

## **Self-supporting box structure for the thermal insulation of a fluid storage tank**

### **Prior art**

- 5 The invention relates to the field of sealed and thermally-insulating storage tanks, comprising membranes, for the storage and/or the transport of fluid such as a cryogenic fluid.
- 10 Sealed and thermally-insulated storage tanks comprising membranes are used, in particular, for the storage of liquefied natural gas (LNG) which is stored at atmospheric pressure, at approximately  $-162^{\circ}\text{C}$ . These storage tanks may be positioned on land or on a
- 15 floating installation. In the case of a floating installation, the tank may be designed for the transport of liquefied natural gas or to receive liquefied natural gas used for fuel for the propulsion of the floating installation.
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### **Technical background**

- The document FR 2 877 638 discloses a sealed and thermally-insulated storage tank comprising a tank wall, fixed to the load-bearing structure of a floating
- 25 installation and successively having, in the thickness direction from the inside to the outside of the tank, a primary sealed barrier designed to be in contact with the liquefied natural gas, a primary insulating barrier, a secondary sealed barrier and a secondary
- 30 insulating barrier, anchored to the load-bearing structure.

The insulating barriers consist of a plurality of juxtaposed parallelepipedal insulating box structures.

The parallelepipedal box structures comprise a bottom panel made of plywood, a top panel made of plywood, a thermally-insulating lining arranged in the form of a layer parallel to the tank wall and load-bearing elements which extend upward through the thickness of the thermally-insulating lining to absorb the compressive stresses between the top panel and the bottom panel.

During operation, the walls of the tank are subjected to numerous stresses. In particular, the walls are subjected to compressive stresses due to the loading of the tank, to thermal stresses during the cooling and to stresses due to dynamic impacts of the fluid contained in the tank. In addition, stresses are exerted tangentially to the top panels of the insulating box structures and are thus liable to cause the toppling of the load-bearing elements of the insulating box structures.

Moreover, the section of load-bearing elements is generally small in order to limit the thermal conductivity through the load-bearing elements. However, load-bearing elements of small section are liable to damage the top and bottom panels by puncturing said panels.

Also disclosed in a document WO 2013124597 is an insulating box structure, wherein the load-bearing elements interposed between the bottom and top panels each comprise a range of pillars, upper and lower plates arranged on the row of pillars and respectively bearing against the top panel and the bottom panel, upper lateral reinforcements fixed to the pillars and

to the upper plate and lower lateral reinforcements fixed to the pillars and to the lower plate. The upper and lower lateral reinforcements permit the toppling of the pillars to be avoided.

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### **Summary**

One idea underlying the invention is to propose an insulating self-supporting box structure which has a good thermal insulating performance whilst having high strength relative to stresses and, in particular, relative to stresses exerted tangentially and at right angles to the walls.

According to one embodiment, the invention provides a self-supporting insulating box structure designed for the thermal insulation of a fluid storage tank comprising:

- a bottom panel and a top panel which are spaced apart in a thickness direction of the box structure;
- 20 - load-bearing elements interposed between said bottom panel and top panel and each comprising a bottom foot fixed to the bottom panel, a top foot fixed to the top panel and a pillar, fixed to the bottom foot and top foot, and extending in the thickness direction of the box structure between the top foot and the bottom foot;
- 25 and

- an insulating lining arranged between the load-bearing elements;

wherein the feet each comprise:

- 30 - a load-spreading sole provided with a planar bearing surface bearing against the bottom panel or the top panel; and
- anti-topple ribs uniformly distributed on the periphery of the foot and arranged so as to absorb the

stresses exerted on the load-bearing element transversely to the thickness direction of the box structure and to transmit said stresses to the load-spreading sole.

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In this manner, such feet enable the puncturing of the top panel and the bottom panel to be avoided due to the load-spreading sole of said feet. Moreover, the strength of the box structure relative to lateral stresses and bending stresses is reinforced by the presence of ribs counteracting the toppling of the load-bearing elements.

According to the embodiments, such an insulating box structure may comprise one or more of the following features:

- the feet comprise a body extending in the thickness direction of the box structure and wherein the anti-topple ribs have an angled shape having two faces forming a right angle extending respectively against the load-spreading sole and against the body of the foot.

- the feet are produced in a thermoplastic material and are fixed by thermoplastic welding to a thermoplastic element of the bottom panel or the top panel. Thus, the load-bearing elements may be assembled to the bottom panel and/or the top panel in a simple and reliable manner, since no fixing member is present to reduce the structural integrity of the load-bearing elements or the top and bottom panels.

- the feet are produced in a composite thermoplastic material comprising a thermoplastic matrix and reinforcing fibers.

- the bottom panel and the top panel each have an internal face facing the interior of the box structure, the internal faces of the bottom panel and the top panel being covered with thermoplastic films for the fixing of the feet of the load-bearing elements.
- the thermoplastic films are produced in a composite thermoplastic material comprising a thermoplastic matrix and reinforcing fibers.
- the bottom panel and/or the top panel comprises a body produced in a composite thermoplastic material comprising a fiber-reinforced thermoplastic matrix, said body forming a thermoplastic element for fixing the feet of the load-bearing elements.
- the bottom panel and/or the top panel comprises a body made of wood impregnated with a thermoplastic matrix for fixing the feet of the load-bearing elements.
- the feet of each load-bearing element are formed in one piece with the pillar of the load-bearing element.
- the feet of a load-bearing element each comprise a sleeve, one end of a pillar of the load-bearing element being nested therein.
- the feet comprise two half-shells which together define the sleeve, one end of a pillar being nested therein.
- the feet are produced in a thermoplastic material and the pillars are produced in a thermoplastic material and comprise ends fixed by thermoplastic welding, respectively inside the sleeve of the bottom foot and inside the sleeve of the top foot.
- the pillars are produced in a composite thermoplastic material comprising a thermoplastic matrix and reinforcing fibers.
- the pillars are made of wood.

- the insulating box structure has a parallelepipedal shape and each foot comprises at least four uniformly distributed anti-topple ribs, each of said anti-topple ribs being arranged in parallel on two opposing sides of the self-supporting insulating box structure.
- the load-spreading soles have a notch between each anti-topple rib.
- the feet comprise a reinforcing collar extending toward the inside of the box structure from the load-spreading sole.
- the insulating box structure further comprises anti-topple reinforcing structures, each comprising two bars arranged diagonally in an X-shape and each extending between a bottom foot and a top foot of two adjacent load-bearing elements.
- the insulating lining consists of at least one block of glass wool, wadding or polymer foam.
- the insulating lining is a bulk insulating material selected from perlite, vermiculite, glass wool or aerogels and said insulating box structure comprises peripheral partitions extending in the thickness direction of the box structure permitting the insulating lining to be retained.
- the peripheral partitions are produced in a thermoplastic material and are fixed by thermoplastic welding to a thermoplastic element of the bottom panel or the top panel.

According to one embodiment, the invention also provides a sealed and thermally-insulating fluid storage tank consisting of a thermally-insulating barrier, comprising a plurality of the aforementioned juxtaposed box structures and a sealing membrane bearing against the thermally-insulating barrier. Such

a tank may be produced with a single sealing membrane or with two sealing membranes alternating with two thermally-insulating barriers.

5 Such a tank may form part of a land-based storage installation, for example to store LNG, or may be installed in a floating structure, onshore or offshore, in particular an LNG carrier, a floating storage and regasification unit (FSRU), a floating production,  
10 storage and offloading unit (FPSO) and the like.

According to one embodiment, a marine vessel for the transport of a cold fluid comprises a double hull and a tank as mentioned above arranged in the double hull.

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According to one embodiment, the invention also provides a method for the supply and discharge of such a marine vessel, wherein a fluid is conducted through insulated pipelines from or to a floating or land-based  
20 storage installation to or from the tank of the marine vessel.

According to one embodiment, the invention also provides a system for transferring a fluid, the system  
25 consisting of the aforementioned marine vessel, insulated pipelines being arranged so as to connect the tank installed in the hull of the marine vessel to a floating or land-based storage installation and a pump for driving a fluid through the insulated pipelines  
30 from or to the floating or land-based storage installation to or from the tank of the marine vessel.

Certain features of the invention refer to the idea of providing an insulating box structure where the

stresses are transmitted in a uniform manner. Certain features of the invention refer to the idea of providing an insulating box structure which is easy to manufacture.

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**Brief description of the drawings**

The invention will be understood more clearly, and further objects, details, features and advantages thereof will appear more clearly during the following  
10 description of several particular embodiments of the invention provided solely by way of illustration and in a non-limiting manner, with reference to the accompanying drawings.

15 • figure 1 is a perspective cut-away view of a tank wall according to one embodiment.

• figure 2 is a sectional view of an insulating tank according to one embodiment.

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• figure 3 is a perspective view of a foot of a load-bearing element according to one embodiment.

• figures 4 and 5 are respectively a plan view and  
25 front view of the foot of figure 3.

• figures 6 and 7 are respectively a view in perspective and a front view of a load-bearing element comprising a pillar, one end thereof being nested in a  
30 foot.

• figure 8 is a sectional view of an insulating box structure according to one embodiment comprising anti-topple devices consisting of two bars forming an X-

shape and extending between the feet of two adjacent load-bearing elements.

• figure 9 is a schematic perspective view of a load-bearing element according to one embodiment comprising  
5 a pillar, one end thereof being nested in a foot.

• figure 10 is a partial view in perspective of a load-bearing element according to a third embodiment.

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• figure 11 is a detailed view of a foot of the load-bearing element of figure 10.

• figures 11 to 14 illustrate feet according to three  
15 further variants.

• figure 15 is a schematic cut-away view of a tank of an LNG carrier and a terminal for the supply and discharge of said tank.

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#### **Detailed description of embodiments**

In the description and the claims, the generic term "thermoplastic" is used to denote, unless specified to the contrary, both composite fiber-reinforced  
25 thermoplastic materials and non-reinforced thermoplastic materials.

In figure 1, a wall of a sealed and thermally-insulating tank is shown. The overall structure of such  
30 a tank is well known and has a polyhedral shape. Thus, only a wall zone of the tank has to be described, given that all of the walls of the tank may have a similar overall structure.

The wall of the tank comprises, from the outside to the inside of the tank, a load-bearing structure 1, a secondary thermally-insulating barrier 2 which is formed from juxtaposed insulating box structures 3 on the load-bearing structure 1 and anchored thereto by secondary retaining members 4, a secondary sealing membrane 5 borne by the insulating box structures 3, a primary thermally-insulating barrier 6 formed from juxtaposed insulating box structures 7 and anchored to the secondary sealing membrane 5 by primary retaining members 8 and a primary sealing membrane 9 borne by the insulating box structures 7 and designed to be in contact with the cryogenic fluid contained in the tank.

The load-bearing structure 1 may, in particular, be a self-supporting metal sheet or more generally any type of rigid partition having appropriate mechanical properties. The load-bearing structure may, in particular, be formed by the hull or the double hull of a marine vessel. The load-bearing structure comprises a plurality of walls defining the overall shape of the tank.

The primary 9 and secondary 5 sealing membranes, for example, consist of a continuous layer of metal plates with raised edges, said plates being welded by their raised edges to parallel weld supports maintained on the insulating box structures 3, 7. The metal plates are, for example, produced from Invar ®: i.e. an alloy of iron and nickel, the coefficient of expansion thereof being typically between  $1.2 \times 10^{-6}$  and  $2 \times 10^{-6} \text{ K}^{-1}$  or in an iron alloy of high manganese content, the coefficient of expansion thereof being typically in the order of  $7 \times 10^{-6} \text{ K}^{-1}$ .

The insulating box structures 3, 7 have an overall shape of a parallelepipedal rectangle. The insulating box structures 3 of the secondary thermally-insulating barrier 2 and the insulating box structures 7 of the primary thermally-insulating barrier 6 may variously have identical or different structures and equal or different dimensions.

Figure 2 illustrates the structure of an insulating box structure 3, 7. The insulating box structure 3, 7 comprises a bottom panel 10 and a top panel 11 which are parallel, spaced apart in the thickness direction of the insulating box structure 3, 7. The bottom panel 10 and the top panel 11 are planar and define the principal faces of the insulating box structure 3, 7.

The top panel 11 has an external support surface permitting the primary 9 or secondary 5 sealing membrane to be received. Moreover, the top panel 11 has grooves 12 on its external face for the housing of the welding supports, permitting the metal plates of the primary 9 or secondary 5 sealing membranes to be welded.

Load-bearing elements 13 extend in the thickness direction of the insulating block 3, 7 and are fixed, on the one hand, to the bottom panel 10 and, on the other hand, to the top panel 11. The load-bearing elements 13 permit the compressive stresses to be absorbed. The load-bearing elements 13 are aligned in a plurality of rows and distributed in a staggered manner. The distance between the load-bearing elements 13 is determined so as to permit an effective

distribution of compressive stresses. In one embodiment, the load-bearing elements 13 are distributed in an equidistant manner.

5 The load-bearing elements 13 comprise a pillar 14 extending in the thickness direction of the insulating box structure 3, 7 between, on the one hand, a bottom foot 15 resting against the bottom panel 10 and fixed thereto and, on the other hand, a top foot 16 bearing  
10 against the top panel 11 and fixed thereto.

An insulating lining 17 extends in the spaces made between the load-bearing elements 13. The insulating lining 17 consists, for example, of glass wool, wadding  
15 or a polymer foam, such as polyurethane foam, polyethylene foam or polyvinyl chloride foam. Such a polymer foam may be arranged between the pillars 14 by an injection operation during manufacture of the insulating box structure 3, 7. Alternatively, it is  
20 possible to produce the insulating lining 17 by creating orifices for receiving the load-bearing elements 13 in a precut block of polymer foam, glass wool or wadding.

25 According to further embodiments, the insulating lining 17 consists of a bulk insulating material. Such an insulating material may be a granular or powder material - such as perlite, vermiculite or glass wool - or a nanoporous material of the aerogel type. In this  
30 case, the insulating box structure 3, 7 is provided with peripheral partitions, not shown, extending in the thickness direction of the box structure, over the periphery thereof and permitting the insulating lining 17 to be retained.

According to a variant, the peripheral partitions are plywood planks which are fixed to the bottom panel 10 and to the top panel 11. The fixing of the partitions  
5 may, in particular, be implemented by bonding, stapling, tack welding and/or screwing. Two opposing lateral partitions are provided with drilled holes permitting an inerting gas to be circulated. To avoid the leakage of insulating lining through said drilled  
10 holes, a fabric permeable to gas, such as glass fiber fabric, is bonded to the internal surface of the lateral partitions in front of the drilled holes.

According to a further variant, the peripheral  
15 partitions are produced in a thermoplastic material and are fixed to the bottom panel 10 and the top panel 11 by thermoplastic welding. In this case, as will be described in detail below, the panels 10, 11 are either covered with a thermoplastic film, are produced in a  
20 composite thermoplastic material or comprise a wooden body impregnated with a thermoplastic matrix, in order to permit the thermoplastic welding operations. The peripheral partitions may, in particular, consist of a thermoplastic strip having a thickness of between 0.1  
25 and 1 millimeter or a thermoplastic film. In this case, as mentioned above, two lateral partitions are provided with drilled holes which are covered by a fabric permeable to gas. Alternatively, the peripheral partitions consist of a thermoplastic fabric permeable  
30 to gas. Optionally, the thermoplastic material of the peripheral partitions comprises a fiber-reinforced thermoplastic matrix. Such a material may, in particular, be a material denoted by the initials GMT for "glass fiber mat reinforced thermoplastics". A GMT

material is made up from an assembly comprising a glass mat and a matrix in the form of a thermoplastic polymer mat commingled in the glass mat and thus forming a fabric designed to be hot-pressed. By way of example, 5 such a material is marketed by Vetrotex under the brand name Twintex ®.

In relation to figures 3 to 5, the structure of a foot 15, 16 according to one embodiment will now be 10 described.

The feet 15, 16 comprise a load-spreading sole 17. The load-spreading sole is provided with a planar bearing surface bearing against the bottom panel 10 or the top 15 panel 11. The load-spreading sole 17 provides a bearing surface greater than the section of a pillar 14. Thus, the load-spreading soles 17 prevent a concentration of stresses over a small section and thus enable damage to the bottom panel 10 and top panel 11 by puncturing to 20 be limited.

The foot 15, 16 also comprises a body 18 extending in the thickness direction of the box structure 3, 7. The body 18 of the foot is hollow so as to define a sleeve 25 19 designed to receive by nesting one end of the pillar 14. As the sleeve 19 is designed here to receive a cylindrical pillar 14, it has a generally cylindrical shape.

30 Moreover, the foot 15, 16 is provided with anti-topple ribs 20 uniformly distributed over the periphery of the foot 15, 16. The anti-topple ribs 20 make it possible to counteract a toppling effect, affecting the load-bearing element 13 when it is subjected to a bending

moment. To achieve this, the anti-topple ribs 20 are capable of absorbing the stresses exerted on the load-bearing element 13 transversely to its longitudinal direction and to transmit said stresses to the load-spreading sole 17. The anti-topple ribs 20 are made of the same material as the load-spreading sole 17 and the body 18 of the foot 15, 16. The anti-topple ribs 20 have a generally angled shape, the faces thereof 20a, 20b being arranged perpendicularly and forming the right angle extending respectively along the load-spreading sole 17 and along the body 18 of the foot 15, 16. The load-spreading sole 17 is provided with notches 21 extending between each of the anti-topple ribs 20.

In the embodiment shown, each foot 15, 16 comprises four anti-topple ribs 20. Each anti-topple rib 20 extends, therefore, in a plane perpendicular to the plane of the adjacent ribs 20. The feet 15, 16 are advantageously arranged relative to the bottom panel 10 and the top panel 11 so that each of said ribs 20 is arranged in parallel on two opposing sides of the insulating box structure 3, 7.

The foot 15, 16 is produced by molding a thermoplastic material. According to one embodiment, the thermoplastic material comprises a fiber-reinforced thermoplastic matrix. The thermoplastic matrix may comprise any appropriate thermoplastic material, such as polypropylene (PP), polyethylene (PE), polyamides (PA), polyethylenimine (PEI), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), acrylonitrile butadiene-styrene copolymer (ABS), polyurethane (PU) in its thermoplastic form, a mixture of these polymers or the like. The

fibers may be glass fibers, carbon fibers or a mixture of carbon fibers and glass fibers. The foot 15, 16 may, in particular, be produced in a GMT material, as disclosed above.

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The foot 15, 16 shown in figures 3 to 5, consists of two identical molded parts 22a, 22b. Each of these parts 22a, 22b forms a half-shell which, when the two parts 22a, 22b are combined, define the sleeve 19  
10 designed to receive one end of a pillar 14. Such a foot structure 15, 16 consisting of two molded parts 22a, 22b, permits the molding operations of the feet 15, 16 and the operations of positioning the feet 15, 16 against the bottom panel 10 or the top panel 11 to be  
15 facilitated.

In a further embodiment, the foot 15, 16 consists of a single one-piece molded part. Moreover, in a further embodiment, the feet 15, 16 of each load-bearing  
20 element 13 are formed in one piece with the pillar 14. In other words, the assembly of the load-bearing element 13 is a single part molded in one piece.

In order to ensure the assembly of the load-bearing  
25 elements 13 to the bottom panel 10 and the top panel 11, the feet 15, 16 are fixed by a thermoplastic welding operation to the bottom panel 10 and the top panel 11.

30 In the embodiment illustrated in figure 2, the bottom panel 10 and the top panel 11 have a body made of plywood. The internal faces of the bottom panel 10 and the top panel 11 facing the inside of the box structure 3, 7 are covered by thermoplastic films 23. A plastic

welding operation is implemented in the interface zones between the thermoplastic films 23 and the load-spreading soles 17 of the feet 15, 16.

- 5 In one embodiment, before proceeding with the welding operations, protective shields are first arranged on the internal faces of the bottom panel 10 and the top panel 11 between the interface zones between the load-bearing elements 13 and the panels 10, 11. When the  
10 welding operations have been carried out, the protective shields may then be removed. Thus, the thermoplastic films 23 are not damaged during the welding operations. Such protective shields are, for example, produced in metal, ceramic and/or glass  
15 materials. Such shields are advantageously provided with a cooling circuit in which a fluid circulates, such as water, air or oil in order to regulate the temperature of said shields.
- 20 According to a variant, not illustrated, the external face of the bottom panel 10 and top panel 11 is also covered by thermoplastic films. Such an arrangement permits the flexion of the top panel 11 and the bottom panel 10 to be equalized, in particular when they are  
25 subjected to significant thermal stresses when the tank is cooled.

According to a further variant, not illustrated, the thermoplastic films only partially cover the internal  
30 faces of the bottom panel 10 and the top panel 11. In this case, the thermoplastic films are only arranged in the interface zones between the bottom panel 10 and the top panel 11 and the feet 15, 16.

The thermoplastic films 23 are produced, for example, in a composite thermoplastic material comprising a fiber-reinforced thermoplastic matrix. The thermoplastic films 23 may, in particular, be produced in a GMT material. Thus, such thermoplastic films contribute to the increase in mechanical strength of the bottom panel 10 and the top panel 11, by increasing their bending stiffness and improving their resistance to puncturing. Such thermoplastic films 23 typically have a thickness in the order of 0.5 to 5 mm.

In one embodiment, the thermoplastic films 23 are fixed to the body of the bottom panel 10 and the top panel 11 by bonding. The adhesive used is, for example, an acrylic adhesive, a polyurethane adhesive or an epoxy adhesive. In a further embodiment, the thermoplastic films 23 are fixed to the body of the panels 10, 11 by a hot pressing method. In such a case, it is conceivable to incorporate the fixing of the thermoplastic films 23 directly into the method for manufacturing the plywood. To achieve this, the previously-bonded plies of wood and the thermoplastic films 23 are superimposed and then the stack thus obtained is subjected to hot-pressing. By way of example, for such a hot-pressing process, the stack is subjected to a temperature in the order of 190 to 200°C and to a pressure in the order of 0.2 MPa for a duration of 5 minutes.

In order to facilitate the welding operations, the thermoplastic films 23 comprise a thermoplastic matrix which is identical to the thermoplastic matrix of the feet 15, 16.

In a further embodiment, it is the body of the bottom panel 10 and the top panel 11, as such, which form the thermoplastic element for fixing the feet 15, 16. According to a first variant, the bottom panel 10 and  
5 top panel 11 comprise a body produced in a composite material comprising a fiber-reinforced thermoplastic matrix, which is identical to that of the feet. According to a second variant, the bottom panel 10 and top panel 11 are manufactured in a body made of wood,  
10 impregnated with a thermoplastic matrix of the same type as that of the feet 15, 16. The body may be manufactured by an agglomeration of fibers previously impregnated with a thermoplastic matrix. Alternatively, the body may be produced in plywood, the internal ply  
15 thereof and optionally the external ply thereof being manufactured in a wood which is sufficiently porous to diffuse the plastic matrix under heat and under pressure inside said plies. Such a wood is, for example, selected from birch, pine, beech or the like.

20 The welding operation is, for example, carried out by infrared radiation. However, it is possible to use any other appropriate plastic welding method, such as ultrasonic welding, induction heating, friction  
25 welding, fusion welding, hot air welding or flame treatment. It should be mentioned that in the case of induction welding it is necessary to use metal inserts on the feet 15, 16 and/or on the bottom panel 10 and/or top panel 11, at the interface between the feet 15, 16  
30 and the bottom panel 10 and top panel 11 so as to permit heating of the thermoplastic material.

Figures 6 and 7 show a pillar 14, one end thereof being nested in the sleeve 19 of a foot 15, 16.

According to one embodiment, the pillars 14 are produced in a thermoplastic material. The thermoplastic material is advantageously a composite thermoplastic material comprising a fiber-reinforced thermoplastic matrix. The examples of material and fibers provided above in relation to the feet 15, 16 are also applicable to the pillars 14. The pillars 14 are fixed to the feet 15, 16 by a thermoplastic welding operation. Thus, in order to facilitate the welding operations, the pillars 14 could be formed in a material comprising a thermoplastic matrix which is identical to the thermoplastic matrix of the feet 15, 16. It is possible to ensure the fixing of the pillars 13 to the feet 15, 16 before fixing the feet 15, 16 to the bottom panel 10 and top panel 11, or conversely, to ensure the fixing of the feet 15, 16 to the bottom panel 10 and to the top panel 11 before fixing the pillars 14 to the feet 15, 16. This last variant is particularly advantageous in that it permits a prepositioning of the feet 15, 16 and thus facilitates the manufacture of insulating box structures 3, 7. According to a further variant, it is conceivable to fix simultaneously by thermoplastic welding, a foot 15, 16 to a panel 10, 11 and to a pillar 14.

It is noteworthy that in the embodiment shown in figures 6 and 7, the pillars 14 have a hollow section of circular shape. However, the invention is not limited to this type of section, and the section of the pillars may also be solid and have a different shape: square, lozenge or rectangular for example. When the section of a pillar 14 is hollow, said pillar is advantageously lined with an insulating material in

order to limit the thermal losses through the pillar 14.

By way of example, in the embodiment shown in figure 9,  
5 the pillars 14 have a solid section of square shape. Such pillars of solid section may also have a section of lozenge or rectangular shape.

Moreover, it is noteworthy that the pillars 14 may be  
10 produced in various materials. Thus, apart from the thermoplastic materials mentioned above, the pillars 14 may also be produced in wood or thermosetting plastic, such as polyurethane (PU), unsaturated polyesters, epoxides, acrylics, vinylesters or the like. Such  
15 thermosetting plastic materials may, in particular, be fiber-reinforced. In these cases, since the pillars 14 are not able to be fixed to the feet 15, 16 by thermoplastic welding, the pillars 14 are fixed to the feet 15, 16 by any other means. By way of example, the  
20 fixing of the pillars 14 to the feet 15, 16 may be carried out, in particular, by bonding, stapling or by means of screws passing through orifices made in the feet 15, 16 and in the pillars 14.

25 In figure 10, the load-bearing element 13 comprises a pillar 14 of solid section of square shape, one end thereof being received by nesting in a sleeve 19 formed in the body 18 of the foot. The sleeve 19 has, therefore, a square section defined by four walls. The  
30 foot 15, 16 shown in detail in figure 11 comprises four ribs 20 having a generally angled shape, each extending along one of the four walls. The foot 15 comprises a circular load-spreading sole 17.

Moreover, the foot comprises a reinforcing collar 27, of annular shape, protruding toward the interior of the box structure 3, 7 from the load-spreading sole 17. The reinforcing collar 27 is arranged about the body 18 of the foot and extends substantially half-way between the body 18 of the foot and the periphery of the load-spreading sole 17. The reinforcing collar 27 is made in the same material as the load-spreading sole 17. In other words, the reinforcing collar 27 is formed in one piece with the load-spreading sole 17.

Figure 12 shows a foot 15, 16 according to a variant which only differs from the foot of figure 11 in that it does not comprise a reinforcing collar 27.

Figures 13 and 14 show feet 15, 16 respectively provided and not provided with a reinforcing collar 27. In these embodiments, the foot 15, 16 comprises two reinforcing ribs 20 extending along each of the four lateral walls defining the body 18 of the foot.

Figure 8 illustrates an embodiment wherein the insulating box structure 3, 7 further comprises anti-topple devices. The anti-topple devices consist of two bars 24, 25 forming an X-shape and extending diagonally between the feet 15, 16 of two adjacent load-bearing elements 13. The two bars 24, 25 may also be made of fiber-reinforced thermoplastic material and welded to the feet 15, 16 by thermoplastic welding operations. It is noteworthy that in the embodiment shown, the bars 25, 26 are welded to anti-topple ribs 20. Such an X-shaped structure permits a particularly high shear stiffness to be obtained, whilst having limited impact on the thermal insulation performance. According to a

variant, such anti-topple devices are only arranged along the lateral faces of the insulating box structure 3, 7. According to a further variant, such anti-topple devices may be arranged between all of the load-bearing elements 14.

With reference to figure 15, a cut-away view of an LNG carrier 70 shows a sealed and insulated tank 71 of generally prismatic shape mounted in the double hull 72 of the marine vessel. The wall of the tank 71 comprises a primary sealed barrier designed to be in contact with the LNG contained in the tank, a secondary sealed barrier arranged between the primary sealed barrier and the double hull 72 of the marine vessel and two insulating barriers respectively arranged between the primary sealed barrier and the secondary sealed barrier and between the secondary sealed barrier and the double hull 72.

In a manner known per se, supply/discharge pipelines 73 arranged on the upper bridge of the marine vessel may be connected by means of appropriate connectors to a marine or harbor terminal to transfer an LNG cargo from or to the tank 71.

Figure 15 shows an example of a marine terminal comprising a supply and discharge station 75, an underwater pipe 76 and a land-based installation 77. The supply and discharge station 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 carries a bundle of insulated flexible pipes 79 which are able to be connected to the supply/discharge pipelines 73. The mobile arm 74, which is able to be

oriented, is adapted to all types of LNG carriers. A connecting pipe, not shown, extends inside the tower 78. The supply and discharge station 75 permits the supply and discharge of the LNG carrier 70 from or to the land-based installation 77. Said land-based installation comprises tanks for storing liquefied gas 80 and connecting pipes 81 connected by the underwater pipe 76 to the supply or discharge station 75. The underwater pipe 76 permits the transfer of liquefied gas between the supply or discharge station 75 and the land-based installation 77 over a long distance, for example 5 km, which permits the LNG carrier 70 to be kept at a long distance from the coast during supply and discharge operations.

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To create the pressure necessary for the transfer of the liquefied gas, pumps mounted on board the marine vessel 70 and/or pumps provided at the land-based installation 77 and/or pumps provided at the supply and discharge station 75 are used.

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Although the invention has been described in connection with several particular embodiments, it is obvious that it is not limited thereby in any respect and it comprises all the technical equivalents of the means disclosed, in addition to combinations thereof if they fall within the scope of the invention.

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The use of the verbs "to consist of" "to comprise" or "to include" and their conjugated forms does not exclude the presence of other elements or other steps from those cited in a claim. The use of the indefinite article "a" or "an" for an element or a step does not

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exclude, unless indicated to the contrary, the presence of a plurality of such elements or steps.

In the claims, any reference between parentheses should  
5 not be interpreted as a limitation to the claim.

## Claims

1. A self-supporting insulating box structure (3, 7) designed for the thermal insulation of a fluid storage tank comprising:
  - a bottom panel (10) and a top panel (11) which are spaced apart in a thickness direction of the box structure;
  - load-bearing elements (13) interposed between said bottom panel (10) and top panel (11) and each comprising a bottom foot (15) fixed to the bottom panel (10), a top foot (16) fixed to the top panel (11) and a pillar (14), fixed to the bottom foot (15) and top foot (16), and extending in the thickness direction of the box structure between the bottom foot (15) and the top foot (16); and
  - an insulating lining (17) arranged between the load-bearing elements (13);wherein the feet (15, 16) each comprise:
  - a load-spreading sole (17) provided with a planar bearing surface bearing against the bottom panel (10) or the top panel (11);said self-supporting insulating box structure (3, 7) being characterized in that the feet (15, 16) each comprise anti-topple ribs (20) uniformly distributed on the periphery of the foot (15, 16) and arranged so as to absorb the stresses exerted on the load-bearing element (13) transversely to the thickness direction of the box structure and to transmit said stresses to the load-spreading sole (17).
2. The self-supporting insulating box structure (3, 7) as claimed in claim 1, wherein the feet (15,

- 16) comprise a body (18) extending in the thickness direction of the box structure (3, 7) and wherein the anti-topple ribs (20) have an angled shape having two faces (20a, 20b) forming a right angle extending respectively against the load-spreading sole (17) and against the body (18) of the foot (15, 16).
3. The self-supporting insulating box structure (3, 7) as claimed in claim 1 or 2, wherein the feet (15, 16) are produced in a thermoplastic material and are fixed by thermoplastic welding to a thermoplastic element (23) of the bottom panel (10) or the top panel (11).
4. The self-supporting insulating box structure (3, 7) as claimed in claim 3, wherein the feet (15, 16) are produced in a composite thermoplastic material comprising a thermoplastic matrix and reinforcing fibers.
5. The self-supporting insulating box structure (3, 7) as claimed in claim 3 or 4, wherein the bottom panel (10) and the top panel (11) each have an internal face facing the interior of the box structure (3, 7), the internal faces of the bottom panel and the top panel being covered with thermoplastic films (23) for the fixing of the feet (15, 16) of the load-bearing elements (14).
6. The self-supporting insulating box structure (3, 7) as claimed in claim 5, wherein the thermoplastic films (23) are produced in a

composite thermoplastic material comprising a thermoplastic matrix and reinforcing fibers.

- 5 7. The self-supporting insulating box structure (3, 7) as claimed in claim 3 or 4, wherein the bottom panel (10) and/or the top panel (11) comprises a body produced in a composite thermoplastic material comprising a fiber-reinforced thermoplastic matrix, said body forming a  
10 thermoplastic element for fixing the feet (15, 16) of the load-bearing elements (14).
- 15 8. The self-supporting insulating box structure (3, 7) as claimed in claim 3 or 4, wherein the bottom panel (10) and/or the top panel (11) comprises a body made of wood impregnated with a thermoplastic matrix for fixing the feet (15, 16) of the load-bearing elements (14).
- 20 9. The self-supporting insulating box structure (3, 7) as claimed in any one of claims 1 to 8, wherein the feet (15, 16) of each load-bearing element (16) are formed in one piece with the pillar (14) of the load-bearing element (13).
- 25 10. The self-supporting insulating box structure (3, 7) as claimed in any one of claims 1 to 8, wherein the feet (15, 16) of a load-bearing element (13) each comprise a sleeve (19), one end of a pillar (14) of the load-bearing element (14) being nested  
30 therein.
11. The self-supporting insulating box structure (3, 7) as claimed in claim 10, wherein the feet (15,

16) comprise two half-shells (22a, 22b) which together define the sleeve (19), one end of a pillar (14) being nested therein.

5 12. The self-supporting insulating box structure (3, 7) as claimed in claim 10 or 11, wherein the feet (15, 16) are produced in a thermoplastic material and wherein the pillars (14) are produced in a thermoplastic material and comprise ends fixed, by  
10 thermoplastic welding, respectively inside the sleeve (19) of the bottom foot (15) and inside the sleeve (19) of the top foot (16).

13. The self-supporting insulating box structure (3,  
15 7) as claimed in claim 12, wherein the pillars (14) are produced in a composite thermoplastic material comprising a thermoplastic matrix and reinforcing fibers.

20 14. The self-supporting insulating box structure (3, 7) as claimed in claim 10 or 11, wherein the pillars are made of wood.

15. The self-supporting insulating box structure (3,  
25 7) as claimed in any one of claims 1 to 14, having a parallelepipedal shape and wherein each foot (15, 16) comprises at least four uniformly distributed anti-topple ribs (20), each of said anti-topple ribs (20) being arranged in parallel  
30 on two opposing sides of the self-supporting insulating box structure (3, 7).

16. The self-supporting insulating box structure (3, 7) as claimed in any one of claims 1 to 15,

wherein the load spreading soles (17) have a notch (21) between each anti-topple rib (20).

17. The self-supporting insulating box structure (3,  
5 7) as claimed in any one of claims 1 to 16,  
wherein the feet (15, 16) comprise a reinforcing  
collar (27) extending toward the inside of the box  
structure (3, 7) from the load-spreading sole  
(17).
- 10 18. The self-supporting insulating box structure (3,  
7) as claimed in any one of claims 1 to 17,  
comprising anti-topple reinforcing structures,  
each comprising two bars (24, 25) arranged  
15 diagonally in an X-shape and each extending  
between a bottom foot (15) and a top foot (16) of  
two adjacent load-bearing elements (14).
19. The self-supporting insulating box structure (3,  
20 7) as claimed in any one of claims 1 to 18,  
wherein the insulating lining (17) consists of at  
least one block of glass wool, wadding or polymer  
foam.
- 25 20. The self-supporting insulating box structure (3,  
7) as claimed in any one of claims 1 to 18,  
wherein the insulating lining is a bulk insulating  
material selected from perlite, vermiculite, glass  
wool or aerogels and wherein said insulating box  
30 structure (3, 7) comprises peripheral partitions  
extending in the thickness direction of the box  
structure (3, 7) permitting the insulating lining  
(17) to be retained.

21. The self-supporting insulating box structure (3,  
7) as claimed in claim 20, wherein the peripheral  
partitions are produced in a thermoplastic  
material and are fixed by thermoplastic welding to  
5 a thermoplastic element (23) of the bottom panel  
(10) or the top panel (11).
22. A sealed and thermally insulating fluid storage  
tank comprising a thermally insulating barrier  
10 comprising a plurality of juxtaposed box  
structures (3, 7) as claimed in any one of claims  
1 to 21, and a sealing membrane bearing against  
the thermally-insulating barrier.
- 15 23. A marine vessel (70) for the transport of a fluid,  
the marine vessel comprising a double hull (72)  
and a tank (71) as claimed in claim 22, arranged  
in the double hull.
- 20 24. A method for loading or unloading a marine vessel  
(70) as claimed in claim 23, wherein a fluid is  
conducted through insulated pipelines (73, 79, 76,  
81) from or to a floating or land-based  
installation (77) to or from the tank of the  
25 marine vessel (71).
25. A system for transferring a fluid, the system  
consisting of a marine vessel (70) as claimed in  
claim 23, insulated pipelines (73, 79, 76, 81)  
30 being arranged so as to connect the tank (71)  
installed in the hull of the marine vessel to a  
floating or land-based storage installation (77)  
and a pump for driving a fluid through the  
insulated pipelines from or to the floating or

land-based storage installation to or from the  
tank of the marine vessel.