of elasticity allowing the sealing membrane, particularly at this level, to withstand or absorb very steep thermal gradients, resulting in particular from particularly significant (thermal) contractions.

20 - Advantageously, the electrode-wheel resistance-seam welding of each of said adjacent turned-up edges to the respective one of said welding supports is performed at a speed of between 1.5 meters per minute (m/min) and 2.5 m/min, preferably at a speed of 1.8 m/min;

 - according to one embodiment of the invention, the aforesaid turned-up edges, and preferably also the welding supports, are made of Invar® or of a steel containing at least 20% manganese, preferably at least 25% manganese, and more preferably still to 28% manganese;

30 - according to one embodiment, the thickness of the turned-up edges, and preferably also the thickness of the aforesaid welding supports, is between 0.5 and 0.8 millimeters (mm) and preferably equal to 0.7 mm;

 - when the turned-up edges, and possibly the welding supports, have such a

thickness (of 0.5 and 0.8 mm), during the electrode-wheel resistance-seam welding, the current strength is comprised between 1.8 and 3.2 kiloamperes, (kA) preferably comprised between 2.2 and 2.8 kA, and the pressure force exerted by each electrode wheel against a respective turned-up edge is comprised between 1.2 and 2.8 bar, preferably between 2 and 2.5 bar;

- according to another embodiment, the thickness of the turned-up edges, and preferably also the thickness of the aforesaid welding supports, is comprised between 0.9 and 1.2 millimeters (mm), and preferably equal to 1 mm;

- when the turned-up edges, and possibly the welding supports, have such a thickness (of 0.9 and 1.2 mm), during the electrode-wheel resistance-seam welding, the current strength is comprised between 2.7 and 3.8 kA, preferably comprised between 3 and 3.5 kA, and the pressure force exerted by each electrode wheel against a respective turned-up edge is comprised between 3.5 and 5 bar, preferably between 4 and 4.5 bar;

- advantageously, during the electrode-wheel resistance-seam welding, the electrode-wheel resistance-seam welding electric current does not flow continuously; as a preference, said electric current flows for a range of time corresponding to 60% to 80% of the time at (or for) a constant frequency, more preferably still, for two thirds (2/3) of the time at (or for) a constant frequency;

- advantageously, the conducting strip is made of a material or of an alloy of materials with a high melting point, higher than the melting point of the turned-up edges and of the welding supports. According to one embodiment, the conducting strip is made of (essentially comprises) copper, a molybdenum-based alloy, a tungsten-based alloy or graphite, and is preferably made of copper.

The invention also relates to a system for welding a membrane of a sealed and thermally insulating tank, the system comprising an electrode-wheel resistance-seam welding device comprising two electrode wheels and possibly, a means for holding said electrode wheels against a surface that is to be welded, and a sealed and thermally insulating tank wall comprising:

- two adjacent metal strakes of the sealing membrane, which are borne by a support surface of the thermally insulating barrier of the sealed and thermally insulating tank, taking the form of a profiled component comprising a planar median portion resting

on the support surface and two turned-up lateral edges projecting from the support surface, and

- two metal welding supports, borne by the thermally insulating barrier, projecting from the support surface between the two adjacent turned-up lateral edges of the two adjacent strakes,

the electrode-wheel resistance-seam welding device making at least one weld between a respective one of said turned-up edges and one of said welding supports,

the system according to the invention being characterized in that the welding device comprises a conducting strip intended to be inserted between the two welding supports so as to weld each of the two aforesaid adjacent turned-up lateral edges to a respective one of said welding supports which are interposed between said adjacent turned-up edges.

It should be noted that all the features set forth hereinabove in connection with the welding method according to the invention apply to the welding system succinctly defined above.

The invention also relates to a sealed and thermally insulating tank integrated in a bearing structure, comprising a sealed and thermally insulating tank comprising at least one metal sealing membrane made up of a plurality of metal strakes and a thermally insulating body comprising at least one thermally insulating barrier adjacent to said membrane, in which tank:

- at least two metal strakes of the sealing membrane, which are borne by a support surface of the thermally insulating barrier, take the form of a profiled component comprising a planar median portion resting on the support surface and two turned-up lateral edges projecting from the support surface, and

- at least two metal welding supports, borne by the thermally insulating barrier, project from the support surface between the two adjacent turned-up lateral edges of the two adjacent strakes.

The tank according to the invention is characterized in that electrode-wheel resistance-seam welding is used to weld together in pairs, in a fluidtight manner, each of the two adjacent turned-up lateral edges of the two adjacent metal strakes and a respective one of said welding supports which are interposed between said adjacent turned-up edges.

While admittedly creating a weld between a strake (the turned-up edge thereof) and an anchoring flange is known per se, from document FR 3054872, the spot of welding with use of the method according to the present invention exhibits a cross section of a shape different than that of this prior art. Specifically, given the positioning of the conducting strip on the side of (contiguous with) the anchoring flange and of an electrode wheel on the side of (contiguous with) the turned-up edge of a strake, the cross section of the spot of welding has a shape that is substantially oval (rather than symmetrical as in the prior art) with its protrusion (protuberance or boss) lying on the side of the strake, namely on the side on which the electrode wheel was positioned during welding. It will be noted that, in the case where two electrode wheels, arranged one on each side of the spot of welding, are used, the spot of welding exhibits a shape that is symmetrical. This cross section of slightly different shape – the attached figure 4 is not representative of this feature concerning the shape of the spot of welding – by comparison with the prior art obviously has no negative impact on the quality of the spot of welding but does allow a spot of welding produced using the method of the present invention to be differentiated from another welding method. Thus, such a tank, comprising all of the features listed hereinabove and characterized by at least one spot of welding produced using an “electrode wheel/conducting strip” pair, is indeed novel.

Finally, the invention also relates to a ship for transporting a cold liquid product, the ship comprising a double hull and a sealed and thermally insulating tank, as described succinctly hereinabove, placed in the double hull.

Advantageously, the ship according to the invention comprises at least one sealed and insulating tank as described hereinabove, said tank comprising two successive sealing barriers, a primary one in contact with a product contained in the tank and a secondary one arranged between the primary barrier and a bearing structure, preferably made up of at least some of the walls of the ship, these two sealing barriers alternating with two thermally insulating barriers or a single thermally insulating barrier positioned between the primary barrier and the bearing structure.

Such tanks are conventionally referred to as integrated tanks according to the International Maritime Organization (IMO), such as tanks of the NO 96[®] type for example.

As a preference, the tank contains a liquefied natural gas (LNG) or a liquefied gas (LG).

According to one embodiment, the invention also provides a method for loading or unloading such a ship, wherein a fluid is conveyed through insulated pipes from or to a floating or on-shore storage facility to or from the tank of the ship.

According to one embodiment, the invention also provides a transfer system for a fluid, in particular a cold liquid product, the system comprising the aforementioned ship, insulated pipes designed to connect the tank installed in the hull of the ship to a floating or on-shore storage facility and a pump for driving a flow of fluid through the insulated pipes from or to the floating or on-shore storage facility to or from the tank of the ship.

Description of the attached figures

The following description is given purely by way of nonlimiting illustration, with reference to the attached figures in which:

- figure 1 is a view in cross section of an anchoring flange of a metal sealing membrane of the prior art, said anchoring flange being anchored in a thermally insulating barrier of a sealed and thermally insulating tank;

- figure 2 is a view in cross section of two anchoring flanges of a metal membrane, the two anchoring flanges having been welded together before being introduced into the thermally insulating body, this figure illustrating a tank wall portion, at the level of two adjacent strakes, prior to the application of the welding method according to the invention;

- figure 3 is a view in cross section identical to figure 2, but this time the elements specific to implementing of the welding method according to the invention are visible in this figure;

- figure 4 is a view in cross section, again showing the elements visible in figures 2 and 3, of a sealed and thermally insulating tank wall portion after implementation of the welding method according to the invention; and

5 - figure 5 is a schematic depiction with cutaway of a tank of a methane carrier ship and of a loading/unloading terminal for loading/unloading this tank.

Detailed description of embodiments of the invention

10 The description hereinbelow refers to a sealing membrane in the context of a sealed and thermally insulating tank. Such a tank comprises an internal space intended to be filled with a combustible or non-combustible gas. The gas may notably be a liquefied natural gas (LNG), namely a gas mixture containing predominantly methane as well as one or more other hydrocarbons, such as ethane, propane, n-butane, i-butane, n-pentane, i-pentane, neopentane and nitrogen in small proportions. The gas may equally be ethane or a liquefied petroleum gas (LPG), namely a mixture of hydrocarbons derived from the refining of crude oil and essentially containing propane and butane.

15 In general, the sealing membrane rests on a support surface formed by a thermally insulating barrier of the tank. This sealing membrane has a repeating structure, comprising alternately, on the one hand, strips of sheet, forming strakes, arranged on the support surface and, on the other hand, elongate welding supports connected to the support surface and running parallel to the strips of sheet over at least part of the length of the strips of sheet. The strips of sheet have turned-up lateral edges arranged and welded against the adjacent welding supports. Such a structure is used for example in methane carrier ship tanks of NO 96[®] type marketed by the applicant company.

20 At the level of the sealed and thermally insulating tank, not depicted in its entirety in the attached figures, the turned-up edges of the strakes are preferably arranged in a longitudinal direction perpendicular or parallel to the longitudinal direction of the ship. Thus, the turned-up edges form bellows able to absorb the forces of contraction in a longitudinal direction of the ship or a transverse direction perpendicular thereto. The strips of sheet and the welding supports are interrupted at the corners, for example in the way described in document WO 2012/072906 or else FR2724623.

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According to one embodiment, the sealing membrane (strakes), one of the sealing membranes or the sealing membranes may be made from a metal chosen from stainless steel, aluminum, Invar[®], namely an alloy of iron and of nickel the coefficient of expansion of which is typically comprised between 1.2×10^{-6} and $2 \times 10^{-6} \text{ K}^{-1}$ or an iron alloy with a high manganese content of which the coefficient of expansion is of the order of 7 to $9 \times 10^{-6} \text{ K}^{-1}$. According to one embodiment, a material exhibiting a thermal contraction coefficient of less than $16 \times 10^{-6}/\text{K}$ is chosen for applications in which the liquid gas is at a temperature comprised between -45°C and -100°C .

Figures 2 to 4 depict a view in cross section of a sealed and thermally insulating tank wall at the level of the connection between two adjacent metal strakes 1, 2 of a sealing membrane of the tank wall and two welding supports 3, 4 anchored on a thermally insulating barrier 5 of the thermally insulating body of the tank wall. Such a thermally insulating barrier 5 is made up of juxtaposed insulating elements. For example, suitable insulating elements are described in document W02012/072906. This thermal barrier 5 of the thermally insulating body may be produced as one or several thicknesses meeting the need for the contents of the tank to be thermally insulated from their surroundings. The material or materials also likely to be present in such a thermally insulating body consist for example of polymer foams, such as polyurethane, polystyrene or polyethylene, preferably very low density polyethylene (LDPE) foams, manufactured glass wool, loose packed glass wool, melamine foams, aerogels, polyester wadding loose or in the form of batts.

The thermally insulating body is conventionally anchored to the bearing structure, not depicted in the attached figures, for example of a ship or of a barge, using retaining members. Each of the insulating elements that makes up the thermally insulating body here has the shape of a rectangular parallelepiped having two large faces, or main faces, and four small faces, or lateral faces. More particularly, the adjacent metal strakes 1, 2 rest on a support surface 10 of the thermally insulating body (or of the thermally insulating barrier 5). This support surface 10 is formed by the upper face of the thermally insulating barrier 5. The welding supports 3, 4 are anchored in the insulating element of the thermally insulating barrier 5 of the thermally insulating body.

In order to anchor the welding supports 3, 4 in the thermally insulating body, the upper face of the body (thermally insulating barrier 5) comprises a slot 11 of which the cross section is in the shape of an inverted T. The upper part of the thermally insulating

barrier 5 may comprise a plywood sheet or a sheet of composite material in which the slot 11 is made. A retaining zone 12 extends into the thickness of the thermally insulating barrier 5 of the insulating thermally insulating body parallel to the support surface 10. The welding supports 3, 4 are inserted by sliding into the slots 11 of the thermally insulating body. The welding supports 3, 4 are thus anchored slidingly onto, or in, the thermally insulating body 5, in the longitudinal direction of the welding supports 3, 4.

Provision may also be made for the retaining zone 12 to extend in a direction which is oblique overall with respect to the support surface 10 and may comprise a component parallel to the support surface 10.

In the embodiment illustrated in figures 2 to 4, the retaining zone 12 is formed by two grooves 13, 14 extending one on each side of the slot 11, at the lower end of said slot 11.

The welding supports 3, 4 consist of two metal anchoring flanges, preferably identical in shape and nature (material). These metal anchoring flanges 3, 4 are essentially symmetrical with respect to a plane perpendicular to the support surface 10 and parallel to a longitudinal direction of the slot 11. Each metal anchoring flange 3 or 4 has an L shaped cross section comprising a base 21 and an anchoring leg 22. The base 21 corresponds to the lower portion of the metal anchoring flange 3, 4 while the anchoring leg 22 corresponds to the longitudinal portion of the same metal anchoring flanges 3, 4.

The base 21 of each metal anchoring flange 3, 4 is housed in a respective groove 13, 14, or cavity, of the slot 11. The bases 21 of the metal anchoring flanges 3, 4 extend parallel to the support surface 10. A lower part of the anchoring leg 22 of one of the metal anchoring flanges 3 or 4 adjoins the other anchoring leg 22 of the metal anchoring flange 3 or 4. Thus, according to one option offered by the invention, the lower portions of the anchoring legs 22 of the two metal anchoring flanges 3, 4 are welded together by a line of welding 23. This line of welding 23 is preferably housed, or situated, in the thickness of the thermally insulating barrier 5 (embodiment depicted in figures 2 to 4) but provision could be made for this line of welding 23 to be situated at the level of the support surface 10, or even slightly above the latter 10. An upper part of the anchoring leg 22 of each of the metal anchoring flanges 3, 4 projects, from the support surface 10, out of the slot 11, toward the inside of the tank.

In other words, the two adjacent metal strakes 1, 2 are arranged on the support surface 10 on either side of the welding supports 3, 4. Each metal strake 1, 2 has a planar

median portion 6, 7. Each metal strake 1, 2 has two turned-up edges 8, 9 situated along two opposite longitudinal edges of the planar median portion 6, 7. Just one turned-up edge 8, 9 of each of the two metal strakes 1, 2 is depicted in figures 2 to 4. Each turned-up edge 8, 9 projects with respect to the support surface 10.

5 Figure 2 illustrates the way in which the various elements 1, 2, 3, 4, 5, 6, 7, 8 and 9, namely the two adjacent strakes 1, 2, 6, 7, 8, 9, the two anchoring flanges 3, 4 (fixed together here at the spot of welding 23) and the thermally insulating body 5, are positioned prior to application of the welding method according to the invention.

10 Figure 3 illustrates the elements specific to said welding method and device according to the invention, in addition to the aforesaid elements of figure 2. Thus, by comparison with figure 2, there are present, in this figure 3, a conducting strip 30 (the expression “conducting band” may also be used to refer to the “conducting strip” 30) and two resistance-seam welding electrode wheels 31, 32, said conducting strip 30 and said electrode wheels 31, 32 being connected to electrode-wheel resistance-seam welding
15 equipment not depicted in the attached figures. The conducting strip 30 is positioned in the space defined between the two anchoring flanges 3, 4, more specifically in the space between the anchoring legs 22 of each of the anchoring flanges 3, 4 projecting from the support surface 10. The two electrode wheels 31, 32 are positioned contiguously against the exterior face/side (the face/side that is on the opposite side to the side on which the
20 anchoring flanges are situated) of each of the turned-up edges 8, 9 of the two strakes 1, 2. By applying to the electrode wheels 31, 32, against each of the turned-up edges 8, 9, a pressure directed toward the conducting strip 30, it is possible to cause a current to pass through the thickness consisting of an electrode wheel 31 or 32, a turned-up edge 8 or 9, an anchoring flange 3 or 4 and the conducting strip 30 so as to resistance-seam weld each
25 of the turned-up edges 8, 9 to the contiguous anchoring flange 3, 4.

 In the context of the present invention, the choice of the current strength and of the pressure exerted by the electrode wheels is determined, following a great deal of experimentation, in such a way as to ensure optimum electrode-wheel resistance-seam welding. The ranges of current strength and of pressure (for example expressed in bar)
30 are consistent with those set out previously, for defined thicknesses and types of material.

 From the point of view of operation of the welding device according to the invention, it is possible to envision a number of configurations regarding the polarity of

the various elements in order to perform the welding operation. Thus, it is possible to envision:

- having one electrode wheel 31 or 32 acting as a positive terminal and the other electrode wheel 31 or 32 acting as a negative terminal,
- 5 - having both electrode wheels 31, 32 acting as a positive terminal with the conducting strip 30 acting as a negative terminal,
- having the conducting strip 30 acting as a positive terminal and the two electrode wheels 31, 32 acting as a negative terminal.

Of course, the conducting strip 30 may also be used as a (simple) electrically
10 conducting element. Thus, in this preferred embodiment, one of the electrode wheels 31 or 32 acts as a positive terminal and the other electrode wheel 31 or 32 as a negative terminal, the conducting strip 30 having no polarity.

The conducting strip 30 is made of an electrically conducting material which needs to have a high melting point and be mechanically strong enough that it does not deform
15 under the pressure forces from the electrode wheels 31, 32. Copper is an economically advantageous material but other materials are possible, such as molybdenum-based alloys, tungsten-based alloys or graphites.

The turned-up edges 8, 9 of the strakes 1, 2 advantageously have a thickness of 0.7 millimeters (mm), like the anchoring flanges 3, 4, at least at the level of the anchoring
20 leg 22 that is welded to the corresponding turned-up edge 8, 9. Of course, provision may be made for the thicknesses of the turned-up edges 8, 9, as well as that of the anchoring flanges 3, 4, to be greater, resulting in the need for a higher strength of current. It is also possible to select different thicknesses for the turned-up edges 8, 9 and the anchoring flanges 3, 4, just as the nature of the material or materials constituting the turned-up edges
25 8, 9 (strakes 1, 2) and the anchoring flanges 3, 4 may possibly differ.

As visible in figure 4, once the welding method according to the invention has been performed, the turned-up edge 8, 9 of each of the two adjacent metal strakes 1, 2 is welded to a single respective metal anchoring flange 3, 4 acting as a welding support. More specifically, each turned-up edge 8, 9 is welded along a line of welding 40, 41 to the upper
30 portion of a single metal anchoring flange 3, 4.

The technique described hereinabove for creating a sealing membrane of a sealed and thermally insulating tank can be used in various types of tank, for example to

constitute the sealing membrane of an LNG tank in an on-shore facility or in a floating structure such as a methane carrier ship or the like.

With reference to figure 5, a cutaway view of a methane carrier ship 70 shows a sealed and insulating tank 71 of prismatic overall shape mounted inside the double hull 72 of the ship. The wall of the tank 71 comprises a primary sealing barrier intended to be in contact with the LNG contained in the tank, a secondary sealing barrier arranged between the primary sealing barrier and the double hull 72 of the ship, and two insulating barriers arranged respectively between the primary sealing barrier and the secondary sealing barrier and between the secondary sealing barrier and the double hull 72.

In the way known per se, loading/unloading pipes 73 arranged on the upper deck of the ship can be coupled, using suitable connectors, to a maritime or harbor terminal to transfer an LNG cargo from or to the tank 71.

Figure 5 depicts an example of a maritime terminal comprising a loading and unloading station 75, an underwater pipe 76 and an on-shore facility 77. The loading and unloading station 75 is a fixed off-shore facility comprising a mobile arm 74 and a tower 78 supporting the mobile arm 74. The mobile arm 74 carries a bundle of insulated flexible pipes 79 that can be connected to the loading/unloading pipes 73. The orientable mobile arm 74 adapts to suit all sizes of methane carrier. A connecting pipe, not depicted, extends up inside the tower 78. The loading and unloading station 75 allows a methane carrier 70 to be loaded and unloaded from or to the on-shore facility 77. This facility comprises liquefied gas storage tanks 80 and connecting pipes 81 connected by the underwater pipe 76 to the loading or unloading station 75. The underwater pipe 76 allows the liquefied gas to be transferred between the loading or unloading station 75 and the on-shore facility 77 over a great distance, for example 5 km, which allows the methane carrier ship 70 to stand off a long distance away from the shoreline during the loading and unloading operations.

In order to generate the pressure needed for transferring the liquefied gas, use is made of pumps carried onboard the ship 70 and/or pumps with which the on-shore facility 77 is equipped and/or pumps with which the loading and unloading station 75 is equipped.

Although the invention has been described in connection with a number of specific embodiments, it is quite obvious that it is not in any way restricted thereto and that it encompasses all technical equivalents of the means described and combinations thereof where these fall within the scope of the invention.

The use of verbs such as “comprise”, “have” and “include” and the conjugated forms thereof does not exclude there being other elements or other steps than those listed in a claim.

5 In the claims, any reference sign between parentheses must not be interrupted as a limitation on the claim.

CLAIMS

1. A method for welding a membrane of a sealed and thermally insulating tank,
in which method a sealed and thermally insulating tank comprises at least one metal
5 sealing membrane and a thermally insulating body comprising at least one thermally
insulating barrier (5) adjacent to said membrane, in which method:

- at least two metal strakes (1, 2) of the sealing membrane, which are borne by
a support surface (10) of the thermally insulating barrier (5), take the form of a profiled
component comprising a planar median portion (6, 7) resting on the support surface (10)
10 and two turned-up lateral edges (8, 9) projecting from the support surface (10), and

- at least two metal welding supports (3, 4), borne by the thermally insulating
barrier (5), project from the support surface (10) between the two adjacent turned-up
lateral edges (8, 9) of the two adjacent strakes (1, 2),

characterized in that a conducting strip (30) is inserted between the two
15 aforesaid metal welding supports (3, 4) and in that, thereafter, electrode-wheel resistance-
seam welding is used to weld together in pairs, in a fluidtight manner, each of the two
turned-up lateral edges (8, 9) of the two adjacent metal strakes (1, 2) and a respective one
of said metal welding supports (3, 4) which are interposed between said adjacent turned-
up edges (8, 9).

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2. The method as claimed in claim 1, wherein at least one of the welding
supports (3 or 4), and preferably both (3, 4), consists of an anchoring flange so as to
anchor the sealing membrane to the thermally insulating barrier (5) of the thermally
insulating body.

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3. The method as claimed in claim 2, wherein the anchoring flange (3, 4) takes
the form of an L and comprises a longitudinal portion (22) and a lower portion (21)
engaging with the thermally insulating barrier (5).

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4. The method as claimed in claim 3, wherein the lower portion (21) of the
anchoring flange (3, 4) extends, parallel to the median portion (6, 7) of the metal strakes
(1, 2), in a cavity (13, 14) of the thermally insulating barrier (5) of the thermally insulating
body.

5 5. The method as claimed in any one of the preceding claims, wherein, prior to each of said turned-up edges (8, 9) being welded to one of said welding supports (3, 4), said welding supports (3, 4) have been fixed to one another in a fluidtight manner using welding.

10 6. The method as claimed in any one of the preceding claims, wherein the electrode-wheel resistance-seam welding of each of said adjacent turned-up edges (8, 9) to the respective one of said welding supports (3, 4) is performed at a speed of between 1.5 meters per minute (m/min) and 2.5 m/min, preferably at a speed of 1.8 m/min.

15 7. The method as claimed in any one of the preceding claims, wherein the aforesaid turned-up edges (8, 9), and preferably also the welding supports (3, 4), are made of Invar or of a steel containing at least 20% manganese, preferably at least 25% manganese.

20 8. The method as claimed in claim 7, wherein the thickness of the turned-up edges (8, 9), and preferably also the thickness of the aforesaid welding supports, is between 0.5 and 0.8 millimeters (mm) and preferably equal to 0.7 mm.

25 9. The method as claimed in claim 8, wherein, during the electrode-wheel resistance-seam welding, the current strength is comprised between 1.8 and 3.2 kiloamperes, preferably comprised between 2.2 and 2.8 kiloamperes, and the pressure force exerted by each electrode wheel (31, 32) against a respective turned-up edge (8, 9) is comprised between 1.2 and 2.8 bar, preferably between 2 and 2.5 bar.

30 10. The method as claimed in claim 7, wherein the thickness of the turned-up edges (8, 9), and preferably also the thickness of the aforesaid welding supports (3, 4), is comprised between 0.9 and 1.2 millimeters (mm), and preferably equal to 1 mm.

11. The method as claimed in claim 10, wherein, during the electrode-wheel resistance-seam welding, the current strength is comprised between 2.7 and 3.8 kiloamperes, preferably comprised between 3 and 3.5 kiloamperes, and the pressure force

exerted by each electrode wheel (31, 32) against a respective turned-up edge (8, 9) is comprised between 3.5 and 5 bar, preferably between 4 and 4.5 bar.

12. The method as claimed in any one of the preceding claims, wherein, during
5 the electrode-wheel resistance-seam welding, the electrode-wheel resistance-seam welding electric current does not flow continuously; as a preference, said electric current flows for a range of time corresponding to 60% to 80% of the time at a constant frequency.

13. The method as claimed in any one of the preceding claims, wherein the
10 conducting strip (30) is made of a material or of an alloy of materials with a high melting point, higher than the melting point of the turned-up edges (8, 9) and of the welding supports (3, 4).

14. A system for welding a membrane of a sealed and thermally insulating tank,
15 the system comprising an electrode-wheel resistance-seam welding device comprising two electrode wheels (31, 32), a means for holding said electrode wheels (31, 32) against a surface that is to be welded, and a sealed and thermally insulating tank wall comprising:

- two adjacent metal strakes (1, 2) of the sealing membrane, which are borne
by a support surface (10) of the thermally insulating barrier (5) of the sealed and thermally
20 insulating tank, taking the form of a profiled component comprising a planar median portion (6, 7) resting on the support surface (10) and two turned-up lateral edges (8, 9) projecting from the support surface (10), and

- two metal welding supports (3, 4), borne by the thermally insulating barrier
(5), projecting from the support surface (10) between the two adjacent turned-up lateral
25 edges (8, 9) of the two adjacent strakes (1, 2),

the electrode-wheel resistance-seam welding device making at least one weld
between a respective one of said turned-up edges (8, 9) and one of said welding supports
(3, 4),

characterized in that the welding device comprises a conducting strip (30)
30 intended to be inserted between the two welding supports (3, 4) so as to weld each of the two aforesaid adjacent turned-up lateral edges (8, 9) to a respective one of said welding supports (3, 4) which are interposed between said adjacent turned-up edges (8, 9).

15. A sealed and thermally insulating tank integrated in a bearing structure, comprising a sealed and thermally insulating tank comprising at least one metal sealing membrane made up of a plurality of metal strakes (1, 2) and a thermally insulating body comprising at least one thermally insulating barrier (5) adjacent to said membrane, in
5 which tank:

- at least two metal strakes (1, 2) of the sealing membrane, which are borne by a support surface (10) of the thermally insulating barrier (5), take the form of a profiled component comprising a planar median portion (6, 7) resting on the support surface (10) and two turned-up lateral edges (8, 9) projecting from the support surface (10), and
- 10 - at least two metal welding supports (3, 4), borne by the thermally insulating barrier (5), project from the support surface (10) between the two adjacent turned-up lateral edges (8, 9) of the two adjacent strakes (1, 2),

characterized in that a welding method as claimed in any one of claims 1 to 13 is used to weld together in pairs, in a fluidtight manner, each of the two adjacent turned-up lateral edges (8, 9) of the two adjacent metal strakes (1, 2) and a respective one of said
15 welding supports (3, 4) which are interposed between said adjacent turned-up edges (8, 9).

16. A ship (70) for transporting a cold liquid product, the ship comprising a
20 double hull (72) and a sealed and thermally insulating tank (71), as claimed in claim 15, placed in the double hull.

17. A transfer system for a fluid, the system comprising a ship (70) as claimed in claim 16, insulated pipes designed to connect the tank (71) installed in the hull of the ship to a floating or on-shore storage facility and a pump for driving a flow of fluid
25 through the insulated pipes from or to the floating or on-shore storage facility to or from the tank of the ship.

18. A method for loading or unloading a ship (70) as claimed in claim 17, wherein a fluid is conveyed through insulated pipes from or to a floating or on-shore storage facility to or from the tank of the ship (71).