

SEALED AND THERMALLY INSULATING TANK WALL COMPRISING SPACED-APART SUPPORT ELEMENTS

The invention relates to the field of producing sealed and thermally
5 insulating tanks. In particular, the present invention relates to tanks which are
intended for the storage or transport of hot or cold liquids, for example, tanks
for the storage and/or transport of liquefied gas by sea.

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

A tank for storing hot or cold products in a ship is in particular
described in document FR2877638. The tank comprises a tank wall which
15 has, from the inner side to the outer side of the tank, a primary sealed barrier,
a primary insulating barrier, a secondary sealed barrier and a secondary
insulating barrier. The insulating barriers are constituted by thermally
insulating elements. The thermally insulating elements comprise a lining of
thermal insulation between a lower panel and a covering panel. Pillars
20 extend through the insulating lining between the covering panel and the
lower panel in order to form a thermally insulating element which has good
resistance to compression.

According to an embodiment, a tank wall comprises from the outer
25 side of the tank to the inner side of the tank:

- a carrier wall,
- a secondary thermal insulation barrier which is retained on the carrier wall,
the thermal insulation barrier being constituted by a plurality of secondary
thermally insulating elements which are juxtaposed so as to form a
30 secondary support surface,
- a primary thermal insulation barrier which is retained on the secondary
thermal insulation barrier, the primary thermal insulation barrier being

constituted by a plurality of primary thermally insulating elements which are juxtaposed in order to form a primary support surface,

a sealing barrier which is in abutment with the primary support surface,

each primary thermally insulating element and each secondary thermally

5 insulating element comprising:

a thermally insulating lining,

a plurality of carrier elements which extend through the thermally insulating lining perpendicularly to the tank wall, and

10 a panel which is parallel with the tank wall and which is arranged at an end of the carrier elements of the thermally insulating element in order to form an outer wall of the thermally insulating element,

wherein at least one from the panel of the primary thermally insulating element and the panel of the secondary thermally insulating element is arranged between the carrier elements of the primary insulation barrier and

15 the carrier elements of the secondary insulation barrier.

One of the carrier elements or a sub-group of the carrier elements, in particular the carrier elements which are not on the edges, or each carrier element from the plurality of carrier elements of the primary thermally insulating element is spaced apart relative to the subjacent carrier elements

20 of the secondary thermally insulating element in a view projected in a plane parallel with the tank wall. At least one carrier element from the plurality of carrier elements of the primary thermally insulating element is not superimposed on the subjacent carrier elements of the secondary thermally insulating element in a view projected in a plane parallel with the tank wall.

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

According to embodiments, each carrier element from the plurality of carrier elements of the primary thermally insulating element is positioned outside characteristic perimeters which surround the subjacent carrier elements of the secondary thermally insulating element.

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According to embodiments, the carrier elements are pillars having a small cross-section in the plane parallel with the tank wall relative to the dimensions of the thermally insulating element.

According to embodiments, the thermally insulating elements are
 5 parallelepipedal and the characteristic perimeter which surrounds a carrier element is rectangular, the perimeter comprising a first side which is parallel with a length direction of the thermally insulating element, and a second side which is parallel with a width direction of the thermally insulating element,
 10 the dimension of the first side of the perimeter being greater than or equal to double a first characteristic dimension of the cross-section of the pillar in the length direction of the thermally insulating element, and the dimension of the second side of the perimeter being greater than or equal to double a second characteristic dimension of the cross-section of
 15 the pillar in the width direction of the thermally insulating element.

According to embodiments, the pillars have a rectangular cross-section and the perimeter has a rectangular shape which is centered on the rectangular cross-section, the long sides of the perimeter being parallel with the long sides of the rectangular cross-section, the dimensions of the
 20 perimeter being equal to double the dimensions of the rectangular cross-section.

According to embodiments, the perimeters have a circular shape and are each centered on a pillar, the radius of the perimeter being equal to a characteristic diameter of the cross-section of the pillar.

25 According to embodiments, the pillars of a thermally insulating element are arranged in rows of pillars which are parallel with a side of the thermally insulating element, a row of pillars of the primary thermal insulation barrier being positioned in each case in the projected view halfway between two rows of pillars of the secondary thermal insulation barrier.

30 According to embodiments, a carrier element of the primary thermal insulation barrier is in each case arranged in the projected view in a position

located halfway between two adjacent carrier elements of the secondary thermal insulation barrier.

According to embodiments, the primary thermally insulating element comprises a lower panel which extends parallel with the tank wall and which carries the carrier elements of the primary thermally insulating element.

According to embodiments, the secondary thermally insulating element comprises a lower panel which extends parallel with the tank wall and which carries the carrier elements of the secondary thermally insulating element.

According to embodiments, the secondary thermally insulating element comprises a covering panel which extends parallel with the tank wall and which is carried by the carrier elements of the secondary thermally insulating element, the covering panel comprising an outer surface which forms the secondary support surface.

According to embodiments, the covering panel of the secondary thermally insulating element comprises:

a distribution panel which is fixed to the carrier elements and which is in abutment with the carrier elements,

a spacer element which is in abutment with and fixed to the distribution panel, the spacer element comprising a plurality of beams which are spaced apart from each other and which extend parallel with the distribution panel,

an upper panel which is parallel with the distribution panel and which is fixed and supported by the plurality of beams.

According to embodiments, the primary thermally insulating element comprises a covering panel which extends parallel with the tank wall and which is carried by the pillars, the covering panel comprising:

a distribution panel which is fixed to the carrier elements and which is in abutment with the carrier elements,

a spacer element which is in abutment with and fixed to the distribution panel, the spacer element comprising a plurality of beams which are spaced apart from each other and which extend parallel with the

distribution panel,

an upper panel which is parallel with the distribution panel and which is fixed and supported by the plurality of beams, the upper panel comprising an outer surface which forms the primary support surface.

5 According to embodiments, the beams from the plurality of beams of the primary thermally insulating element are perpendicular to the beams of the plurality of beams of the secondary thermally insulating element.

According to embodiments, a primary thermally insulating element and a secondary thermally insulating element are parallelepipedal and the
10 primary thermally insulating element comprises primary securing pillars which are each arranged in the region of a corner of the primary thermally insulating element, the secondary thermally insulating element comprising secondary securing pillars which are each arranged in the region of a corner of the secondary thermally insulating element, the primary securing pillars
15 and the secondary securing pillars being superimposed.

According to embodiments, the tank wall further comprises a secondary sealing barrier which is in abutment with the secondary support surface of the secondary thermal insulation barrier.

According to embodiments, the tank wall further comprises a
20 secondary sealing barrier which is in abutment with the secondary support surface of the secondary thermal insulation barrier.

Such a tank may be part of a land-based storage installation, for example, for storing LNG, or may be installed in a floating structure, at the
25 coast or in deep water, in particular an LNG tanker, a floating storage regasification unit (FRSU), a remote floating production, storage and offloading unit (FPSO) and the like.

According to an embodiment, a ship for transporting a cold liquid product comprises a double hull and an above-mentioned tank which is
30 arranged in the double hull.

According to an embodiment, the invention also makes provision for a method for loading or unloading such a ship, in which a cold liquid

product is conveyed through insulated pipes from or to a floating or land-based storage installation to or from the tank of the ship.

According to an embodiment, the invention also makes provision for a transfer system for a cold liquid product, the system comprising the above-mentioned ship, insulated pipes which are arranged so as to connect the tank which is installed in the hull of the ship to a floating or land-based storage installation and a pump for bringing about a flow of cold liquid product through the insulated pipes from or to the floating or land-based storage installation to or from the tank of the ship.

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A notion forming the basis of the invention is to provide a tank wall in which there is arranged a primary thermally insulating element which comprises carrier elements on a secondary thermally insulating element which itself also comprises carrier elements so that the carrier elements of the primary thermally insulating element are not superimposed on the carrier elements of the secondary thermally insulating element. In this manner, an upper rigid panel of the primary vessel may become deformed in order to distribute a load over the adjacent pillars.

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Some aspects of the invention are based on the notion of deforming panels of the thermally insulating elements in order to resiliently absorb a load, in particular to preserve the resistance of the carrier elements which are subjected to dynamic loads, for example, during the sloshing action of the fluid in the tank.

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Some aspects of the invention are based on the notion of providing a thermally insulating element which has a good compromise between the thermomechanical performance levels, in particular in the event of dynamic stresses, and the cost of implementation.

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The invention will be better understood, and other objectives, details, features and advantages thereof will be appreciated more clearly during the following description of several specific embodiments of the invention,

given purely by way of non-limiting example, with reference to the appended drawings.

In the drawings:

- Figure 1 is a broken-away partial, perspective view of a thermally insulating sealed tank wall in which thermally insulating elements according to embodiments of the invention can be used.
- Figure 2 is a broken-away, perspective, schematic illustration of a thermally insulating element which may be included in the tank wall of Figure 1 and which comprises pillars.
- Figure 3 is a schematic side view of the thermally insulating element of Figure 2 when it is subjected to a small load.
- Figure 4 is a schematic side view of the thermally insulating element of Figure 2 when it is subjected to a large load.
- Figure 5 is a schematic side view of the thermally insulating elements set out in Figure 2 when the tank wall is subjected to a localized load.
- Figure 6 is a schematic side view of the thermally insulating elements set out in Figure 2 when the tank wall is subjected to an extensive load.
- Figure 7 is a perspective view of the thermally insulating elements of Figure 2 superimposed in order to form a primary thermally insulating barrier and a secondary thermally insulating barrier of the tank wall illustrated in Figure 1.
- Figure 8 is a schematic illustration of the position of the pillars of the primary thermally insulating barrier and the secondary thermally insulating barrier according to a projection in a plane parallel with the tank wall.
- Figures 9a to 9c are plan views which show pillars which have geometrically different cross-sections and which show non-overlapping zones which extend around pillars.
- Figure 10 is a broken-away schematic illustration of an LNG tanker tank and a terminal for loading/unloading this tank.

Figure 1 illustrates sealed and insulating walls of a tank which is integrated in a carrier structure of a ship.

The carrier structure of the tank is in this instance constituted by the internal hull of a double-hull ship, the wall of which has been designated 1.

A tank wall is arranged in each case on a wall 1 of the carrier structure. Each tank wall is produced by successively superimposing a layer of secondary thermal insulation 2, a secondary sealed barrier 3, a layer of a primary thermal insulation 4 and a primary sealed barrier 5.

The primary insulation layer 4 and the secondary insulation layer 2 are formed by a plurality of parallelepipedal thermally insulating vessels 6 and 7 which are juxtaposed in accordance with a regular pattern. The secondary thermally insulating vessels 6 and the primary thermally insulating vessels 7 thus form a substantially planar surface which carries the secondary sealed barrier 3 and the primary sealed barrier 5, respectively.

The secondary insulating vessels 6 and the primary insulating vessels 7 are secured to the carrier wall 1 by means of securing members 8 and 9. In particular the securing members 8 of the secondary thermal insulation layer 2 are fixed to the carrier wall 1 by means of pins 10 which are welded perpendicularly to the carrier wall 1. As can be seen in Figure 1, securing members 8 and 9 are positioned in the region of the corners of the vessels 6 and 7. In this manner, a securing member 8 or 9 which is located in the region of a vessel corner may retain four adjacent vessels 6 or 7. Other securing members 8 and 9 are arranged in a central zone of the vessels 6 and 7.

The secondary sealed barrier 3 and the primary sealed barrier 5 are constituted by parallel invar strakes 11. These invar strakes 11 are arranged alternately with elongate welding supports 13 which are also of invar and which comprise edges 12 which are raised toward the inner side of the tank.

In particular, each weld support 13 is in the form of a strip of invar which is folded in order to have an L-shaped cross-section. The weld supports 13 are retained on the subjacent layer of insulation 2 or 4 and are

accommodated in a sliding manner in grooves 15 in the form of an inverted T which are provided in covering panels 14 of the vessels 6 and 7. In this manner, a portion of the L-shaped strip protrudes from the T-shaped groove toward the inner side of the tank and perpendicularly to the carrier wall 1.

5 The raised edges 12 of the invar strakes 11 are welded along the protruding portion of the weld supports 13.

Figures 2 to 4 illustrate the structure of a vessel 16 which may be used in such a tank wall.

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The vessel 16 comprises a lower panel 17 to which distribution plates 18 are fixed. A row of pillars 19 or 23 abuts and is fixed in each case to a corresponding distribution plate 18. In particular, the pillars 20 of each row of pillars 19 or 23 extend over the thickness of the vessel 16 and therefore in a direction perpendicular to the carrier wall 1. The pillars 20 have a solid rectangular cross-section. Each row of pillars 19 or 23 is parallel relative to a lateral side 21 of the vessel 16. The rows of pillars carry a reinforced covering panel 22. The pillars 20 in particular allow the transmission of stresses applied to the covering panel 22 to the wall 1 and therefore have a function of

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20 compression resistance.

The successive rows of pillars 19 and 23 are offset relative to each other. This is because the pillars 20 of two successive rows 19 and 23 comprise pillars 20 which are spaced apart with the same regular spacing; however, the two rows of pillars 19 and 23 are offset in the direction of the length thereof by a half-spacing.

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A thermally insulating lining which is not illustrated fills the space between the pillars 20 and may, for example, be constituted by an insulating foam which is poured between the pillars 20 or a block of foam which is machined to be adapted to the pillars 20.

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The reinforced covering panel 22 comprises an upper panel 24 and a lower panel 25 which each have a thickness of 6.5 cm. The upper panel 24 and the lower panel 25 are spaced apart by a series of parallel solid beams

26. In particular, the beams 26 extend parallel with the lateral side 21 of the vessel 16. A beam 26 is in each case positioned along and above a row of pillars 19 or 23. The beams 26 have a rectangular cross-section and a thickness of 6.5 cm. The beams 26 and the panels 24 and 25 are connected
 5 in a rigid manner. Such a reinforced cover partially allows distribution of a load which is applied to the cover over a plurality of pillars, as a result of the rigidity thereof.

Each beam 26 is spaced apart from the other beams 26 in order to delimit a space between two beams 26 and between the panels 24 and 25.
 10 These spaces form circulation channels for the fluids between the sides of the thermally insulating element. The juxtaposition of the thermally insulating vessels 16 thus allows a circuit to be formed in the wall of the tank, in which circuit it is possible to inject an inert gas in order to neutralize the wall of the tank and thus to prevent any risk of explosion in the event of leakage in the
 15 presence of oxygen. Furthermore, such a gas circuit enables a leak to be detected in the sealed barriers 3 and 5. In order to improve the thermal resistance capacities of the insulating vessel 16, a porous thermally insulating lining may be positioned in the circulation channels.

20 Figures 3 and 4 illustrate the behavior of the vessel when it is placed on a rigid surface, each of Figures 3 and 4 illustrating a load with a different intensity.

Figure 3 is a schematic side view of the vessel 16 when it is subjected to a small localized load 27 in alignment with a central pillar 28, the base of
 25 the pillars 20 being fixed.

It should be noted that in this instance the reinforced covering panel 22 is subjected to little deformation. The main portion of the force 29 corresponding to the load is absorbed by the central pillar 28. A small portion of the load 30 applied in alignment with the central pillar 28 is absorbed by
 30 the adjacent pillars 31 which are nearest with respect to the position in which the force 27 is applied. This is because the rigidity of the reinforced cover 22 and the central pillar prevents the deformation of the cover 22. In this

manner, few forces (indicated by the arrows 30) are absorbed by the adjacent pillars 31.

Figure 4 illustrates this same vessel when a greater load 32 is applied in alignment with the central pillar 28. In this instance, the central pillar 28 is subjected to high levels of stress which in particular bring about the loading thereof in terms of flexion. These high levels of stress bring about a slight settlement of the central pillar 28 and therefore a slight deformation of the reinforced covering panel 22. This slight deformation of the reinforced covering panel 22 allows the load to be better distributed over the adjacent pillars 31 relative to the load. However, since the pillar 28 has a high level of rigidity, the settlement thereof remains relatively small. In this manner, the deformation of the panel 22 is of a small extent and the load is therefore weakly distributed over the adjacent pillars 31. Furthermore, excessively great stresses applied to the central pillar 28 may bring about the breakage of this pillar 28.

In order to improve the distribution of the load within the tank wall set out in Figure 1, the pillars 20 are arranged so as to allow the settlement thereof to a greater extent. In particular, the pillars of the primary vessels 7 are not superimposed on the pillars of secondary vessels 6. The advantage of such an arrangement of the pillars of the primary layer of thermal insulation and the secondary layer of thermal insulation will be better understood with reference to Figures 5 and 6.

Such an arrangement is in particular set out in Figure 5 which is a schematic side view of the vessels which form the primary insulation layer 4 and the secondary insulation layer 2 of the tank wall of Figure 1.

In particular, it should be noted that a vessel 16 constitutes a primary thermally insulating vessel 7 of the primary thermal barrier 4 and that the secondary layer of insulation comprises a secondary thermally insulating vessel 6 which has a different structure from the vessel 16.

This is because the secondary vessel 6 comprises a lower panel 33, an upper panel 34 and a thermally insulating lining 35 which is arranged

between the upper panel 34 and the lower panel 33. In the Figure, it can be seen that ladder-like arrangements of pillars 36 extend through the thermally insulating lining 35. The ladder-like arrangements of pillars 36 are each formed by a row of secondary pillars 37 which are attached at the ends thereof between an upper lath 38 and a lower lath 39 which each extend along the row of pillars 37. In the same manner as the pillars 20 of the vessel 16, the ladder-like arrangements of pillars 36 allow a portion of the compression forces to which the tank wall is subjected to be absorbed.

It should be noted that the primary vessel 7 is positioned in abutment with the secondary vessel 6 so that a row of pillars 19 or 23 is in each case positioned halfway between two ladder-like arrangements of pillars 36. In particular, a primary pillar 40 is in this instance positioned in each case between two secondary pillars 37.

Such an arrangement promotes better distribution of the load applied to the pillars. This is because, in a similar manner to Figures 3 and 4, a localized load 41 is illustrated in Figure 5. This localized load 41 is applied to a central pillar 28 of the primary vessel. Since the central pillar is positioned between two ladder-like arrangements of pillars 36 of the secondary vessel, the lower panel 17 and the upper panel 33 settle under the stress applied by the central pillar 28. This resilient deformation is illustrated by the lines 42 and 43 which illustrate the deformation of the upper panel 34 and the lower panel 17, respectively. In this manner, the central pillar 28 is positioned on a flexible surface, which allows it to be lowered. This movement allows the resilient deformation of the reinforced covering panel 22 which thus brings about a force on the adjacent pillars. The lines 44 illustrate the deformation of the upper panel 24 and the lower panel 25 which thus each have an arrow which is orientated toward the carrier wall 1 in the region of the central pillar 28. This deformation allows the load to be better distributed over the lateral pillars as indicated by the arrows 45.

Figure 6 illustrates the same tank wall and shows another advantage of such an arrangement of the primary and secondary pillars.

This is because Figure 6 illustrates the tank wall when it is subjected to a load 46 which is distributed over a plurality of pillars. Such a load may be involved, for example, in the sloshing action of the fluid in the tank. Such a sloshing action takes the form of a mass of fluid which strikes a tank wall.

5 In this instance, similarly to Figure 5, the lower panel 17 of the primary vessel 7 and the upper panel of the secondary vessel 6 become resiliently deformed under the stress applied by the primary pillars 40 and the abutment formed by the secondary pillars 37. These deformations are illustrated by the lines 47. These panels 17 and 33 therefore have portions
10 which are located between each ladder-like arrangement of pillars and which have an arrow which is orientated toward the carrier wall. The primary pillars 40 located above these arrows move toward the carrier wall. In this manner, the reinforced covering panel 22 becomes resiliently deformed in a similar manner to the panels 17 and 33, as illustrated by the lines 48.

15 These resilient deformations of the primary vessels 7 and secondary vessels 6 thus allow a portion of the energy originating from the impacts to which the tank wall is subjected to be resiliently taken up, for example, following the sloshing action or the fall of a heavy item into the tank. This energy is then returned after the impact, in the manner of a damper.

20 Furthermore, this arrangement of the pillars prevents punching of the components forming the vessels by the pillars 40 and 37, in particular the distribution plates 18 and the panels. Furthermore, this resilient deformation prevents breakage of the pillars 40 and 37 when the tank wall is subjected to significant dynamic stresses. In this manner, with such an arrangement of the
25 primary pillars 40 and secondary pillars 37, the vessels 6 and 7 thus act as a "mattress" which damps the loads applied to the tank wall.

Another embodiment of the tank wall will now be set out with reference to Figure 7.

30 In this Figure, only a vessel 7 of the primary insulation layer 4 and a vessel 6 of the secondary insulation layer 2 are illustrated. It should be noted that the two insulation layers 2 and 4 are constituted by vessels 16. The

vessels 16 are superimposed in an offset manner. In this manner, the primary pillars 40 and the secondary pillars 140 are not superimposed.

The position of the pillars 40 and 140 is illustrated in Figure 8. This is because Figure 8 is a partial top projection of the primary pillars 40 and secondary pillars 140 in a plane parallel with the tank wall. Only nine adjacent pillars 40 and 140 are illustrated in this instance, which corresponds to a portion of the pillars of the vessels 6 and 7 of Figure 7.

A primary pillar 40 is in each case present between four adjacent secondary pillars 140. More specifically, a secondary pillar 140 is positioned halfway between two primary pillars 40 of the same row of pillars.

Returning to Figure 7, it should be noted that the orientation of the rows of pillars 19 and 23 is different between the two vessels 6 and 7. This is because the rows of pillars 19 and 23 of the primary vessels 7 are perpendicular relative to the rows of pillars 19 and 23 of the secondary vessels 6. This orientation can be seen in particular as a result of the distribution plates 18 and 118 which are perpendicular. In a similar manner, the beams 26 and 126 are perpendicular.

Furthermore, it is possible to see the grooves 15 in the form of an inverted T which are intended to receive the weld supports 13. Furthermore, notches (not illustrated) are formed in the lower panel 17 and optionally in the distribution plates 18 and the pillars 20. These notches allow the weld supports 13 and the raised edges of the secondary sealed barrier 3 to be received. Corner pillars 49 are each present in the region of a corner of the vessels 16. These corner pillars 49 have a trapezoidal cross-section. In this manner, when four vessels 16 are juxtaposed in a corner, the corner pillars 49 form a chimney-like member which allows a securing member to be mounted, in particular couplers, which extend(s) along the adjacent pillars 49 and which adjoin a flat member 51 in order to keep the vessel 16 secured against the carrier wall 1.

In other embodiments, however, the vessels are superimposed so that the corner pillars 49 are superimposed in order to ensure a degree of rigidity for receiving the stresses applied by the securing members. In these

other embodiments, the positioning of the pillars in the primary vessel 7 and the positioning of the pillars in the secondary vessel 6 are different so that they are spaced apart when the vessels 6 and 7 are superimposed.

5 It is not necessary for the pillars of a first level of vessels, for example, of the primary insulation layer, to be located in each case halfway between two pillars of a second level, for example, the secondary insulation layer. This is because a satisfactory arrangement can be obtained in particular when the pillars of one level are not superimposed on the pillars of the lower or
10 higher level and are positioned at a specific distance therefrom. For example, the pillars of the primary insulation layer must preferably be located outside a non-overlapping zone 52 of the secondary pillars 140. Such a non-overlapping zone 52 is illustrated in Figure 8. The zone is defined, in the projection in the plane parallel with the tank wall, by a rectangular perimeter
15 53 which extends around the secondary pillar 140. In this manner, the secondary pillars 140 are at a sufficient distance from the primary pillars 40 to allow the panels to flex and to prevent shearing of the panels by the pillars.

Other types of pillars are illustrated in Figures 9a to 9d which show the cross-section thereof in the region of the ends thereof, with which the panels
20 are in abutment, and their respective non-overlapping zones.

In particular, Figure 9a illustrates a pillar having a triangular cross-section 54. A circle circumscribed by the triangular cross-section 54 is illustrated. The perimeter 55 which forms the non-overlapping zone comprises a circle which is centered on the center of gravity of the triangular cross-
25 section 54 and whose radius is equal to the diameter of the circle which is circumscribed by the triangular cross-section.

Figure 9c shows a similar circular perimeter which corresponds to a pillar having a circular cross-section 56. In a similar manner to the perimeter 55, a circular perimeter 57 delimits the non-overlapping zone. The circular
30 perimeter 57 has a radius which is equal to the diameter of the cross-section 56 of the pillar and which is concentric with respect to the pillar.

Figure 9b has a pillar having a rectangular cross-section 58. The non-overlapping zone is formed by a rectangular perimeter 59 whose long sides are parallel with the long sides of the rectangular cross-section 58. The rectangular perimeter 59 is centered on the rectangular cross-section 58 of the pillar and has dimensions which are equal to double the dimensions C1 and C2 of the rectangular cross-section 58.

In a similar manner to Figure 9b, Figure 9d illustrates a rectangular non-overlapping zone. This non-overlapping zone corresponds to a pillar which has a cross-section 60 of any shape. The width D4 corresponds to the dimensions of the cross-section in a length direction 62 of the vessel which comprises the pillar and the length D3 corresponds to the width of the pillar in a width direction 63 of the vessel. The rectangle which forms the perimeter 61 of the non-overlapping zone has dimensions which correspond to double the lengths D4 and D3 and is centered on the center of the cross-section, the center corresponding to the mean of the dimensions D4 and D3 taken over the cross-section of the pillar.

Alternatively, the pillars may be hollow in order to increase their thermal resistance and may also be filled with an insulating material. In other embodiments, the pillars may have an H-shaped cross-section.

The pillars may be obtained, for example, using thermoplastic or thermosetting materials, which are optionally reinforced by fibers or which may be produced from wood or plywood.

Of course, the distribution of the beams 26 with respect to the pillars may be different. For example, the beams 26 are not necessarily positioned in alignment with the rows of pillars 19 and 23 but may be arranged between the rows of pillars 19 and 23.

In other embodiments, the pillars of the vessels may be replaced by cross-member plates. Such vessels are in particular described in document FR2798902A1. In this instance, a cross-member plate of the primary insulation layer is in each case positioned between two cross-member plates of the secondary insulation layer so that they are not superimposed on each other.

It is also possible, in some tank walls, to superimpose more than two levels of thermally insulating vessels which have pillars. For example, a secondary insulating barrier may comprise two layers of thermally insulating vessels. In this instance, the arrangement of the pillars may also be carried
5 out so that two thermally insulating vessels which are directly superimposed do not have any superimposition of pillars.

The vessel described above may be produced in various manners. For example, in a first production method of the vessel 16, the lower panel
10 17, the laths 18 and the pillars 20 are assembled by means of stapling. The thermally insulating lining is then inserted or injected between the pillars. The lower panel 25 is stapled to the pillars 20 in a manual or automated process, then the beams 26 are stapled to the lower panel 25. An optional porous thermally insulating lining is inserted between the beams 26, and the upper
15 panel 24 is then stapled to the beams 26.

The fixing of the pillars, panels and spacer elements between the lower and upper panels may be produced by means of screws. However, it is also possible to bring about their connection by means of bonding, stapling or nailing.

20 The panels, beams and pillars may be produced from plywood or solid wood, for example, from birch, beech or fir. These elements may also be produced from bamboo, composite materials, plastics material or metal.

Any type of thermally insulating lining 35 may be used to produce
25 the vessels described above. Typically, such a lining 35 may comprise, for example, a block of machined foam, or a foam which is poured between the pillars. Such a foam may or may not be reinforced, for example, using glass fiber and may in particular be a polyurethane foam. Alternatively, the lining may be constituted by a material of the aerogel type having a porosity
30 in the nanometric order of magnitude. Aerogels may be packaged in different forms, for example, in the form of powder, balls, non-woven fibers, fabric, etcetera.

The types of vessel set out above may be used in the primary insulation layer 4 and/or in the secondary insulation layer 2.

The reinforced covering panels set out above may be replaced by reinforced covering panels which have a different configuration. For example, the reinforced covering panels may be replaced with reinforced covering panels described in the French patent application filed under the number 1255316. The reinforced covering panel may also be replaced by a simple rigid cover or constituted by two plates which are directly superimposed. The primary vessel panel which abuts the primary pillars may have a thickness between 12 and 80 mm.

The tanks described above may be used in different types of installation, such as land-based installations or in a floating installation, such as a liquefied gas tanker or the like.

With reference to Figure 10, a broken-away view of a liquefied gas tanker 70 shows a sealed and insulated tank 71 of generally prismatic form mounted in the double hull 72 of the ship. The wall of the tank 71 comprises a primary sealed barrier which is intended to be in contact with the LNG contained in the tank, a secondary sealed barrier which is arranged between the primary sealed barrier and the double hull of the ship, and two thermally insulating barriers which are arranged between the primary sealed barrier and the secondary sealed barrier, respectively, and between the secondary sealed barrier and the double hull 72.

In a manner known per se, loading/unloading pipes which are arranged on the upper bridge of the ship may be connected using appropriate connectors to an off-shore or port-based terminal in order to transfer a cargo of LNG from or to the tank 71.

Figure 10 shows an example of an off-shore terminal comprising a loading and unloading station 75, an underwater conduit 76 and a land-based installation 77. The loading and unloading station 75 is a fixed off-shore installation comprising a movable arm 74 and a tower 78 which supports the movable arm 74. The movable arm 74 carries a bundle of insulated flexible

pipes 79 which may be connected to the loading/unloading pipes 73. The movable arm 74 which can be orientated adapts to all the gauges of liquefied gas tankers. A connection conduit which is not illustrated extends inside the tower 78. The loading and unloading station 75 allows the liquefied gas tanker 70 to be loaded and unloaded from or to the land-based installation 77. It comprises storage tanks for liquefied natural gas 80 and connection conduits 81 which are connected via the underwater conduit 76 to the loading or unloading station 75. The underwater conduit 76 allows the liquefied gas to be transferred between the loading or unloading station 75 and the land-based installation 77 over a large distance, for example, 5 km, which allows the liquefied gas tanker 70 to be kept at a great distance from the coast during loading and unloading operations.

In order to bring about the pressure required for the transfer of the liquefied natural gas, there are used pumps which are on-board the ship 70 and/or pumps which are provided in the land-based installation 77 and/or pumps which are provided in the loading and unloading station 75.

Although the invention has been described in connection with several specific embodiments, it is evident that it is in no way limited thereto and that it comprises all the equivalent techniques of the means described and the combinations thereof if they are included within the scope of the invention.

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

In the claims, any reference numeral between brackets is not intended to be interpreted as a limitation of the claim.

CLAIMS

1. A sealed and thermally insulating tank which is integrated in a carrier structure in order to contain a fluid, wherein a tank wall comprises from the outer side of the tank to the inner side of the tank:

5 a carrier wall,

a secondary thermal insulation barrier which is retained on the carrier wall, the thermal insulation barrier being constituted by a plurality of secondary thermally insulating elements which are juxtaposed so as to form a secondary support surface,

10 a primary thermal insulation barrier which is retained on the secondary thermal insulation barrier, the primary thermal insulation barrier being constituted by a plurality of primary thermally insulating elements which are juxtaposed in order to form a primary support surface,

15 a sealing barrier which is in abutment with the primary support surface, each primary thermally insulating element and each secondary thermally insulating element comprising:

a thermally insulating lining,

a plurality of carrier elements which extend through the thermally insulating lining perpendicularly to the tank wall, and

20 a panel which is parallel with the tank wall and which is arranged at an end of the carrier elements of the thermally insulating element in order to form an outer wall of the thermally insulating element, wherein at least one from the panel of the primary thermally insulating element and the panel of the secondary thermally insulating element is arranged between the carrier elements of the primary insulation barrier and the carrier elements of the secondary insulation barrier,

25 characterized in that

in a view projected in a plane parallel with the tank wall, at least one carrier element from the plurality of carrier elements of the primary thermally insulating element is spaced apart relative to the subjacent carrier elements of the secondary thermally insulating element, wherein the at least one carrier element from the plurality of carrier elements of the

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primary thermally insulating element is not superimposed on the subjacent carrier elements of the secondary thermally insulating element.

2. The tank as claimed in claim 1, wherein the carrier elements are pillars having a small cross-section in the plane parallel with the tank wall relative to the dimensions of the thermally insulating element.

3. The tank as claimed in claim 2, wherein each pillar from the plurality of pillars of the primary thermally insulating element is positioned outside defined perimeters which surround the subjacent pillars of the secondary thermally insulating element and in which the thermally insulating elements are parallelepipedal and in which the defined perimeter which surrounds a pillar is rectangular, the perimeter comprising a first side which is parallel with a length direction of the thermally insulating element, and a second side which is parallel with a width direction of the insulating element, the dimension of the first side of the perimeter being greater than or equal to double a first characteristic dimension equal to the larger dimension of the cross-section of the pillar in the length direction of the thermally insulating element, and

the dimension of the second side of the perimeter being greater than or equal to double a second characteristic dimension equal to the larger dimension of the cross-section of the pillar in the width direction of the thermally insulating element.

4. The tank as claimed in claim 2, wherein each pillar from the plurality of pillars of the primary thermally insulating element is positioned outside defined perimeters which surround the subjacent pillars of the secondary thermally insulating element and wherein the pillars have a rectangular cross-section, and wherein the defined perimeter surrounding a subjacent pillar has a rectangular shape which is centered on the rectangular cross-section of said subjacent pillar, the long sides of the defined perimeter surrounding said subjacent pillar being parallel with the long sides of the rectangular cross-section of said subjacent pillar, the dimensions of the defined perimeter surrounding said subjacent pillar being equal to double the dimensions of the rectangular cross-section of said subjacent pillar.

5. The tank as claimed in claim 2, wherein each pillar from the plurality of pillars of the primary thermally insulating element is positioned outside defined perimeters which surround the subjacent pillars of the secondary thermally insulating element, said subjacent pillars of the secondary thermally insulating element having
5 a circular cross-section, and wherein the defined perimeters have a circular shape and are each centered on a subjacent pillar, the radius of the defined perimeter being equal to the diameter of the circular cross-section of the subjacent pillar.

6. The tank as claimed in claim 2, wherein each pillar from the plurality of pillars of the primary thermally insulating element is positioned outside characteristic
10 perimeters which surround the subjacent pillars of the secondary thermally insulating elements, said subjacent pillars of the secondary thermally insulating element having a triangular cross-section, and wherein the characteristic perimeters have a circular shape and are each centered on a subjacent pillar, the radius of the characteristic perimeter being equal to the diameter of the circumscribed circle of the triangular
15 cross-section of the subjacent pillar.

7. The tank as claimed in one of claims 2 to 6, wherein the pillars of a thermally insulating element are arranged in rows of pillars which are parallel with a side of the thermally insulating element, a row of pillars of the primary thermal insulation barrier being positioned in each case in the projected view halfway
20 between two rows of pillars of the secondary thermal insulation barrier.

8. The tank as claimed in one of claims 1 to 7, wherein a carrier element of the primary thermal insulation barrier is in each case arranged in the projected view in a position located halfway between two adjacent carrier elements of the secondary thermal insulation barrier.

9. The tank as claimed in one of claims 1 to 8, wherein the primary thermally insulating element comprises a lower panel which extends parallel with the tank wall and which carries the carrier elements of the primary thermally insulating element.

10. The tank as claimed in one of claims 1 to 9, wherein the secondary thermally insulating element comprises a lower panel which extends parallel with the tank wall and which carries the carrier elements of the secondary thermally insulating element.

11. The tank as claimed in one of claims 1 to 10, wherein the secondary thermally insulating element comprises a covering panel which extends parallel with the tank wall and which is carried by the carrier elements of the secondary thermally insulating element, the covering panel comprising an outer surface which forms the secondary support surface.

12. The tank as claimed in claim 11, wherein the covering panel of the secondary thermally insulating element comprises:

a distribution panel which is fixed to the carrier elements and which is in abutment with the carrier elements,

5 a spacer element which is in abutment with and fixed to the distribution panel, the spacer element comprising a plurality of beams which are spaced apart from each other and which extend parallel with the distribution panel,

an upper panel which is parallel with the distribution panel and which is fixed and supported by the plurality of beams.

10 **13.** The tank as claimed in one of claims 1 to 12, wherein the primary thermally insulating element comprises a covering panel which extends parallel with the tank wall and which is carried by the pillars, the covering panel comprising:

a distribution panel which is fixed to the carrier elements and which is in abutment with the carrier elements,

15 a spacer element which is in abutment with and fixed to the distribution panel, the spacer element comprising a plurality of beams which are spaced apart from each other and which extend parallel with the distribution panel,

an upper panel which is parallel with the distribution panel and which is fixed and supported by the plurality of beams, the upper panel comprising an outer surface
20 which forms the primary support surface.

14. The tank as claimed in claims 12 and 13 taken in combination, wherein the beams from the plurality of beams of the primary thermally insulating element are perpendicular to the beams of the plurality of beams of the secondary thermally insulating element.

25 **15.** The tank as claimed in one of claims 1 to 14, wherein a primary thermally insulating element and a secondary thermally insulating element are parallelepipedal and wherein the primary thermally insulating element comprises primary securing pillars which are each arranged in the region of a corner of the primary thermally insulating element, the

secondary thermally insulating element comprising secondary securing pillars which are each arranged in the region of a corner of the secondary thermally insulating element, the primary securing pillars and the secondary securing pillars being superimposed.

5 **16.** The tank as claimed in one of claims 1 to 15, wherein the tank wall further comprises a secondary sealing barrier which is in abutment with the secondary support surface of the secondary thermal insulation barrier.

17. A ship for transporting a cold liquid product, the ship comprising a double hull and a tank as claimed in one of claims 1 to 16 arranged in the double hull.

10 **18.** Use of a ship as claimed in claim 17, wherein a cold liquid product is conveyed through insulated pipes from or to a floating or land-based storage installation to or from the tank of the ship in order to load or unload the ship.

19. A transfer system for a cold liquid product, the system comprising a ship as claimed in claim 17, insulated pipes which are arranged so as to connect the tank
15 which is installed in the hull of the ship to a floating or land-based storage installation and a pump for bringing about a flow of cold liquid product through the insulated pipes from or to the floating or land-based storage installation to or from the tank of the ship.