

SEALED AND THERMALLY INSULATING TANK COMPRISING METAL STRIPS

The invention relates to the field of the manufacture of sealed and thermally insulating tanks and the constituent parts thereof. In particular, the present invention relates to tanks intended for storing or transporting cold or hot liquids, for example tanks for the storage and/or transport of liquefied gas by sea.

Sealed and thermally insulating tanks may be used in various industries to store hot or cold products. For example, in the field of energy, liquefied natural gas (LNG) is a liquid that can be stored at atmospheric pressure at approximately -163°C in on-shore storage tanks or in tanks carried on board floating structures.

A storage tank built into the hull of a ship is known, for example, from FR-A-2968284, where the sealed barrier, notably a primary sealed barrier in contact with the product contained in the tank, is made up of metal strakes which are joined together, in a sealed manner, by turned-up edges defining deformable gussets on each side of a welding flange. These strakes are connected at their ends to a connecting ring by filling sheets welded both to the connecting ring and to the strakes.

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According to one embodiment, the invention provides a sealed and thermally insulating tank incorporated into a bearing structure, the bearing structure comprising a plurality of bearing walls, the tank comprising

25 a plurality of tank walls each fixed to a respective bearing wall, a tank wall comprising:

a thermal insulation barrier held on the bearing wall, the thermal insulation barrier having a planar support surface parallel to the respective bearing wall,

30 a sealing barrier supported by the insulation barrier and comprising a repeating structure alternately made up of an elongate metal strake and an elongate welding flange connected to the support surface and projecting

with respect to the latter, the welding flange running parallel to the metal strake over at least part of the length of the metal strake, the metal strake comprising in the widthwise direction a planar central portion placed on the support surface and lateral edges that are turned up with respect to the support surface and arranged against the adjacent welding flanges and welded in a sealed manner to the welding flanges,

in which the metal strake extends between two opposite edges of the tank wall and has two end portions which are each assembled in a sealed manner to a respective stopping structure at said opposite edges of the tank wall,

characterized in that the metal strake is made up of at least one continuous metal strip having several longitudinal portions of different thicknesses, the longitudinal portions comprising an intermediate portion and at least one end portion of which the thickness is greater than the thickness of the intermediate portion of the strip, the thicker end portion forming an assembly zone for assembling the strip with the stopping structure or with another continuous metal strip butt-joined to the first continuous metal strip to constitute the metal strake.

According to some embodiments, such a tank may comprise one or several of the following features.

According to one embodiment, the metal strake is made up of a single metal strip extending in one piece between the two opposite edges of the tank wall, and in which the two end portions of the strip are thicker than the intermediate portion and are each assembled with the respective stopping structure at the opposite edges of the tank wall.

According to one embodiment, the metal strake comprises a second continuous metal strip butt-joined to the first continuous metal strip in the continuation of the first continuous metal strip, in which each of the two continuous metal strips has, at the region of connection of the two metal strips, an end portion that is thicker than the intermediate portion of the strip.

According to one embodiment, at least one of the two continuous metal strips has, at the opposite end to the region of connection of the two

metal strips, a second end portion which is thicker than the intermediate portion of the strip, the second end portion being connected to the stopping structure at an edge of the tank wall.

5 According to one embodiment, at least one of the two continuous metal strips has, at the opposite end to the region of connection of the two metal strips, a second end portion of the same thickness as the intermediate portion of the strip, the second end portion being connected to the stopping structure at an edge of the tank wall.

10 According to some embodiments, each end portion of the strake is welded in a sealed manner to the respective stopping structure.

According to some embodiments, the strake is welded to the stopping structure by a CMT (which stands for Cold Metal Transfer) or TIG (which stands for Tungsten Inert Gas) process, or by cold welding.

15 According to some embodiments, the stopping structure comprises a plate positioned over the insulating barrier and the end portion comprises a first segment bearing against the plate of the stopping structure and a second segment bearing against the thermal insulating barrier, the first segment and the second segment being connected by a folded segment forming a discontinuity in the thickness direction of the metal strake.

20 According to some embodiments, the welding flanges are interrupted before the end of the metal strake, the turned-up edges of two adjacent metal strakes being welded to one another by an edge weld positioned along part of their length as far as the end of the metal strake.

25 According to some embodiments, the edge weld of the turned-up edges is performed using a cold metal transfer process, or a TIG process with filler wire.

According to some embodiments, the end portion has a thickness greater than or equal to 0.9 mm.

30 According to some embodiments, the intermediate portion has a thickness less than 0.9 mm and preferably a thickness of 0.7 mm.

According to some embodiments, the stopping structure is welded to a bearing wall.

According to some embodiments, the metal strake and the stopping structure are made of a nickel-steel alloy with a low coefficient of expansion, notably known by the name of Invar®.

According to one embodiment, the metal strake is made of an alloy
5 based on iron and comprises by weight:

$$34.5\% \leq \text{Ni} \leq 53.5\%$$

$$0.15\% \leq \text{Mn} \leq 1.5\%$$

$$0 \leq \text{Si} \leq 0.35\%, \text{ preferably } 0.1\% \leq \text{Si} \leq 0.35\%$$

$$0 \leq \text{C} \leq 0.07\%$$

10 optionally:

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$$0.01\% \leq \text{Cr} \leq 0.5\%$$

the rest being iron and unavoidable impurities resulting from the production
15 process.

According to some embodiments, the tank wall further comprises:
a secondary thermal insulation barrier produced in a similar way to the
primary insulation barrier,
a secondary sealing barrier supported by the secondary insulation barrier
20 and bearing the primary insulation barrier,
the secondary sealing barrier being produced in a similar way to the primary
sealing barrier.

According to some embodiments, the thickness varies progressively
over a distance of 500 mm. According to some embodiments, the end
25 portion extends over 400 mm.

Such a tank may form part of an on-shore storage facility, for
example for storing LNG or may be installed in a floating, on-shore or off-
shore structure, notably a methane tanker, a floating storage and
30 regasification unit (FSRU), a floating production storage and off loading unit
(FPSO) and the like.

According to one embodiment, a ship for transporting a cold liquid product comprises a double hull and an aforementioned tank placed inside the double hull.

5 According to one embodiment, the invention also provides a method for loading or unloading such a ship, in which method a cold liquid product is conveyed through insulated pipes from or to a floating or on-shore storage facility to or from the hull of the ship.

10 According to one embodiment, the invention also provides a transfer system for a cold liquid product, the system comprising the aforementioned ship, insulated pipes arranged in such a way as 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 stream of cold liquid product through the insulated pipes from or to the floating or on-shore storage facility to or from the tank of the ship.

15 According to one embodiment, the invention also provides a continuous metal strip with turned-up lateral edges suited to the creation of an aforementioned tank, the metal strip being obtained from a blank having, along its length, a reinforced first end zone having a first thickness and a central second zone having a second thickness smaller than the first
20 thickness and a third end zone having the first thickness or the second thickness, the metal strip having, across its width, a planar central zone and two lateral edges bent up substantially perpendicular to the planar central zone, the two lateral edges having a width that is small in comparison with the planar central zone.

25 For preference, the metal strip is made of an alloy based on iron and comprising by weight:

$$34.5\% \leq \text{Ni} \leq 53.5\%$$

$$0.15\% \leq \text{Mn} \leq 1.5\%$$

$$0 \leq \text{Si} \leq 0.35\%, \text{ preferably } 0.1\% \leq \text{Si} \leq 0.35\%$$

30 $0 \leq \text{C} \leq 0.07\%$

optionally:

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$$0.01\% \leq \text{Cr} \leq 0.5\%$$

the rest being iron and unavoidable impurities resulting from the production process.

5 According to one embodiment, the reinforced first zone has a first mean grain size and the second zone has a second mean grain size, the difference, in terms of absolute value, between the first grain size and the second grain size being less than or equal to 0.5 of a grain size number in accordance with standard ASTM E112-10.

10 According to one embodiment, the iron-based alloy comprises, by weight:

$$34.5 \leq \text{Ni} \leq 42.5\%$$

$$0.15\% \leq \text{Mn} \leq 0.5\%$$

$$0.1\% \leq \text{Si} \leq 0.35\%$$

15 $0.010\% \leq \text{C} \leq 0.050\%$

optionally:

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$$0.01\% \leq \text{Cr} \leq 0.5\%$$

20 the rest being iron and unavoidable impurities resulting from the production process.

25 The invention sets out from the observation that the quantity of material needed to manufacture a bearing structure comprising a sealed and thermally insulating tank is dependent on the fatigue strength of the tank. In particular, the fatigue strength of the tank is dependent on the fatigue strength of the welds present on the sealed barriers that form the tank.

30 Thus, the idea on which the invention is based is to propose a sealed and thermally insulating tank which comprises a sealed barrier that has good fatigue strength while at the same time limiting the amount of material needed for creating such a sealed barrier. According to one aspect of the

invention, the sealed barrier is created using strakes extending in one piece between two stopping structures, and the strakes have a thickness that can vary so that they can be connected directly to the stopping structures at their ends while at the same time having a smaller thickness between these
5 ends. According to another aspect of the invention, the sealed barrier is created using strakes made up of several strips butt-welded together at the reinforced portions of these strips, so that the strength of this welded assembly is high.

Certain aspects of the invention start out from the idea of
10 connecting the strakes to the stopping structures using a weld that has good fatigue strength.

The invention will be better understood and further objects, details, features and advantages thereof will become more clearly apparent, during
15 the course of the following description of a number of particular embodiments of the invention, given solely by way of nonlimiting illustration, with reference to the attached drawings.

In these drawings:

- 20 • Figure 1 is a cutaway partial perspective view of a wall of a sealed and thermally insulated tank wall in which embodiments of the invention may be employed.
- Figure 2 is a perspective partial view of region II of figure 1, depicting the primary sealed membrane.
- 25 • Figure 3 is a view in cross section along the line III-III of a detail of a sealed membrane of the tank wall of figure 1.
- Figure 4 is a schematic depiction with cutaway of a methane tanker tank and of a terminal for loading/unloading this tank.
- Figure 5 is schematic view in longitudinal section of an initial strip.
- 30 • Figure 6 is a schematic view in longitudinal section of an intermediate strip.

- Figure 7 is a schematic view in longitudinal section of a strip of variable thickness.
- Figure 8 is a schematic depiction of a blank obtained from the strip of variable thickness.
- 5 • Figure 9 is a schematic depiction in longitudinal section of a first assembly of a blank with a second component.
- Figure 10 is a schematic depiction in longitudinal section of two blanks butt-joined together.
- 10 • Figure 11 is a schematic view from above depicting a number of embodiments of a strake with turned-up lateral edges suitable for creating a sealed membrane.

Figure 1 depicts sealed and insulating walls of a tank incorporated into a bearing structure of a ship.

15 The bearing structure of the tank here consists of the internal hull of a double-hulled ship, the bottom wall of which has been identified by the numeral 1, and by transverse partitions 2, which define compartments in the internal hull of the ship. The walls of the bearing structure are adjacent in pairs at the edge.

20 On each wall of the bearing structure, a corresponding wall of the tank is created by successively superposing a secondary insulating layer 3, a secondary sealed barrier 4, a primary insulating layer 5 and a primary sealed barrier 6. At the corner between the two walls 1 and 2, the secondary sealed barriers 4 of the two walls 1 and 2 and the primary sealed barriers 6 of the

25 two walls are connected by a connecting ring 10 in the form of a square tube. The connecting ring 10 forms a structure capable of absorbing the tensile loads resulting from thermal contraction, notably of the metal elements that make up the sealed barriers, the deformation of the hull caused by the sea and by movements of the cargo. One possible structure

30 for the connecting ring 10 is described in greater detail in FR-A-2549575.

The primary insulating layer and the secondary insulating layer are made up of insulating elements and more particularly of parallelepipedal

insulating caissons 20 and 21 which are juxtaposed in a regular pattern. Each insulating caisson 20 and 21 comprises a bottom panel and a lid panel 23. Lateral panels 24 and internal webs 25 extend between the bottom panel and the lid panel 23. The panels delimit a space within which an insulated lining which may for example be made of expanded perlite, is placed. Each
 5 caisson 20 and 21 is held on the bearing structure via anchoring members 26. The caissons 20 and 21 of the primary insulating layer 5 and of the secondary insulating layer 3 respectively bear the primary sealed barrier 6 and the secondary sealed barrier 4.

10 The secondary 4 and primary 6 sealed barriers are each made up of a series of parallel Invar® strakes 8 with turned-up edges, which are arranged in alternation with elongate welding supports 9, likewise made of Invar®. The strakes 8 extend from a first square tube at a first transverse partition 2 as far as a second square tube of a second transverse partition, not depicted,
 15 situated on an opposite side of the tank. The turned-up edges 13 of the strakes are welded to the welding supports 9 in a sealed manner. The welding supports 9 are each held against the underlying insulating layer 3 or 5, for example by being housed in inverted T-shaped slots 7 formed in the lid panels 23 of the caissons 20 and 21.

20 This alternating structure is created over the entire surface of the walls, and this may entail very long lengths of strake 8. Over these long lengths, the sealed welds between the turned-up edges 13 of the strakes 8 and the welding supports 9 interposed between them may be produced in the form of straight welded seams 17, parallel to the wall.

25 The strakes with turned-up edges 8 are connected directly to the connecting ring 10. For that, the strakes with turned-up edges 8 have an end edge 11 welded continuously to the Invar® flanges 27, 28 of the connecting ring 10 in order to absorb tensile loading. The primary sealed barrier 5 and the secondary sealed barrier 3 are thus welded respectively to a primary
 30 flange 27 and to a secondary flange 28. Primary insulating caissons 20 are positioned between the primary flange 27 and the secondary flange 28. The primary flange 27 is fixed to the primary insulating caissons 20 by screws 30.

The secondary flange 28 is fixed in the same way to the secondary insulating elements.

The square tube is connected to the walls 1 and 2 by plates 31 which extend in the continuation of the sealed membranes 4 and 6 and the flanges 27, 28. These plates 31 are welded to flaps welded at right angles to the walls 1 and 2 of the bearing structure.

Figure 2 depicts in greater detail the connection zone at which two strakes 8 of the primary sealed barrier 6 are connected to the welding flange 27. It should be noted that the connection zone where the strakes 8 of the secondary sealed barrier 4 are connected to the welding flange 28 is created in the same way.

The turned-up edges 13 of the strake with turned-up edges 8 have a profile comprising an inclined portion 14 which rises progressively from the edge 11 toward the strakes 8, then a horizontal portion 15. The strakes 8 are butt-welded continuously and in a sealed manner at their upper edge along a first portion 29 using an automated CMT process.

The welding support 9 interposed between two strakes 8 finishes slightly before the flange 27. All along the central portion of the tank wall, and right up to the vicinity of the end edge zone 11, the sealed connection between the turned-up edges 13 of the strakes 8 and the welding supports 9 is realized by straight welded seams 17, which extend more or less mid-way up the turned-up edges 13 on each side of the welding support 9 and parallel to the support surface. The welded seams 17 are created by a welding machine having an electrode wheel.

The straight welded seam 17 extends up to the vicinity of the first portion 29, the welded seam then curves upward to meet the edge weld performed along the edges of the first portion 29.

Figure 3 illustrates in greater detail the arrangement of the tank wall in the region of the weld between the flange 27 of the connecting ring 10 and the strake with turned up edges 8 shown in figure 2.

The flange 27 is fixed to the insulating elements 20 by screws 30 passing through the flange 27 and screwed into the upper panels 23 of the insulating elements 20. Screw-fastening notably allows the flange 27 to be stabilized.

5 The strake 8 extends in a single piece between its two end edges 11. Between these two end edges the strake 8 is, over a first part of its length, bearing against the flanges 27 and, over a second part of its length, bearing against the primary insulating layer 5.

10 The strake 8 has a bent segment 34 to allow the strake 8 to bear both against the flange 27 and against the primary insulating layer 5, over the most-part of its lower surface. The bent section extends up to the vicinity of the edge of the flange 27 parallel to the flange 27 and makes it possible to compensate for the thickness thereof.

15 The strake 8 also has a thickness that can vary along its length. Thus, the strake 8 at its end edges 11 has a thick portion 33 fixed to the flanges 27. A thin portion 35 extends between the thick portions 33 and has a constant thickness. The thin portion 35 is connected to the thick portions 33 by transition portions 36 in which the thickness decreases progressively from each thick portion 33 to the thin portion 35.

20 More specifically, according to one embodiment the thick portion 33 has a thickness of 0.9 mm and extends over a length of 400 mm and comprises the bent segment 34. The transition portion 36 then extends over a distance of 500 mm and has a thickness that decreases from 0.9 mm down to 0.7 mm. Thus, most of the tank wall is covered by the thin portion 35 of the
25 strake 8 which has a thickness of 0.7 mm.

 The thick portion 33 is connected to the flange 27 by a welded seam 37 created between the edge 11 of the strake 8 and the upper surface of the flange 27, the flange 27 having a thickness of 1.5 mm. Thus, the welded seam that connects the strake 8 and the flange 27, namely the welding of a
30 strip 0.9 mm thick to a strip 1.5 mm thick exhibits good fatigue strength.

 The use of such a variable-thickness strake 8 makes it possible to avoid or limit the use, along the length of the strake 8, of a collection of

metal sheets of different thicknesses, joined together by welded seams which would exhibit insufficient fatigue strength. Specifically, a weld created between a 0.9 mm sheet and a 0.7 mm sheet does not have as good a fatigue strength as a weld created between a 0.9 mm sheet and a 1.5 mm sheet. Now, the lower the fatigue strength of the sealed barrier, the greater the constraints placed on the hull of the ship into which the tank is incorporated, entailing significant stiffening of the hull. This stiffening of the hull notably results in a large quantity of steel being needed to produce the hull.

10 The use of a strake 8 the thickness of which varies along its length makes it possible to create a sealed membrane 6 offering good fatigue strength while at the same time avoiding the use of strakes that are thick along their entire length.

15 Because the fatigue strength is greater, the constraints on the hull are less demanding and notably allow a saving on the steel used to create the hull. Such a tank as described hereinabove may notably be incorporated into a ship suited to a dynamic hull criterion of 95 MPa and a static hull criterion of 145 MPa.

20 The use of a strake 8 produced as a single piece along the entire length of the wall also makes it possible to reduce the welding time needed to create the primary sealed barrier 6 and reduce the time taken to inspect the welds in the hull.

The sealed secondary barrier 4 has a configuration similar to the configuration of the primary sealed barrier 6.

25 The variable-thickness strake 8 can be obtained by a method that will be described hereinbelow. One example of a method for manufacturing a strip of a thickness that can vary along its length from an alloy based mainly on iron and on nickel will be described first of all.

30 In a first step of this method, an initial strip 101, obtained by hot-rolling, is supplied.

The initial strip 101 is a strip of alloy of cryogenic Invar type. This alloy comprises by weight:

$$34.5\% \leq \text{Ni} \leq 53.5\%$$

$$0.15\% \leq \text{Mn} \leq 1.5\%$$

$$0 \leq \text{Si} \leq 0.35\%, \text{ preferably } 0.1\% \leq \text{Si} \leq 0.35\%$$

$$0 \leq \text{C} \leq 0.07\%$$

5 optionally:

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$$0.01\% \leq \text{Cr} \leq 0.5\%$$

10 the rest being iron and unavoidable impurities resulting from the manufacturing process.

The silicon has the notable function of allowing deoxidation and of improving the corrosion resistance of the alloy.

An alloy of cryogenic Invar type is an alloy that has three main properties:

15 - It is stable with respect to martensitic transformation down to the liquefaction temperature T_L of a cryogenic fluid. This cryogenic fluid is, for example, butane, propane, methane, liquid oxygen or nitrogen. The contents in gammagenic elements, nickel (Ni), manganese (Mn) and carbon (C), of the alloy are adjusted so that the temperature of the start of
20 martensitic transformation is strictly below the liquefaction temperature T_L of the cryogenic fluid.

- It has a low mean thermal expansion coefficient between the ambient temperature and the liquefaction temperature T_L of the cryogenic fluid.

25 - It has no "ductile-brittle" resilience transition.

The alloy used preferably has:

- a mean thermal expansion coefficient of between 20°C and 100°C less than or equal to $10.5 \times 10^{-6} \text{ K}^{-1}$, particularly less than or equal to $2.5 \times 10^{-6} \text{ K}^{-1}$;

30 - a mean thermal expansion coefficient between -180°C and 0°C less than or equal to $10 \times 10^{-6} \text{ K}^{-1}$, particularly less than or equal to $2 \times 10^{-6} \text{ K}^{-1}$; and

- a resilience greater than or equal to 100 joule/cm², particularly greater than or equal to 150 joule/cm², at a temperature greater than or equal to -196°C.

For preference, the alloy used has the following composition, in % by weight:

$$34.5 \leq \text{Ni} \leq 42.5\%$$

$$0.15\% \leq \text{Mn} \leq 0.5\%$$

$$0 \leq \text{Si} \leq 0.35\%, \text{ preferably } 0.1\% \leq \text{Si} \leq 0.35\%$$

$$0.010\% \leq \text{C} \leq 0.050\%$$

optionally:

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$$0.01\% \leq \text{Cr} \leq 0.5\%$$

the rest being iron and unavoidable impurities resulting from the production process.

In this case, the alloy used preferably has:

- a mean thermal expansion coefficient between 20°C and 100°C less than or equal to $5.5 \times 10^{-6} \text{ K}^{-1}$;

- a mean thermal expansion coefficient between -180°C and 0°C less than or equal to $5 \times 10^{-6} \text{ K}^{-1}$; and

- a resilience greater than or equal to 100 joule/cm², particularly greater than or equal to 150 joule/cm², at a temperature greater than or equal to -196°C.

More particularly still,

$$35\% \leq \text{Ni} \leq 36.5\%$$

$$0.2\% \leq \text{Mn} \leq 0.4\%$$

$$0.02 \leq \text{C} \leq 0.04\%$$

$$0.15 \leq \text{Si} \leq 0.25\%$$

optionally

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$$0.01\% \leq \text{Cr} \leq 0.5\%$$

the rest being iron and unavoidable impurities resulting from the production process.

In this case, the alloy preferably has:

- a mean thermal expansion coefficient between 20°C and 100°C less than or equal to $1.5 \times 10^{-6} \text{ K}^{-1}$;
- a mean thermal expansion coefficient between -180°C and 0°C less than or equal to $2 \times 10^{-6} \text{ K}^{-1}$;
- a resilience greater than or equal to 200 joule/cm² at a temperature greater than or equal to -196°C.

Such an alloy is an alloy of cryogenic Invar® type. The trade name for this alloy is Invar®-M93.

In the conventional way, the alloys used are produced in an electric arc furnace or in a vacuum induction furnace.

After refining operations in a ladle making it possible to regulate the contents of residual alloying elements, the alloys are cast as semi-finished products, which are hot converted, particularly by hot rolling, to obtain strips.

These semi-finished products are, for example, ingots. As an alternative, they are continuously cast slabs produced by a continuous slab casting facility.

The strip thus obtained is stripped and polished in a continuous process in order to limit its defects: scale, oxide penetration, scabs and nonuniformity of thickness in the lengthwise and widthwise direction of the strip.

The polishing is notably performed using grinding wheels or abrasive papers. One function of the polishing is to remove the residues of the scouring.

The outcome of this polishing step is the initial strip 1 supplied in the first step of the method.

As an option, before the step of uniform cold rolling, the strip is annealed to homogenize its microstructure. This annealing to homogenize the microstructure is notably performed on the fly in a heat treatment furnace referred to in the remainder of the description as the microstructure

homogenization annealing furnace, with a residence time in the microstructure homogenization annealing furnace of between 2 minutes and 25 minutes and a strip temperature during the microstructure homogenization annealing process of between 850°C and 1200°C.

5 The initial strip 101 has a constant thickness E_0 of between 1.9 mm and 18 mm (see figure 5).

The initial strip 101 is then rolled during a uniform cold rolling step. The uniform rolling is performed along the length of the initial strip 101.

10 Uniform rolling means a rolling operation that converts a strip of constant thickness into a thinner strip of likewise constant thickness.

More specifically, the uniform rolling step comprises one or more passes through a rolling mill in which the strip passes through a nip delimited between working rolls. The thickness of this rolling nip remains constant throughout each pass in the uniform rolling step.

15 This uniform rolling step culminates in an intermediate strip 103 of thickness E_c that is constant in the direction of rolling, namely in the lengthwise direction of the intermediate strip 103 (see figure 6).

As an option, the uniform rolling step comprises at least one intermediate recrystallization annealing process.

20 When present, the intermediate recrystallization annealing is performed between two successive uniform rolling passes. As an alternative or as an option, it is performed before the step of flexible rolling at the end of the uniform rolling step, namely after all of the rolling passes performed during the uniform-rolling step.

25 For example, the intermediate recrystallization annealing is performed on the fly in an intermediate annealing furnace with a strip temperature during intermediate annealing of between 850°C and 1200°C and a residence time in the intermediate annealing furnace of between 30 seconds and 5 minutes.

30 The intermediate recrystallization annealing, or if several such operations are performed, the last intermediate recrystallization annealing of the uniform rolling step, is performed when the strip has a thickness E_i of

between the thickness E_0 of the initial strip 101 and the thickness E_c of the intermediate strip 103.

When the intermediate recrystallization annealing is performed at the end of the uniform rolling step, the thickness E_i of the strip during the
5 intermediate recrystallization annealing is equal to the thickness E_c of the intermediate strip 103 at the start of the flexible rolling step.

Advantageously, in the embodiment in which at least one intermediate recrystallization annealing operation is performed, a single intermediate recrystallization annealing operation is performed. In particular,
10 this single intermediate recrystallization annealing operation is performed between two successive uniform rolling passes when the strip has a thickness E_i strictly greater than the thickness E_c of the intermediate strip 103.

As a preference, the uniform rolling step comprises no intermediate annealing.

15 The intermediate strip 103 of thickness E_c is obtained at the end of the uniform rolling step and is then subjected to a flexible cold rolling step.

The flexible rolling is performed in a direction of rolling extending along the length of the intermediate strip 103.

The flexible rolling makes it possible to obtain a strip the thickness of
20 which can vary along its length.

For that, the thickness of the rolling nip of the rolling mill used is made to vary continuously. This variation is a function of the desired thickness for the zone of the strip being rolled so as to obtain a strip the thickness of which can vary along its length.

25 More particularly, and as illustrated in figure 7, the flexible rolling step results in a strip 104 of variable thickness comprising first zones 107 of a first thickness $e+s$ and second zones 110 having a second thickness e , less than the first thickness $e+s$. The first thickness $e+s$ and the second thickness e each correspond to a given rolling mill nip thickness.

30 The first zones 107 and the second zones 110 each have a substantially constant thickness, these being $e+s$ and e , respectively.

They are connected to each other by connecting zones 111 of non-constant thickness along the length of the variable-thickness strip 104. The thickness of the connecting zones 111 varies between e and $e+s$. According to one example, it varies linearly between e and $e+s$.

5 The uniform rolling step and the flexible rolling step generate within the first zones 107, which means to say within the thickest zones of the strip 104, a degree τ_1 of plastic deformation, after a potential recrystallization intermediate annealing, greater than or equal to 30%, more particularly comprised between 30% and 98%, more particularly still comprised between
10 30% and 80%. In the aforementioned ranges, the degree τ_1 of plastic deformation is advantageously greater than or equal to 35%, more particularly greater than or equal to 40%, and more particularly still, greater than or equal to 50%.

 The degree τ_1 of plastic deformation generated in the first zones 107
15 is defined as follows:

- If no recrystallization intermediate annealing is performed during the uniform rolling step, the degree τ_1 of plastic deformation is the total degree of reduction brought about in the first zones 107 of the strip 104 by the uniform rolling step and the flexible rolling step, namely the result of the
20 reduction in thickness from the initial thickness E_0 down to the thickness $e+s$.

In this case, the degree τ_1 of plastic deformation, as a percentage, is given by the following formula: $\tau_1 = \frac{E_0 - (e + s)}{E_0} \times 100$ (1).

Thus, in instances in which no recrystallization intermediate annealing is performed, the degree τ_1 of plastic deformation is equal to the total
25 degree of reduction brought about in the first zones 107 by the uniform rolling step and the flexible rolling step.

- If at least one recrystallization intermediate annealing is performed during the uniform rolling step, the degree τ_1 of plastic deformation is the degree of reduction brought about in the first zones 107 as a result of the
30 reduction in thickness of the strip from the thickness E_i that it has during the

last recrystallization intermediate annealing performed during the uniform rolling step down to the thickness $e+s$.

In this case, the degree τ_1 of plastic deformation, as a percentage, is given by the following formula: $\tau_1 = \frac{E_i - (e + s)}{E_i} \times 100$ (2).

5 Thus, when one or more intermediate annealings are performed during the uniform rolling step, the degree τ_1 of plastic deformation is strictly lower than the total degree of reduction brought about in the first zones 107 by the uniform rolling step and the flexible cold rolling step.

10 The degree τ_2 of plastic deformation, after any recrystallization intermediate annealing that might be performed, brought about in the second zones 110, is strictly higher than the degree τ_1 of plastic deformation in the first zones 107. It is calculated in a similar way, by replacing $e+s$ with e in formulae (1) and (2) above.

15 The difference $\Delta\tau$ in degree of plastic deformation between the second zones 110 and the first zones 107 is given by the relationship $\Delta\tau = \tau_2 - \tau_1$.

This difference $\Delta\tau$ is advantageously less than or equal to 13% if the thickness E_0 is strictly greater than 2 mm. It is advantageously less than or equal to 10% if the thickness E_0 is less than or equal to 2 mm.

20 More specifically, the difference $\Delta\tau$ is less than or equal to 10% if E_0 is strictly greater than 2 mm, and the difference $\Delta\tau$ is less than or equal to 8% if E_0 is less than or equal to 2 mm.

25 Advantageously, the thickness E_c of the intermediate strip 103 prior to the flexible rolling step is, in particular, equal to the thickness e of the second zones 110 multiplied by a reduction coefficient k of between 1.05 and 1.5. Advantageously, k is approximately equal to 1.3.

Advantageously, the thicknesses $e+s$ and e of the first and second zones 107, 110 satisfy the equation:

$$e + s = (n + 1).e$$

30 where n is a constant coefficient comprised between 0.05 and 0.5.

In other words, the first thickness $e+s$ is equal to the second thickness e multiplied by a multiplicative coefficient of between 1.05 and 1.5.

This equation can be rewritten as follows: $s = n.e$, which means to say that the additional thickness s of the first zones 107 with respect to the second zones 110 is equal to the coefficient n multiplied by the thickness e of the second zones 110.

The thickness e of the second zones 110 is comprised between 0.05 mm and 10 mm, more particularly between 0.15 mm and 10 mm, more particularly still between 0.25 mm and 8.5 mm. When tapes are being created, the thickness e is less than or equal to 2 mm, advantageously comprised between 0.25 mm and 2 mm. When sheet is being produced, the thickness e is strictly greater than 2 mm, particularly comprised between 2.1 mm and 10 mm, more particularly comprised between 2.1 mm and 8.5 mm.

The variable-thickness strip 104 resulting from the flexible rolling step is next subjected to a final recrystallization annealing.

The final recrystallization annealing is performed on the fly in a final annealing furnace. The temperature of the final annealing furnace is constant for the duration of the final recrystallization annealing. The temperature of the strip 104 during the final recrystallization annealing is comprised between 850°C and 1200°C.

The residence time in the final annealing furnace is comprised between 20 seconds and 5 minutes, more particularly between 30 seconds and 3 minutes.

The speed at which the strip 104 travels through the final annealing furnace is constant. It is, for example, comprised between 2 m/min and 20 m/min for a final annealing furnace with a heating length of 10 m.

Advantageously, the temperature of the strip 104 during final annealing is 1025°C. In that case, the residence time in the final annealing furnace is for example comprised between 30 seconds and 60 seconds for a variable-thickness strip 104 having second zones 110 of thickness e less than or equal to 2 mm. The residence time in the final annealing furnace is, for example, comprised between 3 minutes and 5 minutes for a variable-

thickness strip 104 having second zones 110 of thickness e strictly greater than 2 mm.

The residence time in the final annealing furnace and the final annealing temperature are chosen so as to obtain, after the final recrystallization annealing, a strip 104 having mechanical properties and grain sizes that are almost uniform between the first zones 107 and the second zones 110. The rest of the description specifies what is meant by "almost uniform".

For preference, the final annealing is performed under a reducing atmosphere, which means to say for example, under pure hydrogen or under an H_2-N_2 atmosphere. The freezing point is preferably below $-40^\circ C$. In the case of an H_2-N_2 atmosphere, the N_2 content may be comprised between 0% and 95%. The H_2-N_2 atmosphere comprises for example approximately 70% of H_2 and 30% of N_2 .

According to one embodiment, the variable-thickness strip 104 passes continuously from the flexible-rolling rolling mill to the final annealing furnace, which means to say that it passes without intermediate spooling of the variable-thickness strip 104.

As an alternative, at the end of the flexible-rolling step, the variable-thickness strip 104 is spooled so that it can be transported to the final annealing furnace, then it is unwound and subjected to the recrystallization final annealing.

According to this alternative form, the wound strip 104 has, for example, a length of between 100 m and 2500 m, notably if the thickness e of the second zones 110 of the strip 104 is approximately 0.7 mm.

The end of the recrystallization final annealing yields a strip 104 the thickness of which can vary along its length and that has the following characteristics.

It comprises first zones 107 of thickness $e+s$ and second zones of thickness e , possibly connected to one another by connecting zones 111 of a thickness that varies between e and $e+s$.

For preference, the difference, in terms of absolute value, between the mean grain size of the first zones 107 and the mean grain size of the second zones 110 is less than or equal to 0.5 of a grain number according to standard ASTM E112-10. The mean grain size in terms of ASTM number is
 5 determined using the method of comparing against standard images as described in standard ASTM E112-10. According to this method, in order to determine the mean grain size of a sample, an image, obtained using an optical microscope at a given magnification, of the grain structure of the sample that has undergone a contrast etch, is compared on screen against
 10 standard images that illustrate twinned grains of different sizes which have undergone a contrast etch (corresponding to sheet III of the standard). The mean grain size number for the sample is determined as being the number that corresponds to the magnification used transferred to the standard image that most closely resembles the image seen on the microscope
 15 screen.

If the image seen on the microscope screen is somewhere between two successive standard grain size images, the mean grain size number for the image viewed by the microscope is determined as being the arithmetic mean between the numbers corresponding to the magnifications used for
 20 each of the two standard images.

More specifically, the number $G1_{ASTM}$ for the mean grain size of the first zones 107 is at most 0.5 of a number lower than the number $G2_{ASTM}$ for the mean grain size of the second zones 110.

The variable-thickness strip 104 may have almost uniform mechanical
 25 properties.

In particular:

- the difference, in terms of absolute value, between the elastic limit at 0.2% of the first zones 107, denoted $Rp1$ and the elastic limit at 0.2% of the second zones 110, denoted $Rp2$ is less than or equal to 6MPa, and
 30
- the difference in terms of absolute value between the load at break of the first zones 107 denoted $Rm1$ and the load at break of the second zones 110 denoted $Rm2$ is less than or equal to 6MPa.

The elastic limit at 0.2% means, in the conventional way, the value of the stress at 0.2% plastic deformation.

In the conventional way, the load at break corresponds to the maximum stress of the test specimen prior to necking.

5 In the example illustrated, the variable-thickness strip 104 has a pattern repeating periodically over the entire length of the strip 104. This pattern comprises in succession a first-zone half 107 of length $\frac{L_1}{2}$, a connecting zone 111 of length L_3 , a second zone 110 of length L_2 , a connecting zone 111 of length L_3 , and a first-zone half 107 of length $\frac{L_1}{2}$.

10 Advantageously, the length L_2 of the second zone 110 is very markedly greater than the length L_1 of the first zone 107. By way of example, the length L_2 is between 20 and 100 times the length L_1 .

Each sequence formed of a first zone 107 flanked by two connecting zones 111 forms a region of additional thickness of the variable-thickness strip 104, namely a zone of thickness greater than e . Thus, the variable-thickness strip 104 comprises second zones 110 of length L_2 of thickness e , separated from one another by zones of additional thickness.

After the recrystallization final annealing, the variable-thickness strip 104 is cut in the zones of additional thickness, preferably in the middle of the zones of additional thickness.

This then yields the blanks 112 illustrated in figure 8 comprising a second zone of length L_2 flanked at each of its longitudinal ends by a connecting zone 111 of length L_3 and by a first-zone half 107 of length $\frac{L_1}{2}$.

At the end of the cutting step, the blanks 112 are planished using a known planishing method.

The blanks 112 are then wound into individual reels.

According to an alternative form of the method of manufacture described hereinabove, the variable-thickness strip 104 is planished after the recrystallization final annealing and before the cutting into blanks 112.

With this alternative form, the planished variable-thickness strip 104 is cut in the zones of additional thickness to form the blanks 112. For preference, the strip 104 is cut in the middle of the zones of additional thickness.

5 The cutting is performed for example on the planisher used for planishing the strip 104. As an alternative, the planished strip 104 is wound into a reel, then cut on a different machine from the planisher.

The blanks 112 are then wound into individual reels.

10 Using the method of manufacture described hereinabove there are obtained blanks 112 formed of a piece comprising a central zone 113 of thickness e flanked by reinforced ends 114, i.e. ends of thickness greater than the thickness e of the central zone 113. The ends 114 correspond to zones of additional thickness of the variable-thickness strip 104 and the central zone 113 corresponds to a second zone 110 of the variable-thickness strip 104 from
15 which the blank 112 has been cut.

 These blanks 112, which have a thickness that can vary along their length while still being formed as a single piece, do not have the weaknesses of the welded assemblies of the prior art. Furthermore, their reinforced ends 114 allow them to be assembled by welding to other components while at
20 the same time minimizing the mechanical weaknesses caused by this welded assembly.

 According to alternative forms, the blanks 112 may for example be obtained by cutting the strip 104 at points other than in two successive zones of additional thickness. For example, they may be obtained by cutting
25 alternately in a zone of additional thickness and in a second zone 110. In such a case, the blanks 112 obtained have just one reinforced end 114 of thickness greater than e . Such a blank yields the stroke 108 of figure 11.

 They may equally be obtained by cutting into two second successive zones 110.

30 By way of example, and as illustrated in figure 9, a blank 112 may be assembled with a second component 116 by welding one of the reinforced ends 114 of the blank 112 to an edge of the second component 16. The

thickness of the second component 116 is preferably greater than the thickness of the central zone 113 of the blank 112. The weld created is more particularly a fillet weld, also referred to as a lap weld.

The component 116 may be a blank 112 as described above.

5 Thus, figure 10 illustrates two blanks 112 butt-joined together using weldings. These two blanks 112 are welded together via their reinforced ends 114. The strakes 108 and 208 of figure 11 may be butted together in the same way, as will be described later.

In the examples illustrated in figures 9 and 10:

- 10 - the length of the central zone 113 is for example comprised between 40 m and 60 m; and
- the length of each reinforced end 114 is, for example, comprised between 0.5 m and 2 m.

The second thickness e is notably approximately equal to 0.7 mm.

15 The first thickness $e+s$ is approximately equal to 0.9 mm.

As an alternative, a non-planar component is formed from the blank 112.

The method of manufacturing a strip the thickness of which can vary along its length as described hereinabove is particularly advantageous.

20 Specifically, it makes it possible to obtain a strip made from alloy based chiefly on iron and nickel having the chemical composition defined hereinabove with zones of different thicknesses but almost uniform mechanical properties. These properties are obtained by virtue of the use of a degree of plastic deformation after a possible recrystallization intermediate

25 annealing brought about by the uniform rolling and flexible rolling steps which, in the thickest zones is greater than or equal to 30%.

The experimental examples that follow illustrate the importance of the range of degree of plastic deformation claimed for this type of alloy.

In a first series of experiments, variable-thickness tapes, which means

30 to say variable-thickness strips 104 in which the thickness e of the second zones 10 is less than or equal to 2 mm were manufactured.

Table 1 below illustrates tests of the manufacture of variable-thickness tapes without intermediate recrystallization annealing.

Table 2 below contains properties of the tapes obtained through the tests of table 1.

5 Table 3 below illustrates tests on the manufacture of variable-thickness tapes with a recrystallization intermediate annealing at the thickness E_i .

Table 4 below contains properties of the tapes obtained through the tests of table 3.

10 In a second series of experiments, variable-thickness sheets were manufactured, which means to say variable-thickness strips 104 in which the thickness e of the second zones 110 is strictly greater than 2 mm.

Table 5 illustrates tests on the manufacture of variable-thickness sheets with or without intermediate annealing.

15 Table 6 below contains properties of the sheets obtained through the tests of table 5.

In all of the tables, underlining has been used to indicate tests conforming to a method of manufacturing a strip the thickness of which can vary along its length, from an alloy based on iron and comprising, by weight:

20 $34.5\% \leq \text{Ni} \leq 53.5\%$

$0.15\% \leq \text{Mn} \leq 1.5\%$

$0 \leq \text{Si} \leq 0.35\%$, preferably $0.1\% \leq \text{Si} \leq 0.35\%$

$0 \leq \text{C} \leq 0.07\%$

optionally:

25 $0 \leq \text{Co} \leq 20\%$

$0 \leq \text{Ti} \leq 0.5\%$

$0.01\% \leq \text{Cr} \leq 0.5\%$

the rest being iron and unavoidable impurities resulting from the production process,

30 the method comprising the following succession of steps:

- supplying an initial strip (101) of constant thickness (E_0) obtained by hot rolling;

- uniformly cold rolling the initial strip (101) along its length in order to obtain an intermediate strip (103) the thickness of which is constant (E_c) in the direction of rolling;

5 - flexibly cold-rolling the intermediate strip (103) along its length in order to obtain a strip (104) of variable thickness in the direction of rolling, the variable-thickness strip (104) having, along its length, first zones (107) having a first thickness ($e+s$) and second zones (110) having a second thickness (e) less than the first thickness ($e+s$),

10 - final recrystallization annealing of the variable-thickness strip (104) on the fly in a final annealing furnace,

in which the degree of plastic deformation brought about after a possible recrystallization intermediate annealing, by the uniform cold-rolling and flexible cold-rolling steps in the first zones (107) of the variable-thickness strip (104) is greater than or equal to 30%.

15 It is found that when the degree of plastic deformation τ_1 after a possible recrystallization intermediate annealing is greater than or equal to 30% (tests 1 to 7 of table 1, 1 to 3 of table 3 and 1 to 9 of table 5), the variable-thickness strip 104 obtained has a difference in mean grain size between the mean grain size of the first zones 107 (thickness $e+s$) and the grain size of the second zones 110 (thickness e) that is less than or equal to 0.5 of an ASTM number in terms of absolute value. This small difference in mean grain size between the first zones 107 and the second zones 110 results in almost uniform mechanical properties, namely a difference in elastic limit at 0.2%, ΔR_p , between the first zones 107 and the second zones 110 that is less than or equal to 6 MPa in terms of absolute value, and a difference in load at break ΔR_m between the first zones 107 and the second zones 110 that is less than or equal to 6 MPa in terms of absolute value.

25 It is thus possible to obtain a variable-thickness strip 104 having mechanical properties and grain sizes that are almost uniform after a recrystallization annealing that is very simple, because it is carried out at constant travel speed and constant temperature.

Figure 11 is a schematic plan view of the primary sealed membrane of a sealed and insulating tank wall built in a similar way to the tank of figure 1. The ends of the tank wall are symbolized by the welding flanges 27 that are partially depicted.

5 For the purposes of the illustration, the three metal strakes 8, 108 and 208 depicted in figure 11 are manufactured according to three different embodiments. In practice, a sealed membrane may be constructed with strakes all corresponding to the same embodiment, or alternatively using a combination of strakes from a number of embodiments in any appropriate order. The weld supports 9 are also sketched in figure 11, in an exploded view which positions the welding supports 9 some distance away from the strakes 8, 108 and 208, for the sake of ease of understanding.

15 These strakes of the three embodiments have in common the fact that they stretch longitudinally from one end of the tank wall to the other so as to be welded to the two welding flanges 27 and that they have two turned-up lateral edges 13. For example, the width of the planar central portion of the strake is between 40 and 60 cm and the height of the turned-up edge 13 is between 2 and 6 cm.

20 The turned-up edges 13 of the variable-thickness strake 8 may be obtained from a flat blank 112 using a bending machine comprising three rollers on each side of the blank 112. The rollers apply pressure to the blank in order to deform the blank and generate the turned-up edges. Servo-controlled hydraulic rams allow the position of the rollers and the pressure exerted thereby to be modified according to the variation in thickness of the blank.

25 The strake 8 corresponds to the embodiment described above with reference to figures 2 and 3: it is a metal strip extending in one piece from one end of the tank wall to the other and comprising the reinforced portions 114 at the two ends of the strip and the smaller-thickness central portion 113 between these. For the purposes of the illustration, the boundaries between the thinner portion 113 and the thicker reinforced portions 114 have been

30

drawn in fine broken line, but it should be understood that this boundary may extend over a relatively broad transition zone.

The strake 8 is placed in one piece in the tank. The inclined portion 14 at the two ends of the two turned-up edges of the strake 8 is cut off
5 before welding the assembly and sealing welds to the connecting rings.

The strake 108 or 208 on the other hand is made up of several successive longitudinal strips with turned-up edges which may be laid one after the other, making these embodiments particularly suitable for very long tank walls measuring, for example, around 30 to 50 m per longitudinal strip,
10 making a total length in excess of 50 m. Each successive strip is continuous, which means to say that it is obtained from a single blank described hereinabove rather than by welding several blanks together.

More specifically, the strake 108 comprises two metal strips with turned up edges 13 which are assembled end to end in the continuation of
15 one another at an assembly zone 40, where assembly is for example by welding. Each metal strip is continuous and has a thicker reinforced end portion 114 adjacent to the assembly zone 40 and has a thinner uniform thickness over the remainder of its length 113, as far as the edge of the tank wall where it is assembled with the welding flange 27.

20 The strake 208 is constructed in a similar way to the strake 108, but with strips both ends 114 of which are reinforced with a greater thickness. As a result, the thicker reinforced ends 114 of the strips constituting the strake 208 are present both at the connection zone 40 for connection between the strips and at the edges of the tank wall where the strake 208 is assembled
25 with the welding flanges 27. As an alternative, the strake 208 may be constructed using a higher number of continuous strips placed end to end in the same way.

When a tank wall is covered with a sealed membrane manufactured using the strakes 108 or 208, the assembly zone 40 for each strake 108 or 208
30 may be positioned in the middle of the tank wall or at some other location. For preference, these locations are longitudinally offset from one strake to

another, in order thus to avoid forming a continuous line of welding in the transverse direction of the wall.

Although insulating elements in the form of caissons containing expanded perlite have been described, other forms of insulating elements are possible. In particular, the caissons may be produced using other forms of insulating materials. For example, the caissons may comprise a layer of insulating foam.

The tanks described above can be used in various types of installation such as on-shore installations or in a floating construction such as a methane tanker or the like.

With reference to figure 4, a cutaway view of a methane tanker vessel 70 shows a sealed and insulated tank 71 of prismatic overall shape mounted inside the double hull 72 of the vessel. The wall of the tank 71 comprises a primary sealed barrier intended to be in contact with the LNG contained inside the tank, a secondary sealed barrier arranged between the primary sealed barrier and the double hull of the ship, and two thermally insulating barriers arranged respectively between the primary sealed barrier and the secondary sealed barrier, and between the secondary sealed barrier and the double hull 72.

In a way known per se, loading/unloading pipes arranged on the upper deck of the ship can be connected, by means of suitable connectors, to a shipping or harbor terminal in order to transfer a cargo of LNG from or to the tank 71.

Figure 4 depicts one example of a shipping 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 offshore 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 which can be connected to the loading/unloading pipes 73. The orientable mobile arm 74 can adapt to suit all sizes of methane tanker. A connecting pipe, not depicted, extends down inside the tower 78. The loading and unloading

station 75 allows the methane tanker 70 to be loaded and unloaded from or to the on-shore facility 77. The latter 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 large distance, for example 5 km, allowing the methane tanker 70 to be kept a long way off shore during the loading and unloading operations.

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

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

The use of the verbs "have", "comprise" or "include" and the conjugated forms thereof does not exclude there being other elements or other steps than those listed in a claim. The use of the indefinite article "a" or "an" for an element or a step does not, unless mentioned otherwise, exclude there being a plurality of such elements or steps.

In the claims, any reference sign placed between parentheses must not be interpreted as implying any limit on the claim.

Test	Wavelength (m)	E_0 (mm)	k	E_c (mm)	e (mm)	$n=s/e$	$e+s$ (mm)	L1 (m)	L2 (m)	L3 (m)	τ_1 (%)	τ_2 (%)	$\tau_2-\tau_1$ (%)	Final annealing T°C; duration
<u>1</u>	<u>50</u>	<u>4.2</u>	<u>1.3</u>	<u>2.0</u>	<u>1.5</u>	<u>0.25</u>	<u>1.88</u>	<u>1.50</u>	<u>1.90</u>	<u>44.7</u>	<u>55</u>	<u>64</u>	<u>9</u>	<u>1025°C; 60s</u>
<u>2</u>	<u>50</u>	<u>4.2</u>	<u>1.15</u>	<u>1.7</u>	<u>1.5</u>	<u>0.15</u>	<u>1.73</u>	<u>1.50</u>	<u>1.90</u>	<u>44.7</u>	<u>59</u>	<u>64</u>	<u>5</u>	<u>1025°C; 60s</u>
<u>3</u>	<u>50</u>	<u>3.2</u>	<u>1.15</u>	<u>1.2</u>	<u>1.0</u>	<u>0.15</u>	<u>1.15</u>	<u>1.00</u>	<u>1.50</u>	<u>46.0</u>	<u>64</u>	<u>69</u>	<u>5</u>	<u>1025°C; 60s</u>
<u>4</u>	<u>50</u>	<u>2.6</u>	<u>1.3</u>	<u>0.9</u>	<u>0.7</u>	<u>0.25</u>	<u>0.88</u>	<u>1.00</u>	<u>1.50</u>	<u>46.0</u>	<u>66</u>	<u>73</u>	<u>7</u>	<u>1025°C; 40s</u>
<u>5</u>	<u>50</u>	<u>2.6</u>	<u>1.15</u>	<u>0.8</u>	<u>0.7</u>	<u>0.15</u>	<u>0.81</u>	<u>1.00</u>	<u>1.50</u>	<u>46.0</u>	<u>69</u>	<u>73</u>	<u>4</u>	<u>1025°C; 40s</u>
<u>6</u>	<u>60</u>	<u>2.6</u>	<u>1.3</u>	<u>0.9</u>	<u>0.7</u>	<u>0.15</u>	<u>0.81</u>	<u>1.00</u>	<u>1.50</u>	<u>56.0</u>	<u>69</u>	<u>73</u>	<u>4</u>	<u>1025°C; 40s</u>
<u>7</u>	<u>50</u>	<u>2.1</u>	<u>1.3</u>	<u>0.7</u>	<u>0.5</u>	<u>0.15</u>	<u>0.58</u>	<u>1.20</u>	<u>1.50</u>	<u>45.8</u>	<u>73</u>	<u>76</u>	<u>4</u>	<u>1025°C; 30s</u>
8	50	2.3	1.3	2.3	1.8	0.25	2.25	1.20	1.50	45.8	2	22	20	1025°C; 60s
9	50	2.1	1.3	2.3	1.8	0.15	2.07	1.20	1.50	45.8	1	14	13	1025°C; 60s
10	60	2.1	1.3	2.3	1.8	0.15	2.07	1.20	1.50	55.8	1	14	13	1025°C; 60s

Table 1

Test	Properties at the thickness e+s			Properties at the thickness e			Delta Rp (MPa)	Delta Rm (MPa)	DeltaG _{ASTM}
	G1 _{ASTM}	Rp (MPa)	Rm (MPa)	G2 _{ASTM}	Rp (MPa)	Rm (MPa)			
<u>1</u>	<u>8</u>	<u>288</u>	<u>487</u>	<u>8.5</u>	<u>292</u>	<u>491</u>	<u>-4</u>	<u>-4</u>	<u>0.5</u>
<u>2</u>	<u>8.5</u>	<u>293</u>	<u>492</u>	<u>9</u>	<u>296</u>	<u>495</u>	<u>-3</u>	<u>-3</u>	<u>0.5</u>
<u>3</u>	<u>8.5</u>	<u>293</u>	<u>492</u>	<u>9</u>	<u>295</u>	<u>495</u>	<u>-2</u>	<u>-3</u>	<u>0.5</u>
<u>4</u>	<u>8.5</u>	<u>293</u>	<u>490</u>	<u>9</u>	<u>296</u>	<u>496</u>	<u>-3</u>	<u>-6</u>	<u>0.5</u>
<u>5</u>	<u>9</u>	<u>297</u>	<u>496</u>	<u>9</u>	<u>296</u>	<u>496</u>	<u>1</u>	<u>0</u>	<u>0</u>
<u>6</u>	<u>9</u>	<u>297</u>	<u>495</u>	<u>9</u>	<u>296</u>	<u>496</u>	<u>1</u>	<u>-1</u>	<u>0</u>
<u>7</u>	<u>9.5</u>	<u>300</u>	<u>501</u>	<u>9.5</u>	<u>300</u>	<u>501</u>	<u>0</u>	<u>0</u>	<u>0</u>
8	7.5	284	482	8.5	292	490	-8	-8	1
9	7.5	286	481	8.5	293	491	-7	-10	1
10	7.5	285	483	9	296	496	-11	-13	1.5

Table 2

Test	Wavelength (m)	E_0 (mm)	k	E_i (mm)	Annealing at E_i T°C; duration	E_e (mm)	e (mm)	$n=s/e$	e+s (mm)	L1 (m)	L2 (m)	L3 (m)	τ_1 (%)	τ_2 (%)	$\tau_2-\tau_1$ (%)	Final annealing T°C; duration
1	50	2.6	1.3	1.5	1025°C ; 50s	0.8	0.6	0.25	0.75	1.20	1.50	45.8	50	60	10	1025°C ; 40s
2	50	2.6	1.3	1.5	1025°C ; 50s	0.8	0.6	0.15	0.69	1.20	1.50	45.8	54	60	6	1025°C ; 40s
3	60	2.6	1.3	1.5	1025°C ; 50s	0.7	0.5	0.15	0.58	1.20	1.50	55.8	62	67	5	1025°C ; 30s
4	50	4.2	1.30	2.00	1025°C ; 80s	1.95	1.5	0.25	1.88	1.50	1.90	44.7	6	25	19	1025°C ; 60s
5	50	4.2	1.15	2.00	1025°C ; 80s	1.73	1.5	0.15	1.73	1.50	1.90	44.7	14	25	11	1025°C ; 60s
6	50	3.2	1.30	1.30	1025°C ; 50s	1.30	1.0	0.25	1.25	1.50	1.90	44.7	4	23	19	1025°C ; 60s
7	50	3.2	1.15	1.50	1025°C ; 60s	1.15	1.0	0.15	1.15	1.00	1.50	46.0	23	33	10	1025°C ; 60s
8	50	2.6	1.30	0.90	1000°C ; 40s	0.91	0.7	0.25	0.88	1.00	1.50	46.0	3	22	19	1025°C ; 40s
9	60	2.6	1.15	1.00	1000°C ; 40s	0.81	0.7	0.15	0.81	1.00	1.50	56.0	20	30	11	1025°C ; 40s

Table 3

Test	Properties at the thickness e+s			Properties at the thickness e			Delta Rp (MPa)	Delta Rm (MPa)	DeltaG _{ASTM}
	G1 _{ASTM}	Rp (MPa)	Rm (MPa)	G2 _{ASTM}	Rp (MPa)	Rm (MPa)			
1	8.5	292	491	8.5	293	491	-1	0	0
2	8.5	293	492	8.5	291	492	2	0	0
3	8.5	293	490	9	296	496	-3	-6	0.5
4	7	281	478	8	290	487	-9	-9	1
5	7	281	477	8	288	487	-7	-10	1
6	6.5	277	473	8	288	487	-11	-14	1.5
7	7	282	477	8	289	487	-7	-10	1
8	6.5	277	474	7.5	285	482	-8	-8	1
9	7	282	479	8	289	487	-7	-8	1

Table 4

Test	Wavelength (m)	E ₀ (mm)	k	E _i (mm)	Annealing at E _i T°C; duration	E ₀ (mm)	e (mm)	n=s/e	e+s (mm)	L1 (m)	L2 (m)	L3 (m)	τ1 (%)	τ2 (%)	τ2-τ1 (%)	Final annealing T°C; duration
1	12	16	1.30		None	10.7	8.2	0.25	10.25	1.00	1.50	8.0	36	49	13	1025°C ; 5min
2	6	16	1.15		None	9.4	8.2	0.15	9.43	0.50	0.75	4.0	41	49	8	1025°C ; 5min
3	12	8.2	1.30		None	5.5	4.2	0.25	5.25	0.50	0.75	10.0	36	49	13	1025°C ; 3min
4	12	8.2	1.15		None	4.8	4.2	0.15	4.83	1.50	2.25	6.0	41	49	8	1025°C ; 3min
5	6	8.2	1.30		None	4.2	3.2	0.25	4.00	0.80	1.20	2.8	51	61	10	1025°C ; 3min
6	9	8.2	1.15		None	3.7	3.2	0.15	3.68	1.00	1.50	5.0	55	61	6	1025°C ; 3min
7	12	16	1.30	8.2	1050°C ; 5 min	4.2	3.2	0.25	4.00	1.00	1.50	8.0	51	61	10	1025°C ; 3min
8	12	16	1.15	8.2	1050°C ; 5 min	4.8	4.2	0.15	4.83	0.50	0.75	10.0	41	49	8	1025°C ; 3min
9	6	16	1.15	8.2	1050°C ; 5 min	3.7	3.2	0.15	3.68	0.50	0.75	4.0	55	61	6	1025°C ; 3min

Table 5

Test	Properties at the thickness e+s			Properties at the thickness e			Delta Rp (MPa)	Delta Rm (MPa)	Delta G _{ASTM}
	G1 _{ASTM}	Rp (MPa)	Rm (MPa)	G2 _{ASTM}	Rp (MPa)	Rm (MPa)			
1	7	280	479	7.5	285	483	-5	-4	0.5
2	7	281	477	7.5	285	483	-4	-6	0.5
3	7.5	285	482	8	288	487	-3	-5	0.5
4	8	288	487	8	288	487	0	0	0
5	8.5	293	492	8.5	292	492	1	0	0
6	8.5	292	491	9	297	496	-5	-5	0.5
7	8.5	291	490	8.5	293	490	-2	0	0
8	8	289	487	8.5	292	491	-3	-4	0.5
9	8.5	292	491	8.5	292	490	0	1	0

Table 6

CLAIMS

1. A sealed and thermally insulating tank incorporated into a bearing structure, the bearing structure comprising a plurality of bearing walls (1, 2), the tank comprising
- 5 a plurality of tank walls each fixed to a respective bearing wall (1, 2), a tank wall comprising:
- a thermal insulation barrier (3, 5) held on the bearing wall, the thermal insulation barrier having a planar support surface parallel to the respective
- 10 bearing wall,
- a sealing barrier (4, 6) supported by the insulation barrier and comprising a repeating structure alternately made up of an elongate metal strake (8, 108, 208) and an elongate welding flange (9) connected to the support surface and projecting with respect to the latter, the welding flange (9)
- 15 running parallel to the metal strake (8) over at least part of the length of the metal strake, the metal strake comprising in the widthwise direction a planar central portion placed on the support surface and lateral edges (13) that are turned up with respect to the support surface and arranged against the adjacent welding flanges and welded in a sealed manner to the welding
- 20 flanges (9),
- in which the metal strake extends between two opposite edges of the tank wall and has two end portions which are each assembled in a sealed manner to a respective stopping structure (10, 27, 28) at said opposite edges of the tank wall,
- 25 characterized in that the metal strake (8, 108, 208) is made up of at least one continuous metal strip having several longitudinal portions of different thicknesses, the longitudinal portions comprising an intermediate portion (113, 35) and at least one end portion (114, 33) of which the thickness is greater than the thickness of the intermediate portion of the strip, the thicker
- 30 end portion (114, 33) forming an assembly zone for assembling the strip with the stopping structure (10) or with another continuous metal strip butt-joined to the first continuous metal strip to constitute the metal strake.

2. The tank as claimed in claim 1, in which the metal strake (8) is made up of a single metal strip extending in one piece between the two opposite edges of the tank wall, and in which the two end portions (33) of the strip are thicker than the intermediate portion (35, 36) and are each assembled with the respective stopping structure (10, 27, 28) at the opposite edges of the tank wall.

3. The tank as claimed in claim 1, in which the metal strake (108, 208) comprises a second continuous metal strip butt-joined to the first continuous metal strip in the continuation of the first continuous metal strip, in which each of the two continuous metal strips has, at the region (40) of connection of the two metal strips, an end portion (114) that is thicker than the intermediate portion (113) of the strip.

4. The tank as claimed in claim 3, in which at least one of the two continuous metal strips has, at the opposite end to the region (40) of connection of the two metal strips, a second end portion (114) which is thicker than the intermediate portion (113) of the strip, the second end portion (114) being connected to the stopping structure (10, 27, 28) at an edge of the tank wall.

5. The tank as claimed in claim 3 or 4, in which at least one of the two continuous metal strips has, at the opposite end to the region (40) of connection of the two metal strips, a second end portion (114) of the same thickness as the intermediate portion (113) of the strip, the second end portion (114) being connected to the stopping structure (10, 27, 28) at an edge of the tank wall.

6. The tank as claimed in one of claims 1 to 5, in which each end portion of the metal strake (8, 108, 208) is welded in a sealed manner to the respective stopping structure (10).

7. The tank as claimed in claim 6, in which the strake (8) is welded to the stopping structure by a cold metal transfer CMT method or by TIG welding using a filler metal or by cold welding.

8. The tank as claimed in one of claims 1 to 7, in which the stopping structure (10) comprises a plate (27, 28) positioned over the

insulating barrier and the end portion of the metal stake (8, 108, 208) comprises a first segment bearing against the plate of the stopping structure and a second segment bearing against the thermal insulating barrier, the first segment and the second segment being connected by a folded segment (34) forming a discontinuity in the thickness direction of the metal stake.

9. The tank as claimed in one of claims 1 to 8, in which the welding flanges (9) are interrupted before the end of the metal stake (8, 108, 208), the turned-up edges of two adjacent metal stakes being welded to one another by an edge weld positioned along part of their length as far as the end of the metal stake.

10. The tank as claimed in claim 9, in which the edge weld of the turned-up edges (13) is performed using a cold metal transfer process.

11. The tank as claimed in one of claims 1 to 10, in which the thicker end portion (114, 33) of the metal strip has a thickness greater than or equal to 0.9 mm.

12. The tank as claimed in one of claims 1 to 11, in which the intermediate portion (35) of the metal strip has a thickness less than 0.9 mm and preferably a thickness of 0.7 mm.

13. The tank as claimed in one of claims 1 to 12, in which the stopping structure (10) is welded to a bearing wall.

14. The tank as claimed in one of claims 1 to 13, in which said metal stake and the stopping structure are made of a nickel-steel alloy with a low coefficient of expansion.

15. The tank as claimed in one of claims 1 to 14, in which the metal strip is made of an alloy based on iron and comprises by weight:

$$34.5\% \leq \text{Ni} \leq 53.5\%$$

$$0.15\% \leq \text{Mn} \leq 1.5\%$$

$$0 \leq \text{Si} \leq 0.35\%, \text{ preferably } 0.1\% \leq \text{Si} \leq 0.35\%$$

$$0 \leq \text{C} \leq 0.07\%$$

optionally:

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$0.01\% \leq Cr \leq 0.5\%$

the rest being iron and unavoidable impurities resulting from the production process.

16. The tank as claimed in one of claims 1 to 15, in which the tank wall further comprises:

a secondary thermal insulation barrier (3), the thermal insulation barrier having a planar support surface parallel to the respective bearing wall, and a secondary sealing barrier (4) supported by the secondary insulation barrier and bearing the primary insulation barrier (5),

the secondary sealing barrier comprising a repeating structure alternately made up of an elongate metal stake (8, 108, 208) and an elongate welding flange (9) connected to the support surface and projecting with respect to the latter, the welding flange (9) running parallel to the metal stake (8) over at least part of the length of the metal stake, the metal stake comprising in the widthwise direction a planar central portion placed on the support surface and lateral edges (13) that are turned up with respect to the support surface and arranged against the adjacent welding flanges and welded in a sealed manner to the welding flanges (9), in which the metal stake extends between two opposite edges of the tank wall and has two end portions which are each assembled in a sealed manner to a respective stopping structure (10, 28) at said opposite edges of the tank wall,

characterized in that the metal stake (8, 108, 208) is made up of at least one continuous metal strip having several longitudinal portions of different thicknesses, the longitudinal portions comprising an intermediate portion (113, 35) and at least one end portion (114, 33) of which the thickness is greater than the thickness of the intermediate portion of the strip, the thicker end portion (114, 33) forming an assembly zone for assembling the strip with the stopping structure (10) or with another continuous metal strip butt-joined to the first continuous metal strip to constitute the metal stake.

17. A ship (70) for transporting a cold liquid product, the ship comprising a double hull (72) and a tank (71) as claimed in one of claims 1 to 16 placed inside the double hull.

18. The use of a ship (70) as claimed in claim 17 for loading or
5 unloading a cold liquid product, in which a cold liquid product is conveyed through insulated pipes (73, 79, 76, 81) from or to a floating or on-shore storage facility (77) to or from the tank of the ship (71).

19. A transfer system for a cold liquid product, the system comprising a ship (70) as claimed in claim 17, insulated pipes (73, 79, 76, 81)
10 arranged in such a way as to connect the tank (71) installed in the hull of the ship to a floating or on-shore storage facility (77) and a pump for driving a stream of cold liquid product through the insulated pipes from or to the floating or on-shore storage facility to or from the tank of the ship.

20. A continuous metal strip with turned-up lateral edges suited
15 to the creation of a tank as claimed in claim 1, the metal strip being obtained from a blank (112) having, along its length, a reinforced first end zone (114) having a first thickness (e+s) and a central second zone (113) having a second thickness (e) smaller than the first thickness (e+s) and a third end zone having the first thickness (e+s) or the second thickness (e), the
20 metal strip having, across its width, a planar central zone and two lateral edges bent up substantially perpendicular to the planar central zone, the two lateral edges having a width that is small in comparison with the planar central zone.

21. The metal strip as claimed in claim 20, the metal strip being
25 made of an alloy based on iron and comprising by weight:
 $34.5\% \leq \text{Ni} \leq 53.5\%$

$$0.15\% \leq \text{Mn} \leq 1.5\%$$

$$0 \leq \text{Si} \leq 0.35\%, \text{ preferably } 0.1\% \leq \text{Si} \leq 0.35\%$$

$$0 \leq \text{C} \leq 0.07\%$$

30 optionally:

$$0 \leq \text{Co} \leq 20\%$$

$$0 \leq \text{Ti} \leq 0.5\%$$

$0.01\% \leq \text{Cr} \leq 0.5\%$

the rest being iron and unavoidable impurities resulting from the production process.