

IMPERMEABLE WALL STRUCTURE

The invention relates to the field of production of corrugated metal membrane tanks, in particular tanks

5 which are designed to contain a cold liquid product.

In certain metal membrane tank technologies, in particular in the fields of the transport and storage of liquefied natural gas (LNG), an impermeable membrane
10 consists of corrugated impermeable plates which have on their inner surface a first series of corrugations and a second series of corrugations, the respective directions of which are perpendicular. Corrugations of this type provide the metal membrane with a resilient
15 deformation capacity which is designed to absorb stresses which can arise in particular from thermal contraction, the hydrostatic pressure of the load, the dynamic pressure caused by movements of the load, and, in the case of floating structures, deformation of the
20 hull in swell. However, corrugations of this type can be vulnerable to excessive pressure forces.

In order to improve the resistance of a membrane of this type to pressure, FR-A-2936784 proposes to insert
25 reinforcement elements below the corrugations, between the membrane and its support. One of the reinforcement elements proposed can be clipped onto an undercut of the membrane.

30 According to one embodiment, the invention provides a ready-to-mount assembly which is suitable for producing an impermeable wall structure, the assembly comprising: an impermeable metal plate having a series of first parallel corrugations and a series of second parallel
35 corrugations the first corrugations intersecting with the second corrugations at the level of intersections, the corrugations projecting from the side of an inner surface of the plate;

an elongate reinforcement part being able to be arranged in one of said corrugations on the outer surface of the plate opposite the inner surface, in order to increase resistance to pressure of the plate;

5 and

an anchorage part comprising an attachment unit which can be attached to the outer surface of the plate, at the level of an intersection of the corrugation in which the reinforcement part is to be retained, and a
10 retention unit which can co-operate with a longitudinal end of the reinforcement part in order to retain the reinforcement part in the corrugation.

According to some embodiments, an assembly of this type
15 can have one or a plurality of the following characteristics.

According to one embodiment, the anchorage part comprises a plurality of retention units, for example
20 two, three or four, which can co-operate with respective ends of a plurality of reinforcement parts, for example two, three or four, in order to retain the reinforcement parts in a plurality of corrugation segments which are at the level of the intersection
25 where the anchorage part is attached.

According to one embodiment, the or each retention unit can co-operate with the end of the reinforcement part in a support state in which the retention unit stops
30 the end of the reinforcement part in a direction perpendicular to the plate.

According to one embodiment, the or each retention unit can co-operate with the end of the reinforcement part
35 in a securing state in which the retention unit secures the reinforcement part on the anchorage part, such that the reinforcement part is retained on the plate solely by the effect of the anchorage part.

According to one embodiment, the or each retention unit and the or each reinforcement part are designed such as to be able to co-operate in the two aforementioned co-operation states. Thus, the most appropriate co-operation state can be selected according to the characteristics of the application concerned, always using a single set of anchorage and reinforcement parts.

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According to one embodiment, the or each retention unit of the anchorage part is placed at the end of an arm which is connected to the attachment unit, the arm being placed such as to extend in the corrugation in which the reinforcement part must be retained by the retention unit, in the attached state of the anchorage part.

According to one embodiment, the or each arm of the anchorage part comprises a positioning unit with a contour which is designed for a transverse profile of a corrugation of the plate, the positioning unit being able to co-operate with the plate at the level of the lateral walls of the corrugation, in order to position the arm in the corrugation, in the attached state of the anchorage part.

According to one embodiment, the or each retention unit comprises a lug which can extend longitudinally in a corrugation of the plate, in the attached state of the anchorage part, the reinforcement part comprising a receptacle which is open at the level of a longitudinal end surface of the reinforcement part, and can receive the lug of the retention unit.

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According to one embodiment, the lug of the or each retention unit comprises a thickened portion, which can co-operate with the longitudinal end surface of the

reinforcement part, in order to stop the reinforcement part longitudinally relative to the lug.

5 According to one embodiment, the thickened portion of the lug can be forced into the receptacle of the reinforcement part, in order to secure the reinforcement part firmly on the anchorage part, by resilient deformation of the thickened portion and/or of the receptacle of the reinforcement part. According to one embodiment, a forced engagement of this type can be used to obtain the aforementioned securing state.

10 According to one embodiment, the anchorage part comprises a stop unit which can co-operate with the longitudinal end surface of the reinforcement part, in order to limit the engagement of the lug in the receptacle, beyond the thickened portion.

20 According to one embodiment, a single structural element provides both the aforementioned stop unit and the aforementioned positioning unit.

25 The receptacle of the reinforcement part can be produced in various ways. According to one embodiment, the receptacle of the reinforcement part comprises a longitudinal groove hollowed in an outer surface of the reinforcement part which is designed to face opposite the plate.

30 According to one embodiment, the attachment unit comprises a head which can be attached to the outer surface of the plate by resilient clearance of an undercut of the plate, at the level of the intersection of the corrugations.

35 According to one embodiment, the anchorage part comprises a body to which there is connected the or each retention unit and at least one rod which connects

the head to the body whilst providing an empty space between them. An empty space of this type assists the resilient deformation of the rod in order to absorb any differences of form of the different intersections of
5 the metal plate.

According to one embodiment, the rod has a beveled form which narrows from the body towards the head of the anchorage part. A form of this type can facilitate the
10 insertion of the head in the undercut of the plate.

According to one embodiment, the assembly additionally comprises a second anchorage part comprising an attachment unit which can be attached to the outer
15 surface of the plate at the level of a second intersection of the corrugation in which the reinforcement part must be retained, and a retention unit which can co-operate with a second longitudinal end of the reinforcement part, in order to retain the
20 reinforcement part in the corrugation, the reinforcement part having a length which is designed for the distance between the retention units of the two anchorage parts in the state of attachment to the plate, such that the reinforcement part is retained on
25 the plate, between the two anchorage parts, by co-operation with the two retention units.

According to one embodiment, the two anchorage parts are produced in an identical manner, which simplifies
30 their production and control of the stock of parts of the assembly.

According to one embodiment, the reinforcement part is constituted by a profiled body with a constant cross
35 section. An embodiment of this type permits easy production of the reinforcement parts, in particular by a process of extrusion of a suitable material. According to some embodiments, the reinforcement parts

are produced from materials such as metals, in particular aluminum, metal alloys, plastic materials, in particular polyethylene, polycarbonate, polyether imide, expanded polystyrene, or composite materials comprising fibers, in particular glass fibers, bonded by a plastic resin.

According to one embodiment, the anchorage part, the reinforcement part and the metal plate of the aforementioned assembly are produced separately from one another in order to be able to be assembled to one another in a certain step of the construction of the impermeable wall in which they are designed to be used. The position of this step in the process of construction of the impermeable wall as a whole can be selected in particular according to the organization of the site or logistic constraints.

According to one embodiment, the invention also provides a process for production of an impermeable wall structure comprising:

supplying an impermeable metal plate with a series of first parallel corrugations and a series of second parallel corrugations, the first corrugations intersecting with the second corrugations at the level of intersections, the corrugations projecting from the side of an inner surface of the plate;

arranging an anchorage part comprising an attachment unit and a retention unit, such as to attach the attachment unit to the outer surface of the plate opposite the inner surface at the level of one of the intersections;

arranging an elongate reinforcement part in a corrugation segment adjacent to the intersection on the outer surface of the plate, such as to make a

longitudinal end of the reinforcement part co-operate with the retention unit.

5 A process of this type can be used in particular to prefabricate an impermeable wall structure which is suitable for production of a pressure-resistant impermeable membrane. According to some embodiments, a process of this type can additionally have one or a plurality of the following characteristics.

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According to one embodiment, the process comprises:

15 arranging a second anchorage part comprising an attachment unit and a retention unit, such as to attach the attachment unit to the outer surface of the plate at the level of a second intersection in the vicinity of the first intersection where the first anchorage part is attached;

20 arranging the reinforcement part in the corrugation segment which extends between the two intersections, such that the reinforcement part is retained on the plate, between the two anchorage parts, by co-operation of the two longitudinal ends of the reinforcement part
25 with the two retention units.

According to an alternative embodiment, the process comprises:

30 securing the end of the reinforcement part on the retention unit, such that the reinforcement part is retained on the plate solely by the effect of the anchorage part.

35 In this case, the reinforcement part can be arranged in a corrugation segment which extends between the intersection where the anchorage part is attached, and an edge of the plate, and can extend from the edge of

the plate in order to be able to be engaged in a corrugation of an adjacent plate.

5 A process of this type can be used to secure reinforcement parts in one, or a plurality, or all of the corrugations of the metal plate, in particular according to the requirements for reinforcement of the plate.

10 According to one embodiment, the process comprises:

attaching anchorage parts comprising in each case an attachment unit and four units for retention on the outer surface of the plate, at the level of all the
15 intersections of the plate; and

arranging reinforcement parts in all the corrugation segments which extend in each case between two intersections, by making in each case two longitudinal
20 ends of the reinforcement part co-operate with two retention units of the two anchorage parts which are attached at the level of the two intersections, such as to retain the reinforcement parts on the plate.

25 According to one embodiment, the process additionally comprises:

arranging reinforcement parts in all the corrugation segments which extend between an edge of the plate and
30 intersections adjacent to said edge of the plate; and

securing in each case the end of the reinforcement part on a retention unit of the anchorage part attached at the level of the corresponding intersection, such that
35 the reinforcement part is retained on the plate solely by the effect of the anchorage part extending from the edge of the plate. Measures of this type can be taken along one, or a plurality, or all of the edges of the

plate, according to the requirements of the application concerned.

According to one embodiment, the invention also
5 provides an impermeable insulating vessel arranged in a support structure, the vessel comprising a thermal insulation barrier and an impermeable barrier which is designed to be in contact with a product contained in the vessel, the impermeable barrier comprising an
10 aforementioned ready-to-mount assembly in a mounted state. A vessel of this type can form part of a land storage installation, for example in order to store LNG, or it can be installed in a floating, coastal or deep-water structure, in particular a methane tanker, a
15 floating storage and re-gasification unit (FSRU), a floating production and transported storage unit (FPSO), and the like.

According to one embodiment, a ship for the transport
20 of a cold liquid product comprises a double hull and an aforementioned vessel arranged in the double hull.

According to one embodiment, the invention also provides a process for loading or unloading of a ship
25 of this type, wherein a cold liquid product is conveyed through insulated piping from or to a floating or land storage installation, to or from the vessel of the ship.

30 According to one embodiment, the invention also provides a transfer system for a cold liquid product, the system comprising the aforementioned ship, insulated piping which is placed such as to connect the vessel installed in the hull of the ship to a floating
35 or land storage installation, and a pump to convey a flow of cold liquid product through the insulated piping from or to the floating or land storage installation, to or from the vessel of the ship.

A concept on which the invention is based is to provide a reinforcement device in order to reinforce a corrugated metal impermeable membrane against pressure forces. Certain aspects of the invention are based on the concept of providing a reinforcement device which is easy to produce, easy to assemble to an impermeable membrane, and easy to adapt to impermeable membranes which have corrugations with different dimensions and/or have a limited stock of parts.

Certain aspects of the invention are based on the concept of pre-fabricating an impermeable wall structure suitable for producing a pressure-resistant corrugated metal impermeable membrane. Certain aspects of the invention are based on the concept of producing impermeable wall structures of this type which are modular and easy to combine with one another.

The invention will be better understood, and other objects, details, characteristics and advantages of it will become more apparent during the following description of a plurality of particular embodiments of the invention, provided solely by way of non-limiting illustration, with reference to the attached drawings.

In these drawings:

- Figure 1 is a view in perspective of a corrugated metal plate which can be used in order to produce an impermeable wall.
- Figure 2 is a view in perspective of a cruciform anchorage part which can be attached to the outer surface of the plate in figure 1 at the level of an intersection of its corrugations, in order to retain reinforcement parts.

- Figure 3 is a view in perspective of a reinforcement part suitable for reinforcing a high corrugation of the plate in figure 1.
- 5 • Figure 4 is a view in perspective of a reinforcement part suitable for reinforcing a low corrugation of the plate in figure 1.
- Figure 5 is a partial view in cross section of the plate in figure 1, according to the line V-V, showing the anchorage part in figure 2 attached to
10 the plate by resilient wedging in an undercut of the plate, at the level of an intersection.
- Figure 6 is a partial view in perspective of the outer surface of the plate in figure 1, with a reinforcement part retained in a corrugation by
15 two anchorage parts co-operating with its two ends.
- Figure 7 is an enlarged view of the detail VII in figure 6.
- Figure 8 is a partial plan view of a marginal area
20 of the outer surface of the plate in figure 1 with a reinforcement part retained in a corrugation by an anchorage part which co-operates with one of its ends.
- Figure 9 is a schematic representation of an area
25 of junction between two plates in figure 1, seen in cross section on the median plane of a high corrugation of the plates, with a reinforcement part retained in the corrugation by an anchorage part which co-operates with one of its ends.
- 30 • Figure 10 is a schematic sectional-view representation of a methane tanker vessel comprising an impermeable membrane produced from the plate in figure 1, and a terminal for loading/unloading of this vessel.
- 35 • Figure 11 is a quarter cross-sectional view in perspective of a head for securing the anchorage part in figure 2, attached in an undercut of the plate in figure 1.

- Figure 12 is a view similar to figure 11, according to a viewing angle rotated by approximately 90°.
- 5 • Figure 13 is a plan view of a reinforcement part retained in a corrugation by two anchorage parts which co-operate with its two ends.
- 10 • Figure 14 is a view of the outer surface of the plate in figure 1 with reinforcement parts retained in all its corrugations, in each case by two anchorage parts which co-operate with the two ends of a reinforcement part.

With reference to figure 1, a corrugated metal plate 1 comprises on its inner surface 2 a first series of so-called low parallel corrugations 5 and a second series of so-called high parallel corrugations 6, the respective directions of which are perpendicular. The terms "high" and "low" in this case have a relative meaning and signify that the first series of corrugations 5 has a height lower than the second series of corrugations 6. At the level of an intersection 3 between a low corrugation 5 and a high corrugation 6, the low corrugation 5 is discontinuous, i.e. it is interrupted by a fold 4 which extends the top ridge 7 of the high corrugation 6 by means of projection above the top ridge 8 of the low corrugation 5. This form can be seen better in figure 5.

At the level of an intersection 3, the top ridge 7 of the high corrugation 6 comprises of pair of concave corrugations 9, the concavity of which faces towards the inner surface, and which are arranged on both sides of the top ridge 8 of the low corrugation 5. A high corrugation 6 additionally comprises at the level of each intersection 3 a concave indentation 10 on both sides of the fold 4. A concave indentation 10 has its concavity facing towards the inner surface 2 of the plate 1, and has a double curvature. A first curvature,

which can be seen in figure 1, is around an axis perpendicular to the mean plane of the plate 1. A second curvature, which can be seen in figure 5, is around an axis perpendicular to the plane of figure 5.

5 As can be seen in figure 5, the concave indentations 10 cause widening of the fold 4 in the direction of the base part 12 of the fold 4, i.e. a form of undercut. This form can be used in some embodiments in order to wedge an anchorage part resiliently in the base of the

10 fold 4.

By way of example, the low corrugations 5 have a height defined between the top ridge 8 and the surface of the plate 1 which is approximately equal to 36 mm, and a

15 width at the base of the corrugation 5 of approximately 53 mm. By way of example, the high corrugations 6 have a height defined between the top ridge 7 and the surface of the plate 1 of approximately 54.5 mm, and a width at the base of the corrugation 6 of approximately

20 77 mm.

By way of example, the plate 1 is made of stainless steel or aluminum sheeting, it has a thickness of approximately 1.2 mm, and can be formed by stamping.

25 Other metals or alloys and other thicknesses are possible, in the knowledge that thickening of the plate 1 gives rise to an increase in its cost, and generally increases the rigidity of the corrugations. In the case of the application of impermeable membranes for cold

30 liquid, a certain flexibility of the plate 1 is required in order to permit its thermal contraction, without a risk of rupturing the impermeability.

The corrugated metal plate 1 is well suited for forming

35 an impermeable membrane of a vessel with a large capacity, for example for a cold liquid product. However, the hydrostatic pressure which is exerted by the product contained in the vessel, for example liquid

gas, can generate substantial plastic deformations of the corrugations, and in particular compression of the lateral surfaces of the high corrugations 6 which are spaced from the intersections 3. In a vessel of this type integrated in the bearing structure of a ship, the swell movements of the liquid gas against the lateral walls of the vessel during transport can also generate dynamic pressure surges, such that the corrugations are also subjected to substantial plastic deformations. Deformations of this type can lead to deterioration of the mechanical strength of the plates, which are subjected to substantial thermal contractions, for example when they receive liquid methane, and thus detract from the impermeability of the plates, in particular in the areas of welding at the junction between the different plates of the impermeable wall. A description is provided hereinafter of the reinforcement parts which are designed to prevent or limit plastic deformations of this type.

With reference to figure 3, a reinforcement part 15 which is designed to be inserted in a high corrugation 6 of the outer surface side of the plate 1 is represented. The reinforcement part 15 has a profiled geometry with a constant cross section, which makes it possible to obtain easily a part with the required length, by cutting a profiled body with a long length. A profiled body of this type can be produced in particular by extrusion.

The part 15 has a thin upper wall 16 in the form of a semi-elliptical dome which is substantially adapted to the form of the high corrugation 6 and is designed to face towards the plate 1. If the reinforcement part 15 is made of a material which has thermal performance different from the plate 1, its dimensioning must take into account this difference, in order to support the

wall of the corrugation efficiently at the temperature of use, for example -162°C for LNG.

5 The lower wall 17 of the part 15 which is designed to face opposite the plate 1 has a generally flat form, in order to be able to be supported on a support surface, formed for example by the inner surface of a thermal insulation barrier in the case of a vessel for LNG. A groove 18 with a rectangular cross section is hollowed
10 longitudinally in the lower wall 17, in its middle.

Between the walls 16 and 17, the part 15 is hollow and comprises only fine support ribs, i.e. two oblique ribs 19 which intersect at the level of a core 22, and
15 extend in each case between a connection angle 20 of the walls 16 and 17 and a point which is situated substantially halfway along the height of the opposite part of the wall 16, and a short rib 21 which connects the core 22 to the base of the groove 18.

20 Since the surface area of the low corrugations 5 is smaller than that of the high corrugation 6, the low corrugations 5 are more resistant to pressure. However, it may also be advantageous to reinforce them by means
25 of reinforcement parts. With reference to figure 4, a reinforcement part 115 which is designed to be inserted in a low corrugation 5 of the outer surface side of the plate 1 is represented. Elements which are similar or identical to those of the reinforcement part 15 bear
30 the same reference figure increased by 100. In addition to its smaller dimensions, the reinforcement part 115 differs from the part 15 substantially in the absence of a flat lower wall. The part 115 is thus open between the two angles 120, and the groove 118 is formed below
35 the core 122 by two parallel longitudinal ribs 121 which extend on both sides of the median plane of symmetry of the part, parallel to the latter.

With reference to figure 2, a cruciform anchorage part 30 can be used in order to secure reinforcement parts 15 and 115 in the corrugations 6 and 5 of the plate 1. The anchorage part 30 comprises a central body 31 in
5 the form of a hollow cylindrical section with a globally rectangular cross section, the four outer surfaces of which bear respectively four arms which extend substantially perpendicularly to the axis of the body 31, and can each co-operate with a reinforcement
10 part, in order to retain or contribute towards retaining the reinforcement part in a corresponding corrugation of the plate 1, as will be explained hereinafter.

15 Two rods 32 are connected to the two short sides 37 of the body 31, and extend from the upper surface of the body 31 whilst forming a slight angle which is inclined towards the axis of the body, such as to approach one another without meeting. The rods 32 have a beveled
20 form in the direction of their end which is distant from the body 31. The ends of the rods 32 are connected by a rod 33 which extends perpendicularly to the axis of the body 31, and has a cross section which is wider than the end of the rods 32, and is for example
25 substantially equal to the width of the rods 32 at their base.

The rod 33 forms a securing head which can be wedged resiliently in the undercut of the fold 4 at the level
30 of an intersection 3 of the plate 1, previously described. For this purpose, the rod 33 is dimensioned with a cross section which is slightly wider than the narrowest part of the fold 4.

35 The anchorage part 30 can be produced by molding a plastic resin.

Figure 5 shows the anchorage part 30 thus attached to the plate 1. In order to produce this attachment, the anchorage part 30 is firstly arranged such that the rod 33 is applied against the entry part 11 of the fold 4, the rods 32 are perpendicular to the plate 1, and the arms of the anchorage part 30 are arranged respectively at right angles to the four corrugation segments which meet at the level of the intersection 3. Then, a force is applied to the anchorage part 30 perpendicularly in the direction of the plate 1, for example manually, such that the rod 33 clears the entry part 11 and the narrow part of the fold 4 resiliently, in order to be accommodated in the base part 12, where it is retained firmly by resilient return of the two inclined faces 34. In the attached state, the axis of the body 31 is substantially perpendicular to the mean plane of the plate 1.

As can be seen better in figures 11 and 12, the rod 33 has a cross section which is grooved in its middle by a slot 38 which extends longitudinally between the two ends of the rod 33, where the rods 32 are connected. In plan view, the form of the slot 38 can be a rhombus, or another elongate form. The slot 38 facilitates the resilient compression of the rod 33 when it is inserted in the narrow part of the fold 4. The two inclined faces 34 situated on the sides of the rod 33 which slide against the inner surface of the fold 4 during this insertion movement also facilitate its resilient compression. Thus, the rod 33 can be resiliently deformed in order to adapt to the precise form of the interior of the fold 4, which can vary slightly from one intersection 3 to the other of a single plate 1 because of the production tolerances of the plates 1. Consequently, a single anchorage part 30 is designed to be used in all the intersections 3 of a corrugated plate of the type such as the plate 1, and even in

different plates of this type which have slight dispersion in their production dimensions.

As can be seen better in figures 6 and 8, in the state in which they are attached to the plate 1, the four arms of the anchorage part 30 extend in the four corrugated segments which meet at the level of the intersection 3. These arms and their functions will now be described in greater detail.

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With reference again to figure 2, two longer arms 40 are connected to the short sides 37 of the body 31, and two shorter arms 140 are connected to the long sides 36 of the body 31. The arms 40 engage in the two high segments of the corrugation 6 adjacent to the intersection 3 where the anchorage part 30 is attached. The arms 140 engage in the two segments of the corresponding low corrugation 5.

20 An arm 40 has a globally rectangular cross section, and a general direction which is slightly inclined relative to the plane perpendicular to the axis of the body 31, i.e. which is inclined relative to the mean plane of the plate 1 in the attached state, this inclination being in a direction opposite the rods 32. The arm 40 ends in a positioning plate 41 which is substantially parallel to the axis of the body 31, this plate 41 adopting a position perpendicular to the axis of the high corrugation 6 in the attached state of the part 30, as can be seen in figure 8.

The width and form of the lateral sides 42 of the plate 41 are substantially adapted to the inner cross section of the high corrugation 6, with slight play, such that the lateral sides 42 can co-operate with the inner surface of the high corrugation 6 in order to stabilize the plate 41 in its position perpendicular to the axis of the high corrugation 6, in the attached state of the

part 30. In addition, the form of the plate 41 which widens progressively downwards makes it possible to slide one or each lateral side 42 against the fillets 13 at the base of the high corrugation 6 when the
5 anchorage part 30 is put into place, in order to guide the arm 40 easily towards a substantially centered position in the interior of the high corrugation 6.

A retention lug 44 is connected to the front surface 43
10 of the plate 41, at a position which is centered laterally relative to the plate 41, and adjacent to the lower edge 45 of the plate 41, i.e. at right angles to the point of connection of the arm 40 with the plate 41. The lug 44 extends perpendicularly to the axis of
15 the body 31, i.e. parallel to the axis of the high corrugation 6 in the attached state of the anchorage part 30. The lug 44 has a globally rectangular cross section with a width which is slightly smaller than the groove 18, in order to be able to slide in the latter,
20 except at the level of a widened part which forms a cylindrical pin 46.

As can be seen in figure 6 and in the detail in figure 7, in the attached state of the anchorage part 30 the
25 portion 48 of the lug 44 which is situated beyond the pin 46 can engage in a sliding manner in the entry of the groove 18 of a reinforcement part 15 in order to stop the part 15 in the direction perpendicular to the plate 1. The portion of lug 48 can be slightly beveled
30 in order to facilitate this engagement. In this mode of co-operation between the anchorage part 30 and the reinforcement part 15, known as the support mode, the reinforcement part 15 can tilt relative to the lug 44 if the second end of the reinforcement part 15 is not
35 retained. This co-operation mode thus presupposes the use of an anchorage part 30 or a similar means at each end of the part 15, as can be seen in figure 6 where a second anchorage part 130 is sketched.

In order to retain a reinforcement part 15 in a segment 14 of a high corrugation 6 between two intersections 3, the procedure is thus as follows: a first anchorage part 30 is installed at a first intersection. Then, a reinforcement part 15 is installed between this intersection and the second intersection, whilst engaging the portion of lug 48 of the first anchorage part in an end of the groove 18. Then, a second anchorage part 130 is installed at the second intersection, by engaging the portion of lug 48 of the second anchorage part in the other end of the groove 18. Finally, two identical anchorage parts 30 and 130 are attached respectively in the two intersections 3, such that each has an arm 40 which extends in a respective end portion of the segment 14, in opposite directions. The reinforcement part 15 with a length shorter than or equal to the distance which separates the two pins 46 of the two arms 40 which face one another is therefore retained in the segment 14, in the position shown in figure 6. In this position, the two ends of the reinforcement part 15 are supported respectively by the portions of lugs 48 of the two anchorage parts 30 and 130, such that the reinforcement part 15 is retained on the plate 1 in the direction perpendicular to the plate 1, and cannot tilt. In addition, the pins 46 provide in each direction a stop which can co-operate with the end surface 49 of the reinforcement part 15 at the entry of the groove 18, in order to stop the reinforcement part 15 in the longitudinal direction of the high corrugation 6. Thus, once it has been put into place, the reinforcement part 15 is firmly retained on the plate 1, and the plate 1 thus equipped can be freely handled, displaced or tilted into any position, without the reinforcement part 15 becoming detached.

With reference to figure 8, an arm 40 provides another possible mode of co-operation with a reinforcement part 15. In this mode of co-operation, which is known as the securing mode, the reinforcement part 15 is forced onto
5 the lug 44 until the pin 46 is wedged resiliently in the groove 18, which is narrower than the latter. In order to facilitate the resilient compression of the pin 46, the latter can be produced with an interior recess 50, which for example has a cylindrical form, as
10 can be seen in figure 7. Preferably, the reinforcement part 15 is thrust until the longitudinal end surface 49 is supported against the front surface 43 of the plate 41, which makes it possible to position the reinforcement part 15 accurately relative to the
15 anchorage part 30, and thus relative to the plate 1.

In the securing mode, the reinforcement part 15 is firmly retained on the plate 1 solely by the effect of the anchorage part 30. As can be seen in figure 8, the
20 securing mode can be used in order to retain a reinforcement part 15 in an end segment 51 of the high corrugation 6 which extends between an edge 52 of the plate 1 and the intersection 3 adjacent to this edge. Preferably, the reinforcement part 15 thus secured has
25 a length greater than the segment 51 in order to extend from the edge of the plate 1, and to be able to be engaged below a second adjacent plate, as will be explained hereinafter. The reinforcement part 15 can be
30 put into place in this position for example by means of a sharp tap with the hand on the end of the reinforcement part 15 which extends from the plate 1. This putting into place is simplified in that the reinforcement part 15 is guided axially in the corrugation 6 by support of its upper wall 16 against
35 the plate 1 in the interior of the corrugation 6, and in that the support of the lateral sides 42 of the plate 41 against the plate 1 in the interior of the corrugation 6 maintains the retention lug 44 in a

position centered laterally in the corrugation 6 at a height corresponding to that of the groove 18. The beveled form of the portion of lug 48 also facilitates the guiding of the retention lug 44 in the entry of the
5 groove 18.

The description provided above with reference to an arm 40 of the anchorage part 30 also applies in an identical manner to the other arm 40 which extends in
10 the opposite direction. It also applies to the arms 140 which fulfill the same functions as the arms 40, with the difference that the arms 140 concern the low corrugations 5 and the reinforcement parts 115. In the figures, the elements of the arms 140 thus bear the
15 same reference numbers as the elements of the arms 40 increased by 100, and they will not be described again.

It can thus be seen that an anchorage part 30 can co-operate with two reinforcement parts 15 and two
20 reinforcement parts 115, in order to retain, alone or by means of other adjacent anchorage parts, the four reinforcement parts in the four corrugation segments which are at the level of the intersection 3 where the anchorage part 30 is attached. For a plate 1 with high
25 corrugations 6 which are identical to one another and are regularly spaced, and low corrugations 5 which are identical to one another and are regularly spaced, it is thus possible to equip all the corrugation segments of the plate 1 with parts for reinforcement against
30 pressure by means of only three sets of parts, i.e. anchorage parts 30 which are identical to one another, reinforcement parts 15 which are identical to one another, with a length designed for the distance between two low corrugations 5, and reinforcement parts
35 15 which are identical to one another, with a length designed for the distance between two high corrugations 6.

With reference to figure 14, a description is now provided of a possible method for equipping with reinforcement parts all the corrugations on the outer surface of the plate 1. In order to implement this method, the plate 1 is turned round and supported against a support, for example a wall, such that its outer surface is visible, and the high corrugations 6 are substantially horizontal, the low corrugations 5 being almost vertical. The alphabetical order of the reference letters given in figure 14 indicates the order of mounting of the parts. At letter A, a first anchorage part is placed in an intersection situated at the level of a lower left corner of the plate 1. Then, a reinforcement part 15 and an anchorage part 30 are arranged alternately, sequentially, according to the horizontal high corrugation (letters B to Q), such that the reinforcement parts are in each case in the support mode with the two adjacent anchorage parts. Reinforcement parts 115 are then placed in the segments of low corrugations juxtaposing the high corrugation which has just been equipped, in each case making the lower end of the reinforcement part 115 co-operate with the arm 140 of the underlying anchorage part in the support mode (letters R). The procedure is then carried out along the high corrugation in the same manner as for the first high corrugation, whilst ensuring that each anchorage part 30 added retains a reinforcement part 115 added in the step R in the support mode (letters S, T, U, V, etc.).

It will be appreciated that it is also possible to equip only part of the corrugations or part of the corrugation segments of the plate 1.

In the state represented in figure 14, the end segments 51 of the high corrugations 6 and the end segments 83 of the low corrugations 5 are not equipped with reinforcement parts. Starting from this state, the

method described with reference to figure 8 can be used to equip with reinforcement parts the end segments which are situated along one edge or a plurality of edges of the plate 1.

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The three sets of parts used in this method can be supplied as a reinforcement device in kit form for metal plates of the type such as plate 1. A reinforcement device of this type can be mounted on the plate 1 quickly and easily, manually, by applying relatively moderate manual force. A reinforcement kit of this type is thus also suitable for a corrugated metal plate with dimensions and numbers of corrugations different from those represented in figure 1.

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In addition, if corrugations of the corrugated metal plate to be equipped are distributed irregularly, the production of a plurality of sets of reinforcement parts 15 or 115 with different lengths is easy, since these can be cut from a profile with a long length.

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The plate 1 thus equipped with reinforcement parts 15 and/or 115 retained by anchorage parts 30 can be used as a modular wall structure in order to manufacture a pressure-resistant impermeable membrane, by assembling a plurality of these structures. The interface between two of these structures can be produced according to figure 9.

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Figure 9 shows schematically the interface between two corrugated metal plates 54 and 55 similar to the plate 1 in figure 1, which are juxtaposed such that their respective corrugations are aligned. Figure 9 is a view in cross section along the median plane of a high corrugation 6 which extends through the two plates 54 and 55. Each of the two plates 54 and 55 is equipped with the above-described reinforcement device, for reinforcement of all the corrugations of the plates or

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a sub-assembly from amongst them. In figure 9, these reinforcement devices are very partially represented, i.e. by a respective anchorage part 30 which is attached to each of the plates 54 and 55 at the level of the intersection 3 of the high corrugation 6 which is closest to the edge 52 of the respective plate, and by a reinforcement part 15 which is arranged in the high corrugation 6, partially below the plate 54 and partially below the plate 55. The reinforcement part 15 thus reinforces the high corrugation 6 at the level of the interface between the two plates 54 and 55.

In order to put the plates 54 and 55 into place, it is possible to proceed as follows. The plate 54 already equipped with the reinforcement device is firstly placed on the support surface 60 on which the impermeable membrane is to be mounted. For example, the support surface 60 can be constituted by the upper plate of a known type of thermal insulation barrier. The plate 54 supports the reinforcement part 15 which is secured on the anchorage part 30 such as to extend from the edge 52 of the plate 54 by a certain distance.

The second plate 55, already equipped with the reinforcement device, is then brought above the support surface 60 adjacent to the plate 54, in a state parallel to the plate 54, such that the edge 52 of the plate 55 which must finally straddle the plate 54 is at the correct height. In the segment of corrugation 57 which is situated close to the edge 52 of the plate 55, the high corrugation 6 of the plate 55 does not comprise a reinforcement part. When the plate 55 is deposited in the direction of the arrow 59, a marginal portion of the plate 55 straddles a marginal portion 56 of the plate 54 along the edge 52, whereas the corrugation segment 57 of the plate 55 is engaged on the reinforcement part 15, and the end of the lug 44 of the anchorage part 30 attached to the plate 55 is

positioned opposite the longitudinal end surface 49 of the reinforcement part 15, without interfering with the latter, as a result of the existence of insertion play 58.

5 This insertion play 58 can exist without needing to produce the reinforcement part 15 with dimensions different from the other reinforcement parts used in the interior of the plates 54 and 55. If the plates 54 and 55 have dimensions such that all the low
10 corrugations 5 are finally equidistant, both within each of the plates 54 and 55, and at the interface between the two plates 54 and 55, taking into account their straddling, the reinforcement part 15 with a length which is designed for this regular spacing can
15 both be supported on two retention lugs 44 in the support mode illustrated in figure 6, and can be secured to a single retention lug 44 in the securing mode illustrated in figures 8 and 9, by using the play 58 relative to the other retention lug 44.

20 This property is due to a particular dimensioning of the parts, which will be described in greater detail with reference to figure 13. Figure 13 represents a reinforcement part 15 retained in a high corrugation 6
25 between two anchorage parts 30. The representation of the plate 1 has been completely omitted for the sake of clarity. The dimensions represented designate the following:

- 30 • p: distance between the centers of two successive intersections along the high corrugation;
- d: length between the center of the anchorage part 30 and the end of an arm 40 at the level of the surface 43;
- b: length of the lug 44 from the surface 43;
- 35 • a: distance between the surface 43 and the lug 46;
- $\frac{1}{2}$: length of the reinforcement part 15.

If it is considered that $Y = p-(l+2d)$, these dimensions preferably verify the following equations:

$$Y/2 < b < Y \quad (\text{Eq. 1}) \text{ and}$$

$$Y-b < a < Y/2 \quad (\text{Eq. 2}).$$

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Thus, play 58 with amplitude $(Y-b)$ is maintained in the position in figure 9. In the position in figure 13, the reinforcement part 15 is represented in the support mode centered between the two anchorage parts 30. The dimension c which represents the length of the portion of lug 48 inserted in the groove 18 is then equivalent to:

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$$c = b-Y/2 \quad (\text{Eq. 4}).$$

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Finally, the two plates 54 and 55 can be welded in an impermeable manner at the level of the marginal portion 56. The combination of a plurality of wall structures which have just been described with reference to figure 9 can be produced similarly at the level of all the high corrugations 6 of the plates 54 and 55. In addition, similar measures can be employed in the direction of the low corrugations 5.

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It is thus possible to produce an impermeable membrane with a large surface area by combining in this manner a multitude of rectangular wall structures on a flat support surface. Corrugated metal plates can also be cut according to other forms, and can be equipped in the same manner. The impermeable membrane thus produced can be secured to the support surface 60 by any suitable means.

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In the foregoing description, the retention lug 44 provides two modes of co-operation between the parts 30 and 15, i.e. a co-operation mode of the support type represented in figure 6, and a co-operation mode of the securing type represented in figure 8. As a variant these two co-operation modes could be obtained by means

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of two parts distinct from the anchorage part. Similarly, the plate 41 provides both a unit for positioning of the arm 40 in the high corrugation 6, and a stop unit for the reinforcement part 15 in the
5 fixed state. As a variant, these two functions could be fulfilled by separate elements.

The above described technique for production of an impermeable membrane can be used in different types of
10 tanks, for example in order to constitute the primary impermeable membrane of an LNG tank in a land installation or in a floating structure such as a methane tanker or the like.

15 With reference to figure 10, a sectional view of a methane tanker 70 shows an impermeable insulated vessel 71 with a generally prismatic form, mounted in the double hull 72 of the ship. The wall of the vessel 71 comprises a primary impermeable barrier which is
20 designed to be in contact with the LNG contained in the vessel, a secondary impermeable barrier placed between the primary impermeable barrier and the double hull 72 of the ship, and two insulating barriers which are placed respectively between the primary impermeable
25 barrier and the secondary impermeable barrier, and between the secondary impermeable barrier and the double hull 72.

In a known manner, loading/unloading piping 73 which is
30 arranged on the upper deck of the ship can be connected by means of appropriate connectors to a maritime or port terminal, in order to transfer a cargo of LNG from or to the vessel 71.

35 Figure 10 represents an example of a maritime terminal comprising a loading and unloading unit 75, an undersea pipe 76, and a land installation 77. The loading and unloading unit 75 is a fixed offshore installation

comprising a mobile arm 74 and a tower 78 which supports the mobile arm 74. The mobile arm 74 supports a bundle of insulated flexible tubes 79 which can be connected to the loading/unloading piping 73. The
5 adjustable mobile arm 74 adapts to all gauges of methane tankers. A connection pipe, not represented, extends in the interior of the tower 78. The loading and unloading unit 75 permits loading and unloading of the tanker 70 from or to the land installation 77. The
10 latter comprises liquefied gas storage vessels 80 and connection pipes 81 which are connected by the undersea pipe 76 to the loading or unloading unit 75. The undersea pipe 76 makes it possible to transfer liquefied gas between the loading or unloading unit 75
15 and the land installation 77 over a long distance, for example 5 km, thus making it possible to keep the methane tanker 70 at a long distance from the coast during the loading and unloading operations.

20 In order to generate the pressure necessary for transfer of the liquefied gas, use is made of pumps on board the ship 70 and/or pumps which equip the land installation 77 and/or pumps which equip the loading and unloading unit 75.

25 Although the invention has been described in association with a plurality of particular embodiments, it will be appreciated that it is in no way limited to these, and that it comprises all the techniques which
30 are equivalent to the means described, as well as their combinations, if these come within the scope of the invention.

The use of the verb "contain", "comprise" or "include"
35 and their conjugated forms does not exclude the presence of elements or steps other than those indicated in a claim. The use of the indefinite article "a" or "an" for an element or a step does not exclude

the presence of a plurality of elements or steps of this type, unless otherwise stated.

In the claims, any reference sign in brackets cannot be
5 interpreted as a limitation of the claim.

CLAIMS

1. An anchorage part (30) for an impermeable wall structure, the anchorage part comprising:

an attachment unit (32, 33) which can be attached to an outer surface of an impermeable metal plate (1) comprising corrugations which project from the side of an inner surface (2) of the plate opposite the outer surface, the attachment unit (32, 33) being able to be attached to the plate at the level of an intersection (3) between a first corrugation belonging to a series of first parallel corrugations (5) and a second corrugation belonging to a series of second parallel corrugations (6); and

a retention unit (44) which can co-operate with a longitudinal end of an elongate reinforcement part (15, 115) in order to retain the reinforcement part in one of the corrugations (6, 5) which intersect at the level of said intersection, the reinforcement part being designed to be arranged in the corrugation, in order to increase resistance to pressure of the plate.

2. A ready-to-mount assembly which is suitable for producing an impermeable wall structure, the assembly comprising:

an anchorage part (30) according to claim 1;

the impermeable metal plate (1) having the series of first parallel corrugations (5) and the series of second parallel corrugations (6), the first corrugations intersecting with the second corrugations at the level of intersections (3), the corrugations projecting from the side of the inner surface (2) of the plate; and

the elongate reinforcement part (15, 115) being able to be arranged in one of said corrugations (6, 5) on the outer surface of the plate opposite the inner surface, in order to increase resistance to pressure of the plate.

3. The assembly as claimed in claim 2, wherein the anchorage part comprises a plurality of retention units (44) which can co-operate with respective ends of a plurality of reinforcement parts, in order to retain the reinforcement parts in a plurality of segments of the said corrugations of the impermeable metal plate, wherein the segments of the corrugations meet at the intersection (3) where the anchorage part is attached.

4. The assembly as claimed in claim 2 or 3, wherein the retention unit (44) can co-operate with the end of the reinforcement part (15, 115) in a support state in which the retention unit stops the end of the reinforcement part in a direction perpendicular to the

plate.

5. The assembly as claimed in one of claims 2 to 4, wherein the retention unit can co-operate with the end of the reinforcement part in a securing state in which the retention unit secures the reinforcement part (15, 115) on the anchorage part (30), such that the reinforcement part is retained on the plate solely by the effect of the anchorage part.

6. The assembly as claimed in one of claims 2 to 5, wherein the anchorage part comprises an arm (40) which is connected to the attachment unit, and wherein the retention unit (44) of the anchorage part is placed at the end of the arm (40), the arm being placed such as to extend in the corrugation (6) in which the reinforcement part (15) must be retained by the retention unit, in the attached state of the anchorage part (30).

7. The assembly as claimed in claim 6, wherein the arm comprises a positioning unit (41) with a contour which is designed for a transverse profile of a corrugation of the plate, the positioning unit being able to co-operate with the plate at the level of the lateral walls of the corrugation (6), in order to position the arm in the corrugation, in the attached state of the anchorage part (30).

8. The assembly as claimed in one of claims 2 to 7, wherein the retention unit comprises a lug (44, 48) which can extend longitudinally in a corrugation of the plate, in the attached state of the anchorage part, the reinforcement part comprising a receptacle (18) which is open at the level of a longitudinal end surface of the reinforcement part, and can receive the lug of the retention unit.

9. The assembly as claimed in claim 8, wherein the lug of the retention unit comprises a thickened portion (46), which can co-operate with the longitudinal end surface (49) of the reinforcement part, in order to stop the reinforcement part (15) longitudinally relative to the lug (44).

10. The assembly as claimed in claim 9, wherein the thickened portion (46) of the lug can be forced into the receptacle (18) of the reinforcement part, in order to secure the reinforcement part (15) firmly on the anchorage part (30), by resilient deformation of the thickened portion and/or of the receptacle of the reinforcement part.

11. The assembly as claimed in claim 10, wherein the anchorage part comprises a

stop unit (43) which can co-operate with the longitudinal end surface (49) of the reinforcement part, in order to limit the engagement of the lug (44) in the receptacle, beyond the thickened portion (46).

12. The assembly as claimed in one of claims 8 to 11, wherein the receptacle of the reinforcement part comprises a longitudinal groove (18) hollowed in an outer surface (17) of the reinforcement part which is designed to face opposite the plate.

13. The assembly as claimed in one of claims 2 to 12, wherein the attachment unit comprises a head (33) which can be attached to the outer surface of the plate (1) by resilient clearance of an undercut (4) of the plate, at the level of the intersection (3) of the corrugations.

14. The assembly as claimed in claim 13, wherein the anchorage part comprises a body (31) to which there is connected the or each retention unit (44) and a rod (32) which connects the head to the body whilst providing an empty space (39) between them.

15. The assembly as claimed in claim 14, wherein the rod (32) has a beveled form which narrows from the body (31) towards the head (33) of the anchorage part.

16. The assembly as claimed in one of claims 2 to 15, wherein said anchorage part is a first anchorage part comprising an attachment unit (32, 33) able to be attached to the plate at a first intersection between said corrugation in which the reinforcement part must be retained and a first other corrugation of the impermeable metal plate, wherein said corrugation in which the reinforcement part (15) must be retained further intersects a second other corrugation of the impermeable metal plate at a second intersection, and wherein the assembly additionally comprises a second anchorage part (130) comprising an attachment unit (32, 33) which can be attached to the outer surface of the plate at the second intersection (3) of the corrugation in which the reinforcement part (15) must be retained, and a retention unit (44) which can co-operate with a second longitudinal end of the reinforcement part, in order to retain the reinforcement part in the corrugation, the reinforcement part having a length which is designed for the distance between the retention units (44) of the two anchorage parts (30, 130) in the state of attachment to the plate, such that the reinforcement part is retained on the plate, between the two anchorage parts, by co-operation with the two retention units.

17. The assembly as claimed in one of claims 2 to 16, wherein the reinforcement part (15, 115) is constituted by a profiled body with a constant cross section.

18. A process for production of an impermeable wall structure comprising:
supplying an impermeable metal plate (1) with a series of first parallel corrugations (5) and a series of second parallel corrugations (6), the first corrugations intersecting with the second corrugations at the level of intersections (3), the corrugations projecting from the side of an inner surface of the plate;

arranging an anchorage part (30) comprising an attachment unit (32, 33) and a retention unit (44), such as to attach the attachment unit to an outer surface of the plate opposite the inner surface at the level of one of the intersections;

arranging an elongate reinforcement part (15) in a segment of one of the corrugations of the impermeable metal plate which meet at the intersection where the anchorage part is attached on the outer surface of the plate, such as to make a longitudinal end of the reinforcement part co-operate with the retention unit (44).

19. The process as claimed in claim 18, wherein said anchorage part is a first anchorage part attached to the impermeable plate at a first intersection between the corrugation in which the reinforcement part is arranged and a first other corrugation of the impermeable plate and wherein the process additionally comprises:

arranging a second anchorage part (130) comprising an attachment unit and a retention unit, such as to attach the attachment unit to the outer surface of the plate at a second intersection (3) between the corrugation in which the reinforcement part is arranged and a second other corrugation of the impermeable metal plate in the vicinity of the first intersection where the first anchorage part (30) is attached;

wherein the reinforcement part is arranged in the corrugation segment (14) which extends between the two intersections and is retained on the plate (1), between the two anchorage parts, by co-operation of the two longitudinal ends of the reinforcement part (15) with the two retention units (44).

20. The process as claimed in claim 18, additionally comprising:
securing the end of the reinforcement part (15) on the retention unit (44), such that the reinforcement part is retained on the plate solely by the effect of the anchorage part (30).

21. The process as claimed in claim 20, wherein the reinforcement part (15) is arranged in a corrugation segment (51) which extends between the intersection (3) where

the anchorage part is attached, and an edge of the plate (52), and extends from the edge of the plate in order to be able to be engaged in a corrugation of an adjacent plate (55).

22. The process as claimed in claim 18, additionally comprising:

attaching anchorage parts (30) comprising in each case an attachment unit and four units for retention on the outer surface of the plate, at the level of all the intersections (3) of the plate (1); and

arranging reinforcement parts (15, 115) in all the corrugation segments which extend in each case between two intersections, by making in each case two longitudinal ends of the reinforcement part co-operate with two retention units (44) of the two anchorage parts which are attached at the level of the two intersections (3), such as to retain the reinforcement parts on the plate.

23. The process as claimed in claim 22, additionally comprising:

arranging reinforcement parts (15, 115) in all the corrugation segments which extend between an edge of the plate (52) and intersections adjacent (3) to said edge of the plate; and

securing in each case the end of the reinforcement part on a retention unit (44) of the anchorage part attached at the level of the corresponding intersection, such that the reinforcement part is retained on the plate solely by the effect of the anchorage part extending from the edge of the plate (52).

24. An impermeable insulating vessel (71) arranged in a support structure, the vessel comprising a thermal insulation barrier and an impermeable barrier which is designed to be in contact with a product contained in the vessel, the impermeable barrier comprising a ready-to-mount assembly as claimed in one of claims 2 to 17, in a mounted state.

25. A ship (70) for the transport of a cold liquid product, the ship comprising a double hull (72) and a vessel (71) as claimed in claim 24, arranged in the double hull.

26. The use of a ship (70) as claimed in claim 25 for loading or unloading of a cold liquid product, wherein a cold liquid product is conveyed through insulated piping (73, 79, 76, 81) from or to a floating or land storage installation (77), to or from the vessel of the ship (71).

27. A transfer system for a cold liquid product, the system comprising a ship (70) as

claimed in claim 25, insulated piping which is placed such as to connect the vessel (71) installed in the hull of the ship to a floating or land storage installation (77), and a pump to convey a flow of cold liquid product through the insulated piping from or to the floating or land storage installation, to or from the vessel of the ship.