Sealed, thermally insulated tank with juxtaposed non-conducting elements

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ABSTRACT

A sealed, thermally insulated tank consists of tank walls fixed to the load-bearing structure of a ship, the tank walls having, in succession, in the direction of the thickness from the inside to the outside of the tank, a primary sealing barrier, a primary insulating barrier, a secondary sealing barrier and a secondary insulating barrier, at least one of the insulating barriers consisting essentially of juxtaposed non-conducting elements (3), each non-conducting element including a thermal insulation liner, at least one panel and load-bearing partitions rising through the thickness of the thermal insulation liner in order to take up the compression forces. These partitions include at least one anti-buckle partition (14) that includes a plurality of anti-buckle wall elements that have a respective orientation forming an angle relative to a general longitudinal direction of the anti-buckle partition, for example forming corrugations or double-wall portions.
SEALED, THERMALLY INSULATED TANK WITH JUXTAPOSED NON-CONDUCTING ELEMENTS

[0001] The present invention relates to the production of sealed, thermally insulated tanks consisting of tank walls fixed to the load-bearing structure of a floating structure suitable for the production, storage, loading, ocean carriage and/or unloading of cold liquids such as liquefied gases, particularly those with a high methane content. The present invention also relates to a methane carrier provided with a tank of this type.

[0002] Ocean carriage of liquefied gas at very low temperature involves an evaporation rate per day's sailing that it would be advantageous to minimize, which means that the thermal insulation of the relevant tanks should be improved.

[0003] A sealed, thermally insulated tank consisting of tank walls fixed to the load-bearing structure of a ship has already been proposed, said tank walls having, in succession, in the direction of the thickness from the inside to the outside of said tank, a primary sealing barrier, a primary insulating barrier, a secondary sealing barrier and a secondary insulating barrier, at least one of said insulating barriers consisting essentially of juxtaposed non-conducting elements, each non-conducting element including a thermal insulation liner arranged in the form of a layer parallel to said tank wall, and load-bearing elements that rise through the thickness of said thermal insulation liner in order to take up the compression forces.

[0004] For example, in FR-A-2 527 544 these insulating barriers consist of closed parallelepipedal caissons made from plywood and filled with perlite. On the inside, the caisson includes parallel load-bearing spacers interposed between a cover panel and a base panel in order to withstand the hydrostatic pressure exerted by the liquid contained in the tank. Non-load-bearing spacers made from plastic foam are placed between the load-bearing spacers in order to maintain their relative positioning. Manufacture of a caisson of this type, including the assembly of the outer walls made from plywood sections and the fitting of the spacers, requires a number of assembly operations, particularly stapling. Furthermore, the use of a powder such as perlite complicates the manufacture of the caissons because the powder produces dust. Thus, it is necessary to use high-quality and therefore expensive plywood so that the caisson is well sealed against dust, i.e. knot-free plywood. Furthermore, it is necessary to tamp down the powder with a specific pressure in the caisson, and it is necessary to circulate nitrogen inside each caisson in order to evacuate all the air present, for safety reasons. All these operations complicate manufacture and increase the cost of the caissons. Moreover, if the thickness of the insulating caissons is increased with an insulating barrier, the risk of the walls of the caissons and the load-bearing spacers buckling increases considerably. If it is desired to increase the anti-buckling strength of the caissons and of their internal load-bearing spacers, the cross section of said spacers has to be increased, which increases the thermal bridges established between the liquefied gas and the load-bearing structure of the ship by the same amount. Furthermore, if the thickness of the caissons is increased it is observed that, inside the caissons, gas convection currents arise that are highly detrimental to good thermal insulation.

[0005] FR-A-2 798 902 describes other thermally insulated caissons designed for use in such a tank. Their method of manufacture consists in alternately stacking a plurality of low-density foam layers and a plurality of plywood panels, placing adhesive between each foam layer and each panel until the height of said stack corresponds to the length of said caissons, in cutting the above-mentioned stack into sections in the direction of the height, at regular intervals corresponding to the thickness of a caisson, and in adhesively bonding a base panel and a top panel made from plywood on either side of each stack section thus cut, said panels extending perpendicularly to said cut panels, which serve as spacers. Although the result of this is a good compromise in terms of anti-buckling strength and thermal insulation, it has to be admitted that this manufacturing process also requires numerous assembly stages.

[0006] Document U.S. Pat. No. 4,416,715-A describes a rigid insulation panel composed of a folded sheet and an envelope. The envelope is filled with granular insulation. The folded sheet forms a framework that stiffens the envelope. The folded sheet, in the form of a single piece, which serves as framework for the envelope, is produced by folding a sheet of paper or cardboard. Taken in isolation, the folded sheet has no stiffness in the region of the folds formed, which constitute flexible articulations between the panels. For this reason, when the sheet is transferred between two assembly stations, the folded sheet is held in shape by projections and fingers.

[0007] An object of the invention is to propose a tank of this type while also improving at least one of the following characteristics without detriment to others of these characteristics: the tank's cost price, the ability of the walls to withstand pressure and the thermal insulation of the walls. A further object of the invention is to propose a tank of this type in which the non-conducting elements are easier to manufacture, without compromising the ability of the walls to withstand pressure and the thermal insulation of the walls, and, if possible, improving these characteristics at the same time.

[0008] To that end, a subject of the invention is a sealed, thermally insulated tank including at least one tank wall fixed to the hull of a floating structure, said tank wall having, in succession, in the direction of the thickness from the inside to the outside of said tank, a primary sealing barrier, a primary insulating barrier, a secondary sealing barrier and a secondary insulating barrier, at least one of said insulating barriers consisting essentially of juxtaposed non-conducting elements, each non-conducting element including a thermal insulation liner arranged in the form of a layer parallel to said tank wall, and load-bearing elements that rise through the thickness of said thermal insulation liner in order to take up the compression forces, characterized in that said load-bearing elements of a non-conducting element are produced in the form of at least one load-bearing structure formed from a single piece including on each occasion linking means that rigidly link said load-bearing elements together and at least one height portion of said load-bearing elements.

[0009] A load-bearing structure of this type formed from a single piece combines very advantageous mechanical properties both in terms of stiffness and in terms of anti-buckling resistance in the direction of the thickness of the hollow elements, of ease of forming, of thermal insulation and of cost price. Indeed, for a given geometry of the load-bearing elements, their anti-buckling resistance is...
increased by the rigid integral links as compared with separate load-bearing elements. Furthermore, manufacture of the links between the load-bearing elements and load-bearing elements, i.e. at least one portion of their height, in the form of a single piece makes it possible to dispense with certain assembly operations, makes it possible to obtain a relatively rigid load-bearing structure without excessively increasing the cross section of the load-bearing elements and/or their thickness, and thus the thermal bridges, and simplifies fitting of the thermal insulation liner in the non-conducting element.

[0010] According to a preferred embodiment of the linking means, said linking means of a load-bearing structure include a panel extending parallel to said tank wall on a side of said non-conducting element, said load-bearing elements projecting from an inner face of said panel. In other words, in this case, the load-bearing structure comprises a base panel or a cover panel of the non-conducting element. By convention, “cover” is the name given to a panel on that side of the non-conducting element that faces toward the inside of the tank and “base” is the name given to a panel on the side of the non-conducting element that faces toward the load-bearing structure. The load-bearing structure thus formed may also include both a base panel and a cover panel.

[0011] According to an advantageous embodiment of the load-bearing structure, said at least one load-bearing structure of a non-conducting element has the form of a hollow profiled section having a constant cross section in a longitudinal direction.

[0012] For example, load-bearing structures of this type may be obtained by extrusion or pultrusion of any suitable material. In particular, it is possible to obtain profiled sections of this type with a constant cross section using a continuous extrusion die, at the exit from which the hollow element is cut to the desired length, with the result that the size of the corresponding non-conducting elements can easily be modified. Numerous shapes of the cross section of the profiled section can be produced.

[0013] The load-bearing elements may have any form. According to one advantageous embodiment of the load-bearing elements, said load-bearing elements of a load-bearing structure include at least two longitudinal partitions arranged at a distance from one another in order to define at least one cell of mutually constant cross section, capable of receiving the thermal insulation liner. Partitions of this type serve both as load-bearing spacers to support the pressure being exerted on the non-conducting elements and as separations between the cells. These cells, which may be one, two, three or more in number for each non-conducting element, allow easy insertion of the insulation liner in the non-conducting element, particularly via an end in the case of a profiled section.

[0014] Advantageously, said longitudinal partitions include at least one partition substantially perpendicular to said tank wall. A structure of this type improves the distribution of stresses over the longitudinal partitions. The longitudinal cells may therefore have a substantially rectangular or square cross section.

[0015] Preferably, said longitudinal partitions include at least one partition that is inclined relative to said tank wall, advantageously at least two partitions having inclinations in opposite directions from one another. Inclined partitions of this type make it possible to take up not only shear stresses but also buckling and tilting stresses. Thus, it is possible to provide cells having other cross-sectional forms, for example trapezoidal or triangular cross-sectional forms.

[0016] Advantageously, said linking means of a load-bearing structure include at least one linking wall connecting said longitudinal partitions over their entire length, said longitudinal partitions having a thickening in the region of their zones that link with said at least one linking wall. A linking wall of this type may be parallel to or inclined relative to the tank wall. It may, in particular, be a base panel and/or a cover panel. A thickening of this type improves the robustness and rigidity of the corresponding linking zone.

[0017] According to a particular embodiment of the longitudinal partitions, the non-conducting element includes a base panel and a cover panel and at least one of the outermost longitudinal partitions in a lateral direction of the non-conducting element is at a distance from the lateral edge corresponding to at least one of said bottom and cover panels in order to delimit an end cell having an open lateral side. An end cell of this type, which may be provided on one or two sides of the non-conducting elements, creates a space between the outermost longitudinal partitions of two adjacent non-conducting elements. This space allows the insertion of an insulation liner to guarantee continuity of the insulating barrier in the region of the interfaces between juxtaposed non-conducting elements.

[0018] According to a further embodiment of the load-bearing elements, the load-bearing elements of said at least one load-bearing structure include pillars of small transverse section when compared with the dimensions of the non-conducting element in a plane parallel to said tank walls.

[0019] Small-cross section pillars of this type have the advantage that they can be distributed in the non-conducting element as a function of local requirements. By adapting the number and the distribution of the load-bearing pillars, the non-conducting element’s compression strength can, in particular, be made more uniform than with prior-art spacers. It is also possible to prevent localized depression or pinching of a cover panel. Pillars of this type may have a hollow or solid cross section, for which a number of shapes are possible. In particular, hollow pillars with a closed transverse section make it possible to obtain very good anti-buckling resistance while at the same time minimizing the effective thermal conduction cross section.

[0020] According to a further embodiment of the linking means, said linking means include arms extending between said load-bearing elements. Advantageously, said arms extend parallel to said tank wall along at least one side of said insulation liner. Positioned in this way, the arms offer a supplementary surface, in addition to that of the load-bearing elements, for the fixing of a possible base panel and/or cover panel formed independently of the load-bearing structure.

[0021] According to a particular embodiment of the load-bearing structure, said at least one load-bearing structure has the form of a box with peripheral walls projecting all around the inner face of said panel. A design of this type allows the fitting of an insulation liner in the form of granular material.
However, depending on the construction of the insulation liner, it is possible, also, to use non-conducting elements that do not have peripheral walls.

[0022] The non-conducting elements may be open or closed. Advantageously, the presence of a cover panel provides uniform support for the adjacent sealing barrier. However, the panel of this type is not mandatory because sufficient support of this type may also be obtained from the load-bearing elements alone. Advantageously, the presence of a base panel provides wide distributed transmission of compression forces from the primary insulating barrier toward the secondary insulating barrier or from the secondary insulating barrier toward the hull. However, a panel of this type is not mandatory because this transmission may also be sufficiently guaranteed by the load-bearing elements alone. Panels of this type may be formed in several ways. As mentioned, one possibility is to form a load-bearing structure incorporating, as a single piece, a panel with the load-bearing elements.

[0023] In such a case, according to a particular embodiment of the non-conducting element, it includes a second panel formed independently of said load-bearing structure and fixed to the end of said load-bearing elements opposite the first panel forming said linking means.

[0024] Any fixing means may be used for this purpose. Advantageously, the inner face of the second panel has recesses arranged in such a manner as to interact with the load-bearing elements by means of flush fitting.

[0025] Preferably, in such a case, the second panel has a thermal expansion coefficient that is different from that of said load-bearing elements so as to give rise to gripping between said second panel and said load-bearing elements flush fitted in the latter when the tank is cooled.

[0026] According to a further embodiment of the non-conducting element, it has two load-bearing structures arranged in such a manner that their respective panels have said inner faces turned toward one another, the load-bearing elements projecting from said inner faces being assembled in pairs in the region of their ends located opposite said panels in order to form, on each occasion, a load-bearing element of said non-conducting element. In other words, in such a case, the load-bearing elements of each of the two load-bearing structures are placed end to end in order to form, on each occasion, a load-bearing element having two parts extending, respectively, through a portion of the thickness of the non-conducting element. In particular, it is possible to use two completely symmetrical load-bearing structures.

[0027] Advantageously, an insulation piece having a thermal conductivity that is lower than that of the said load-bearing elements is interposed, on each occasion, between the two assembled load-bearing elements. This makes it possible to improve the thermal insulation obtained by means of the non-conducting element.

[0028] The two load-bearing structures may be assembled by any means. Preferably, the load-bearing elements of the two load-bearing structures are assembled in pairs, on each occasion, by means of a linking piece having a thermal expansion coefficient that is different from that of said load-bearing elements so as to give rise to gripping between said linking piece and said load-bearing elements when the tank is cooled. As a variant embodiment, or in combination, the linking piece may also be flush fitted, adhesively bonded, snap-fitted, etc.

[0029] Preferably, the load-bearing structure or structures of a non-conducting element is (or are) manufactured using a process of molding, extrusion, pultrusion, thermoforming, blow-molding, injection-molding or rotational molding. The load-bearing structures may be manufactured from any material suitable for the above-mentioned processes, particularly plastics such as PC, PBT, PA, PVC, PE, PS, PU and other resins.

[0030] Advantageously, the load-bearing structures are produced from a composite material. The use of this type of materials brings together the conditions necessary for obtaining load-bearing elements with a thinner wall thickness than with plywood, while at the same time offering better or equivalent thermal conductivity and a lower expansion coefficient. For example, said load-bearing structures may be produced from a polymer-resin-based composite material, for example polyester resin or another resin. Within the meaning of the invention, polymer-resin-based composite materials include polymers or mixtures of polymers with all kinds of fillers, additives, reinforcements or fibers, for example glass fibers or other fibers, providing sufficient rupture strength and rigidity and other properties. Additives may also be employed to reduce the material's density and/or improve its thermal properties, particularly reducing its thermal conductivity and/or its expansion coefficient. Use may also be made of a composite that includes a high proportional of sawdust with a synthetic binder. In certain embodiments, the load-bearing structure may also be made from laminated wood or plywood molded by hot compression.

[0031] According to a particular embodiment, said at least one insulating barrier consisting of said non-conducting elements is covered, on each occasion, by one of said sealed barriers that is formed from thin metal plate strakes with a low expansion coefficient, the edges of which are raised toward the outside of said non-conducting elements, said non-conducting elements having cover panels carrying parallel grooves spaced by the width of a plate strake in which weld supports are slidably retained, each weld support having a continuous wing projecting from the outer face of the cover panel and on whose two faces the raised edges of two adjacent plate strakes are welded in a leak-tight manner. The sliding weld supports form gliding joints allowing different barriers to move relative to one another through the effect of differences in thermal contraction and movements of the liquid contained in the tank.

[0032] Advantageously, said parallel grooves are provided in longitudinal ribs projecting from said cover panels. This embodiment makes it possible to reduce the thickness of the cover panels between the ribs. Advantageously, a layer of insulating foam is provided between said longitudinal ribs on said cover panels in order to support the sealing barrier covering the hollow elements.

[0033] Advantageously, secondary retention members integral with the load-bearing structure of the ship fix the non-conducting elements forming the secondary insulating barrier against said load-bearing structure, and primary retention members linked to said weld supports of the secondary sealing barrier retain said primary insulating
barrier against the secondary sealing barrier, said weld supports retaining said secondary sealing barrier against the cover panels of the non-conducting elements of the secondary insulating barrier. Thus, the primary insulating barrier is anchored on the secondary insulating barrier, with no effect on the continuity of the secondary sealing barrier interposed between them.

[0034] According to a preferred embodiment, said thermal insulation liner includes reinforced or unreinforced, rigid or flexible foam of low density, i.e. under 60 kg/m³, for example around 40 to 50 kg/m³, which has very good thermal properties. It is also possible to use a material of nanoscale porosity of the aerogel type. A material of the aerogel type is a low-density solid material with an extremely fine and highly porous structure, possibly with a porosity up to 99%. The pore size of these materials is typically in the range between 10 and 20 nanometers. The nanoscale structure of these materials greatly limits the mean free path of the gas molecules, and therefore also convective heat and mass transfer. Aerogels are thus very good thermal insulators, with a thermal conductivity, for example, below 2x10⁻³ W m⁻¹ K⁻¹, preferably less than 16x10⁻¹ W m⁻¹ K⁻¹. They typically have a thermal conductivity 2 to 4 times as low as that of other, conventional insulators, such as foams. Aerogels may be in different forms, for example in the form of powder, beads, nonwoven fibers, fabric, etc. The very good insulating properties of these materials make it possible to reduce the thickness of the insulating barriers in which they are used, which increases the useful volume of the tank.

[0035] The invention also provides a floating structure, in particular a methane carrier, characterized in that it comprises a sealed, thermally insulated tank according to the subject of the above invention. A tank of this type may, in particular, be employed in an FPSO (floating, production, storage and offloading) facility, used to store the liquefied gas with a view to exporting it from the production site, or an FSRU (floating storage and regasification unit) used to unload a methane carrier with a view to supplying a gas transportation system.

[0036] The invention will be better understood and other objects, details, characteristics and advantages thereof will become more clearly apparent in the course of the following description of a particular embodiment of the invention that is given solely by way of non-limiting illustrative example with reference to the appended drawings, in which:

[0037] FIG. 1 is a stripped-back perspective view of a tank wall according to a general embodiment that is useful for understanding the invention;

[0038] FIGS. 2 and 3 show a primary retention member of the tank wall of FIG. 1 seen in two perpendicular directions;

[0039] FIG. 4 is a transverse sectional view of a tank wall according to one embodiment of the invention;

[0040] FIG. 5 is a partial perspective view of an insulating caisson of the tank wall shown in FIG. 4;

[0041] FIG. 6 is an enlarged view of the zone XV of FIG. 4;

[0042] FIG. 7 is a stripped-back perspective view of a zone of a tank wall according to another embodiment of the invention;

[0043] FIGS. 8 to 10 show the transverse section of further embodiments of a non-conducting element with a load-bearing structure in the form of a hollow profiled section;

[0044] FIG. 11 shows, in perspective, a load-bearing structure molded as a single piece;

[0045] FIG. 11A is a partial, sectional view showing a variant embodiment of the load-bearing structure of FIG. 11;

[0046] FIG. 12 is an expanded perspective view of two types of non-conducting element produced with the aid of the load-bearing structure of FIG. 11;

[0047] FIG. 13 is a partial, sectional view showing the assembly of a non-conducting element of FIG. 12;

[0048] FIGS. 14 and 15 are views similar to FIG. 11, showing other variant embodiments of the load-bearing structure;

[0049] FIG. 16 is a partial, sectional view of a non-conducting element according to a further embodiment of the invention;

[0050] FIG. 17 is a plan view of the load-bearing structure of the non-conducting element of FIG. 16;

[0051] FIGS. 18 to 21 show further embodiments of load-bearing elements in the form of pillars, seen in transverse section;

[0052] FIGS. 22 and 23 show, in plan view and in sectional view on the line XXIII-XXIII, a load-bearing structure of a non-conducting element according to a further embodiment;

[0053] FIG. 24 shows, in perspective, a load-bearing structure thermoformed from a single piece; and

[0054] FIG. 25 is an expanded perspective view of a non-conducting element according to a further embodiment, the insulation liner being omitted.

[0055] A description will be given below of several embodiments of a sealed, thermally insulated tank incorporated in and anchored to the double hull of a structure of the FPSO or FSRU type or of a methane-type carrier. The general structure of such a tank is well known per se and has a polyhedral form. Therefore, a description will be given only of a wall zone of the tank, it being understood that all the walls of the tank have a similar structure.

[0056] A description is now given of a general embodiment that is useful for understanding the invention, with reference to FIGS. 1 to 3. FIG. 1 shows a zone of the double hull of the ship, denoted by 1. The tank wall is composed, in succession, in its thickness, of a secondary insulating barrier 2 formed from caissons 3 juxtaposed on the double hull 1 and anchored to the latter by means of secondary retention members 4, then a secondary sealing barrier 5 carried by the caissons 3, then a primary insulating barrier 6 formed from juxtaposed caissons 7 anchored to the secondary sealing barrier 5 by primary retention members 48, and finally a primary sealing barrier 8 carried by the caissons 7.

[0057] The caissons 3 and 7 are parallelepipedal non-conducting elements with a mutually identical or different structure and mutually identical or different dimensions.
Secondary retention members 4 are fixed on pins 31 welded to the double hull 1 in a regular rectangular grid arrangement so that these retention members 4 can, on each occasion, hold four caissons 3, whose corners meet. Also provided are two secondary retention members 4 in the central zone of each caisson 3.

The secondary sealing barrier 5 is produced in accordance with the known technique in the form of a membrane consisting of Invar plate strakes 40 with raised edges. As may be seen better in FIG. 3, the cover panels 11 of the caissons 3 have longitudinal grooves, with an inverted-T-shaped cross section, denoted by 41. A weld support 42 in the form of a strip of Invar folded in the form of an L, is inserted sideby side in each groove 41. Each plate strake 40 extends between two weld supports 42 and has two raised edges 43 welded, on each occasion, continuously by a weld bead 44 to the corresponding weld support 42, as may be seen in FIGS. 2 and 3.

Similarly, the caissons 7 of the primary insulating barrier are anchored, on each occasion, to the four corners and at two points in the central zone of the caisson 7. To that end, use is made, on each occasion, of a primary retention member 48 shown in detail in FIGS. 2 and 3. The primary retention member 48 has a lower sleeve 49 integral with a lug 50 welded at several, for example three, points 51 of a weld support 42 above the raised edges 43 of the plate strakes 40. A rod 52 made from Pernium, a composite material based on resin-impregnated beech wood, has a lower end fixed in the lower sleeve 49 and an upper end fixed in a sleeve 54 integral with a support washer 53 that bears on the cover panels 11 of the caissons 7, being accommodated in counterinks 28 at the corners of the caissons 7 and at the central shafts 30. The sleeve 54 is threaded and is screwed onto a corresponding threaded end of the rod 52. When the washer 53 has been thus positioned, immobilizing screws 56 are engaged through holes 55 provided in the washer 53 and screwed into the panel 11 in order to prevent any subsequent rotation of the washer 53. In each insulating barrier, the caissons 3 and 7 are juxtaposed with a small intermediate space of the order of 5 mm.

Advantageously, a layer of nanoporous materials of the aerogel type, which are very good thermal insulators, is included as insulation liner in the caissons 3 and/or 7. Aerogels also have the advantage of being hydrophobic, so absorption of the moisture from the boat into the insulating barriers is thus prevented. An insulation layer may be produced with aerogels, possibly pocketed, in textile form or in the form of beads.

Generally speaking, aerogels may be made from a number of materials, including silica, alumina, hafnium carbide and also varieties of polymers. Furthermore, in accordance with the manufacturing process, aerogels may be produced in powder, bead, monolithic sheet and reinforced flexible fabric form. Aerogels are generally manufactured by extracting or displacing the liquid of a gel of micronic structure. The gel is typically manufactured by means of chemical conversion and reaction of one or more dilute precursors. This results in a gel structure in which a solvent is present. Use is generally made of hypercritical fluids such as CO₂ or alcohol, to displace the gel solvent. Aerogels’ properties may be modified by using a variety of doping and reinforcement agents.

The use of aerogels as insulation liners significantly reduces the thickness of the primary and secondary insulating barriers. It is, for example, possible to conceive of barriers 2 and 6 having a thickness of 200 mm and 100 mm, respectively, by using an aerogel bed in textile form in the caissons 3 and 7. The tank wall then has a total thickness of 310 mm. As a variant embodiment, it is possible to conceive of a tank wall having a total thickness of 400 mm by using, on each occasion, a layer of aerogel particles, particularly aerogel beads, in the caissons 3 and 7.

With reference to FIGS. 4 and 5, a description will now be given of a first embodiment of a sealed, thermally insulated tank according to the invention. In the first embodiment, the primary and secondary insulating barriers are formed from monobloc profiled caissons 70 filled with an insulation liner, instead of the above-mentioned caissons 3 and 7. A caisson 70 of this type is shown in perspective in FIG. 5. It is obtained by extension of a composite material based on polymer resin and fibers, for example a polyester or an epoxy resin reinforced with glass or carbon fibers. To achieve this, the material may be worked as follows: the fibers are firstly impregnated with resin in a static or pressurized bath. They then pass through a die, whose role is to confer the geometry of the corresponding profiled section. Polymerization takes place simultaneously. The product obtained is continuous and cut to the appropriate dimensions. This is thus a mass-manufacturing process that includes, from one end to the other, the fibers and the resin, the die and the finished product to be cut to size.

The caisson 70 has the form of a profiled section with a constant cross section, with a base panel 71 and a cover panel 72 that are parallel and rectangular and, between these panels there are longitudinal partitions 75 defining a plurality of longitudinal cells 73 with a globally rectangular cross section and also two end cells 74 in the region of the two lateral sides of the caisson 70. The longitudinal partitions 75 become thicker in the region of the end zones 68 connected to the base plates 71 and to the cover plate 72. The cells 73 and 74 serve to receive an insulation liner 76, for example phenolic foam, low-density polyurethane foam, possibly fiber-reinforced, and/or one or more layers of aerogel-based insulation.

In the example shown in FIG. 5, the thickness of the base panel 71 is 6 mm, the thickness of the cover panel 72 is 9 mm and the thickness of the longitudinal partitions 75 is, on each occasion, 6 mm. The number of longitudinal partitions 75 is a purely illustrative example, and may be modified as desired.

The base panel 71 has, in the region of two cells 73, longitudinal notches 71 traversing, on each occasion, the entire thickness and the entire length of the panel 71. These notches 77 serve for the passage of the retention members of the caissons 70. Vertically above the two notches 77, the cover panel 72 has two longitudinal grooves 78 with a cross section in the shape of an inverted T. The grooves 78 have the same function as the grooves 41 of the first embodiment. A weld support 42, in the form of a strip of Invar folded in the form of an L, is inserted sideby side in each groove 78.

The caissons 70 of the secondary insulating barrier 2 and of the primary insulating barrier 6 are, on each occasion, anchored at four points. To achieve this, the cover panel 72 has holes 80 surrounded, on each occasion, by a
countersinking 81 and arranged, also, vertically above the two notches of the base panel 71.

[0069] Production of the tank wall according to this first embodiment is now described with reference to FIGS. 4 and 6. The caissons 70 forming the secondary insulating barrier 2 are anchored to the double hull 1, on each occasion, by four pins 82 welded to the double hull 1 and arranged opposite the holes 80, and on which, on each occasion, a washer 83, bearing on the base panel 71, and a nut 84 are engaged. As the geometry of the double hull 1 is irregular, provision is made for shims around the threaded pins 82. The thickness of each shim is calculated by computer on the basis of a topographical survey of the inner surface of the double hull 1. Thus, the base panels 71 are positioned along a theoretical regular surface. Between the base panels 71 and the double hull 1, provision is conventionally made for beads of polymerizable resin (not shown) that are adhesively bonded to the base panels 71 and are crash against the double hull when the caissons 70 are fitted, so as to provide their support. To avoid this resin adhering to the double hull, a sheet of Kraft paper (not shown) is provided between them.

[0070] A cylindrical shaft 85 is provided in the insulating liner 76 so that these operations can be performed from the top of the caisson 70, this shaft subsequently being filled in with insulation.

[0071] In a variant embodiment, the washer 83 may also be arranged so as to bear on the cover panel 72 instead of the base panel 71. To achieve this, the washer 83 is attached to the top of an elongate coupling member (for example a member similar to the members 48), which is inserted via the shaft 85 and whose base is fixed to the pin 82, for example by means of a threaded sleeve.

[0072] The sealing barriers 5 and 8 are produced as in the general embodiment by Invar plate strips 40 welded to weld supports 42 housed in the grooves 78 of the caissons 70. The weld supports 42 of the secondary sealing barrier engage via the longitudinal notches 77 of the caissons 70 forming the primary insulating barrier 6. The caissons 70 forming the primary insulating barrier 6 are anchored with the aid of primary retention members 48 identical to those described in the general embodiment. On each occasion, the bearing washer 53 is housed in the bottom of a countersinking 81.

[0073] In the two insulating barriers, the caissons 70 are juxtaposed edge-to-edge with minimal clearance, allowing alignment errors to be compensated for.

[0074] Providing the holes 80 vertically above the notches 77 ensures that the retention members 48 operate properly in the axial direction when linked to the underlying weld supports 42. This makes it possible, also, to use strictly identical caissons to make the two insulating barriers, which simplifies their manufacture. However, in the caissons of the secondary insulating barrier the notches 77 could be replaced by cylindrical holes.

[0075] The holes 80 could also be offset relative to the grooves 78 in each of the insulating barriers.

[0076] With reference to FIG. 7, a description is now given of a tank wall in which the primary and secondary insulating barriers 6, 2, respectively, are formed from caissons 170a, 170b, respectively, according to a further embodiment. In the caissons 170a and 170b, the elements that are identical or similar to those of the caisson 70 bear the same reference numeral increased by 100 and are not described unless they are different therefrom. Four caissons in the service position are shown in FIG. 7.

[0077] An important feature of the caissons 170a and 170b is that they have oblique longitudinal partitions 192 and 193, i.e. partitions that are not perpendicular to the base 171 and cover 172 panels. In the example shown, each partition includes a partition 192 inclined at approximately 30 to 50° in one direction and a partition 193 inclined at approximately 30 to 50° in the opposite direction. These partitions are, on each occasion, provided in a longitudinal cell 173 adjacent to an end cell 174 in order to divide it into two triangular-section cells. However, other configurations are possible in terms of number, position and inclination of the inclined partitions. Sections of this type take up not only shear forces but also buckling and tilting forces applied to the caisson.

[0078] On the caissons 170a and 170b, the grooves 178 designed to receive the weld supports 42 extend in the direction of the width, i.e. perpendicularly to the longitudinal partitions 175. The base panel 171 of the caissons 170a and 170b thus has no longitudinal notches.

[0079] In the caisson 170a, notches 177 for the passage of the weld supports 42 traverse the entire width of the caisson, intersecting the longitudinal partitions 175. Furthermore, these notches 177 are offset relative to the grooves 178. Thus, the coupling member 48 retaining the barrier 6 bear on the cover panel 172 in the region of the countersinking 181 surrounding the holes 180, which are offset relative to the grooves 178. Provision has been made for there to be nine coupling members 48 per caisson 170a at regular intervals in FIG. 7. However, more or fewer than nine anchoring points per caisson 170a and 170b may be sufficient, for example four or six, depending on the size of the caisson.

[0080] The caissons 170b forming the second insulating barrier 2 are anchored to the double hull 1, on each occasion, by four pins 82 welded to the double hull 1 and engaging, on each occasion, in a corresponding hole of the base panel 171. Vertically in line with these holes (not shown) there is a cylindrical passage comprising holes 191 through the oblique partitions 192 or 193 and holes 190 through the cover panel 172. These holes allow a box wrench to be inserted to tighten the nut 84. Alternately, provision may be made for a coupling member traversing these holes in order to couple the pin 82 to the cover panel 172 rather than anchoring the caisson 170b in the region of its base panel 171.

[0081] The caissons 70 and 170a-b are self-supporting caissons capable of withstanding the pressure of the liquid in the tank, such that the sealing barriers 5 and 8 supported by them have no need themselves to support this pressure and are advantageously produced in the form of very thin membranes with a thickness, for example, of 0.7 mm of Invar.

[0082] FIG. 8 shows the transverse section of a non-conducting caisson 270 that also has a profiled load-bearing structure. This load-bearing structure has an upturned
U-shaped cross section with a cover panel 272 and two load-bearing partitions 275 substantially perpendicular to it. It may be manufactured using the process indicated previously, or by molding of plastic. In accordance with a further possibility, this U-shaped cross section may be obtained by forming a laminated-wood or plywood panel. Insulation 276, for example low-density plastic foam, fills the space between the partitions 275 and adheres to the profiled load-bearing structure.

[0083] FIG. 10 shows a non-conducting caisson 470 whose transverse section has the form of a comb, with a cover panel 472 and perpendicular load-bearing partitions 475 each having a thickening 468 in the region of the link with the panel 472. Insulation 476 fills the longitudinal cells formed between the partitions 475. This comb structure may be extruded or molded as a single piece. Another possibility is to fix a plurality of caissons with the shape of the caisson 270 together, side-by-side, for example by adhesive bonding or stapling.

[0084] The caisson 270 or 470 may be used in place of the caisson 170a or 170b of FIG. 7. In such a case, the primary caisson rests on the second sealing barrier 5 with the aid of the partitions 275 or 475. The secondary caisson rests in the same manner on the above-mentioned strips of resin. To prevent pinching of the barrier 5 or of the strips of resin, provision may be made for a flat sole plate that is widened at the end of each partition 275 or 475. Provision may also be made for a base panel (not shown) fixed to the lower face of the caisson 270 or 470, for example by means of adhesive bonding, stapling and/or flush-fitting of the ends of the partitions 275 or 475 in the thickness of the panel. If such sole plates or a separate panel are added, the caisson 270/470 may obviously be used in the inverted position, i.e. with the panel 272/472 as the base and the sole plates or separate panel as cover, with grooves retaining the weld supports of the adjacent sealing barrier.

[0085] FIG. 9 shows a non-conducting caisson 370 in which the profiled load-bearing structure has a crenelated cross section, with alternate cover panels 372 and base panels 371, each extending over a portion of the width of the caisson and connected, on each occasion, by load-bearing partitions 375. A layer of insulation is formed by longitudinal foam slabs 376a and 376b bonded, on each occasion, between two partitions 375 on the panels 371 and under the panels 372. The caisson 370 may be used as shown or, alternately, with a supplementary cover panel and/or base panel fixed to it. Other profiled load-bearing structural sections may also be produced, for example in the form of an H or I.

[0086] With reference to FIGS. 11 to 15, a description is given of further embodiments of non-conducting caissons or elements that can be used to form the insulating barriers of the tank wall, the general structure of which was described for FIGS. 1 to 3. The production of the sealing barriers and the attachment of the various barriers is similar to the preceding embodiments, there will be no point in describing them again here.

[0087] FIG. 12 shows, in expanded perspective view, a caisson 570 and a caisson 670 that are, respectively, manufactured with the aid of molded load-bearing structures 500, a description of which will now be given with reference to FIG. 11.

[0088] The load-bearing structure 500 is an injection-molded piece made from any appropriate material. It has a flat plate 571 with chamfered corners, for example in the form of a 1.5-m-sided square or of a rectangular, from one face of which sixteen hollow circular cylindrical pillars 575 project, arranged in the form of a regular square grid, plus two tubes 581 of smaller cross section in the region of a central zone of the plate, and also four triangular cylindrical pillars 580 in the region of the four corners of the plate. The plate 571 is continuous in the region of the base of the pillars 575 and 580, but pierced in the region of the base of the tubes 581 in order to allow the passage of a coupler rod. Furthermore, in the case of a caisson of the primary barrier 6, the plate 571 is slotted in order to allow through the weld supports 42 and the raised edges 43 of the plate the strakes of the secondary sealing barrier. The pillars 580 serve to receive the bearing forces of the coupling members used at each corner of the non-conducting elements. The cross section of the pillars 575 is, for example, 300 mm for a 1.5 m square plate. As for the insulating liner, the load-bearing structure 500 may be covered with a layer of low-density foam, which is poured between and into the pillars 575.

[0089] The cross section of the pillars may be reasonably large, the important thing being to always make provision for several pillars per caisson. Thus, the dimensions of the pillars in terms of cross section may be ⅓ or even ⅔ of the corresponding dimensions of the caisson.

[0090] In order to form the caisson 570, an independent panel 572 with the same dimensions as the plate 571 is fixed on the end of the pillars 575 opposite this plate. This panel may be fixed by any means (adhesive bonding, stapling, flush fitting, etc.). In FIG. 12, provision has been made for circular grooves 573 on the inner face of the panel 572, for receiving the end of each pillar 575 tightly.

[0091] The materials of the structure 500 and of the panel 572 may be chosen so as to produce heat-shrinking of the pillars 575 in the panel. For example, with a piece 500 made from PVC and a panel 572 made from plywood, which exhibits less heat shrinkage, the end of the pillars 575 is made to grip the circular core delimited by the groove 573 when the tank is cooled. Conversely, gripping of the pillars 575 could also be obtained with a panel 572 that contracts more than the piece 500.

[0092] The panel 572 has holes 574 opposite the tubes 581 of the molded structure 500.

[0093] In the caisson 670, two identical molded structures 500 are arranged symmetrically and assembled together by causing their respective pillars 575 to bear against one another. This assembly may be produced by any means (adhesive bonding, welding, flush fitting, etc.). In FIG. 12, it is achieved with the aid of a linking ring 680 interposed, on each occasion, between two aligned pillars 575 and flush fitted over them. This assembly can be seen better in FIG. 13, where it will be observed that the linking ring 680 has an outer annulus 682 and an inner annulus 681 that are connected by means of a radial tongue 683. The pillars 575 flush fit between the two annuli 681 and 682 and abut on either side of the tongue 683. The material of the ring 680 may be chosen to have lower conductivity than that of the pillars 575, in order to fulfill a thermal insulation function. They may also, alternately or in combination, be chosen to have an expansion coefficient that is different from that of
the pillars 575 in order to fulfill a thermal assembly function. In a variant embodiment, two molded structures having pillars with complementary cross sections may be fixed together by means of direct nesting of the pillars together.

[0094] The foam-filled piece 500 may also be used alone without a supplementary panel by rotating the plate 571 toward the inside of the tank in order to support the adjacent sealing barrier. The non-conducting element thus formed rests via the pillars 575 on the secondary sealing barrier or on the strips of resin fixed to the hull.

[0095] FIGS. 14 and 15 show molded load-bearing structures 600 and 700 that make it possible to produce non-conducting elements in a manner similar to the structure 500 described previously.

[0096] In FIG. 14, identical reference numerals to those in FIG. 11 denote identical elements. The structure 600 includes planar peripheral walls 601 extending continuously along the four edges of the plate 571, forming a box capable of containing insulation in the form of powder, beads or the like. For example, a structure 600 containing aerogel beads may be combined with a structure 600 containing low-density foam to form a caisson 670 as shown in FIG. 12.

[0097] In FIG. 15, the planar plate 771 carries thirty-six hollow tubular pillars 775 of smaller cross section (for example 100 mm) than the above-mentioned pillars 575, four hollow tubular pillars 780 with an even smaller cross section (for example 50 to 60 mm) in the region of its corners, and two tubular pillars 781, similar to the pillars 780, in the region of a central zone of the plate 771 in order to allow the coupling members serving to attach the insulating barrier to pass through.

[0098] The structures 500, 600 and 700 may be injection-molded. A similar structure may also be obtained by thermoforming from a plastic plate. This possibility is illustrated in FIG. 11A. In such a case, the initially planar plate 571 is heated and deformed to match the impression of a female mold 560. This results in load-bearing pillars 575 whose plate-side end is open and whose opposite end is closed by a wall 583. In such a case, the space 582 located inside the pillars 575 is filled with, for example, foam from the face of the plate 571 opposite these pillars.

[0099] The walls 601 may also be obtained by thermoforming.

[0100] FIG. 24 shows, in perspective, a thermoformed load-bearing structure 1300 that includes a plate 1371 that can act as a base panel or cover panel for a caisson, and load-bearing pillars 1375 obtained in a similar way to the pillars 575 in FIG. 11A. In the example shown, the pillars 1375 have a frustoconical shape, which facilitates their forming. For example, provision may be made for a pillar diameter that varies from 160 mm at the base to 120 mm at the top, over a height of approximately 100 mm.

[0101] In order to serve as base panel of a caisson of the primary insulating barrier, the plate 1371 is provided with two longitudinal ribs 1384 extending over the entire length of the plate 1371. Each rib 1384 is obtained during the thermoforming operation by pushing the material in the same direction as the pillars 1375, so as to form a V-shaped fold that is open on the planar face of the plate 1371, the inner space 1385 of which allows the weld supports 42 and

the raised edges 43 of the secondary sealing barrier to pass through. In the case of the secondary insulating barrier, the ribs 1384 are unnecessary.

[0102] A description was given previously of the load-bearing structures that include a plate acting as cover or base panel. A description is now given of a further embodiment of a non-conducting element 870 with reference to FIG. 16, in which the molded load-bearing structure 800 includes load-bearing elements 875 of small cross section connected by arms 890. This load-bearing structure is in plan view in FIG. 17. The load-bearing elements 875 are hollow circular cylindrical pillars arranged in a regular grid and connected by arms 890 that are arranged in the form of a square-mesh grid. A cover panel 872 and a base panel 871, for example made from plywood, plastic, composite or another material, are adhesively bonded to the two faces opposite the load-bearing structure 800. The arms 890 are located at the end of the load-bearing elements 875 adjacent to the panel 872 and have a planar upper face, which may serve for adhesive bonding of the panel 872.

[0103] FIG. 25 shows the non-conducting element 870 in expanded perspective view, in a version that its slightly modified in terms of the arrangement of the linking arms 890.

[0104] Other arms may be provided in the region of the lower end of the pillars 875. The arms may also be placed in another region of the load-bearing pillars (for example half way up).

[0105] The inner space of the caisson 870, i.e. the inner space 880 of the pillars 875, and the space 876 between the pillars is filled with one or more types of insulation. When low-density foam is used, the caisson may be manufactured by placing a structure 800 of rectangular form in plan view in a mold, pouring the foam into the mold so as to embed the structure 800 in a parallelepipedic block of foam, then fixing the panels 872 and 871 to this block. The base panel 871 is not always necessary. One of the panels may also be molded as a single piece with the structure 800.

[0106] Although a description has been given of hollow load-bearing pillars of circular cross section in the load-bearing structures 500, 600, 700 and 800, the load-bearing pillars may have any other form in terms of cross section and any type of regular or irregular spatial distribution. For example FIG. 18 shows a load-bearing pillar 975 consisting of a plurality of concentric cylindrical walls 976. In the pillar 1075 of FIG. 19, the cylindrical walls 1076 have a square cross section. The pillars may also have a cross section that varies over their height, for example frustoconical pillars.

[0107] FIG. 20 shows pillars 1175 distributed in lines in the form of a regular figure and with a hollow, square cross section with chamfered corners. In FIG. 21, pillars 1275, for example solid circular cylinders, are distributed in a staggered arrangement. Other cross sections are also achievable, i.e. rectangular, polygonal, L-shaped, solid or hollow, dihedral, etc. cross sections.

[0108] In all cases, such pillars may be molded so as to project from a plate and/or be linked by arms and/or by any linking means formed as a single piece with them. When use is made of low-density foam as thermal insulation liner layer, it is particularly advantageous to pour this foam in a single step over the entire surface area of the linking plate,
between and possibly into the load-bearing pillars. Another possibility is to machine wells in a block of foam formed in advance and to insert the load-bearing elements into the wells formed for that purpose.

[0109] In the case of a granular insulation, it is necessary to use a non-conducting element with peripheral walls that are preferably formed as a single piece with the load-bearing structure, as in FIG. 14. By virtue of the form of the load-bearing elements of small cross section, the inner space of the box between them is not compartmentalized, and therefore the granular material is easier to distribute over the entire surface area of the non-conducting element. The granular material may also be inserted into hollow pillars.

[0110] Load-bearing pillars of very small cross section, for example smaller than 40 mm, may be left empty without detriment to the thermal insulation. Hollow pillars of small cross section may also be filled with a flexible-PE foam cone or with glass wool.

[0111] With reference to FIGS. 22 and 23, a description is now given of an embodiment of a non-conducting element that comprises a monobloc hollow caisson 1470 produced by rotational molding or by injection blow-molding. This caisson has the form of a closed hollow envelope 1477 that includes eight frustoconical pillars 1475 formed so as to project from the base wall 1471 of the envelope and each having a top wall 1483 capable of bearing against the top wall 1472 of the envelope in order to take up the compression forces.

[0112] To fix the caisson, six frustoconical shafts 1480 are provided, arranged at the periphery of the envelope and open through the top wall 1472. These shafts each have a base wall capable of bearing against the base wall 1471 in order to take up the compression forces and capable of being pierced in order to receive a fixing rod, shown diagrammatically at 1431, which is, for example, a pin welded to the hull or a coupling device fixed to an underlying sealing barrier.

[0113] The inner space 1476 of the caisson and the inner space 1482 of the pillars 1475 may be filled with any suitable insulation, for example by injection of foam.

[0114] Similarly, the shafts 1480 may be filled with insulation, for example PE foam or glass wool, after the caisson is fixed.

[0115] To mold the caisson 1470, use may be made, for example, of high-density PE, polycarbonate, PBT or another plastic. The shafts 1480 may also be dispensed with if use is made of another method of attaching the caissons, for example coupling members passing between the caissons to be attached and bearing on the top wall 1472 in the manner of the retention members 48 of FIGS. 2 and 3. Base and/or cover panels may also be fixed to the walls of the envelope in order to reinforce it.

[0116] In the load-bearing structures 500, 600, 700, 800, 1300 and 1470 described above, the pillars may also be replaced by partitions that create compartments inside the load-bearing structure.

[0117] Although a description has been given of essentially parallelepipetal, right-angled non-conducting elements, other forms of cross section are possible, notably any polygonal form capable of rendering a planar surface discrete.

[0118] Of course, the insulation liner of a non-conducting element may include an number of layers of material.

[0119] When one of the primary and secondary insulating barriers is produced with the aid of the non-conducting elements described above, it is possible, but not necessary, to produce the other insulating barrier in an identical manner. Non-conducting elements of two different types may be used in the two barriers. One of the barriers may consist of prior-art non-conducting elements.

[0120] The caissons of the secondary insulating barrier and of the primary insulating barrier may be anchored to the ship’s hull in a different way from the example shown in the figures, for example with the aid of retention members engaged on the base panel of the caissons.

[0121] In a known manner, corner connections of the primary and secondary barriers in zones where the walls of the load-bearing structure meet at angles may be achieved in the form of a connection ring whose structure remains substantially constant along the entire intersection ridge of the walls of the load-bearing structure. The structure of such a connection ring is well known and will not be described in detail here. In the case of a tank incorporated into a ship, a ring of this type is generally arranged along the angle formed between a longitudinal wall of the double hull of the ship and a partition running across the ship.

[0122] Within the meaning of the invention, “tank wall” includes the corner connection zones, particularly the connecting rings, irrespective of their shapes, where the non-conducting elements described above may also be used.

[0123] Although the invention has been described in connection with a number of particular embodiments, it is obviously not limited to these in any way and includes all technical equivalents of the means described and also combinations thereof if they fall within the scope of the invention.

1. Sealed, thermally insulated tank including at least one tank wall fixed to the hull (1) of a floating structure, said tank wall having, in succession, in the direction of the thickness from the inside to the outside of said tank, a primary sealing barrier (8), a primary insulating barrier (6), a secondary sealing barrier (5) and a secondary insulating barrier (2), at least one of said insulating barriers consisting essentially of juxtaposed non-conducting elements (3, 7), each non-conducting element including a thermal insulation liner (76, 276, 376a-b, 476) arranged in the form of a layer parallel to said tank wall, and load-bearing elements (75, 175, 192, 193, 275, 375, 475, 575, 775, 875, 975, 1075, 1175, 1275, 1375, 1475) that rise through the thickness of said thermal insulation liner in order to take up the compression forces, characterized in that said load-bearing elements of a non-conducting element are produced in the form of at least one load-bearing structure (70, 170a, 170b, 270, 370, 470, 500, 600, 700, 800, 1300, 1477) formed from a single piece including on each occasion linking means (71, 72, 171, 172, 272, 371, 372, 472, 571, 771, 890, 1371, 1471) that rigidly link said load-bearing elements together and at least one height portion of said load-bearing elements, said at least one load-bearing structure of a non-conducting element (70, 170a-b, 270, 370, 470) having the form of a hollow profiled section having a constant cross section in a longitudinal direction.
2. Sealed, thermally insulated tank according to claim 1, characterized in that said linking means of a load-bearing structure include a panel (71, 72, 171, 172, 272, 371, 372, 472, 571, 771, 1371, 1471) extending parallel to said tank wall on a side of said non-conducting element, said load-bearing elements projecting from an inner face of said panel.

3. Sealed, thermally insulated tank according to claim 1, characterized in that said load-bearing elements of a load-bearing structure include at least two longitudinal partitions (75, 175, 192, 193, 275, 375, 475) arranged at a distance from one another in order to define at least one cell (73, 173) of mutually constant cross section, capable of receiving the thermal insulation liner (76, 276, 376a-b, 476).

4. Sealed, thermally insulated caisson according to claim 3, characterized in that said longitudinal partitions include at least one partition (75, 175) substantially perpendicular to said tank wall.

5. Sealed, thermally insulated tank according to claim 3, characterized in that said longitudinal partitions include at least one partition (192, 193) that is inclined relative to said tank wall.

6. Sealed, thermally insulated tank according to claim 5, characterized in that said longitudinal partitions include at least two partitions (192, 193) having inclinations in opposite directions from one another.

7. Sealed, thermally insulated tank according to claim 3, characterized in that said linking means of a load-bearing structure include at least one linking wall (71, 72, 171, 172, 472) connecting said longitudinal partitions (75, 175, 475) over their entire length, said longitudinal partitions having a thickening (68, 168, 468) in the region of their zones that link with said at least one linking wall.

8. Sealed, thermally insulated tank according to claim 3, characterized in that the non-conducting element (70, 170a-b) includes a base panel and a cover panel and in that at least one of the outermost longitudinal partitions in a lateral direction of the non-conducting element is at a distance from the lateral edge corresponding to at least one said bottom and cover panels in order to delimit an end cell (74, 174) having an open lateral side.

9. Tank according to claim 2, characterized in that said non-conducting element (570) includes a second panel (572) formed independently of said load-bearing structure (500) and fixed to the end of said load-bearing elements (575) opposite the first panel (571) forming said linking means.

10. Sealed, thermally insulated tank according to claim 9, characterized in that the inner face of said second panel has recesses (573) arranged in such a manner as to interact with said load-bearing elements (575) by means of flush fitting.

11. Sealed, thermally insulated tank according to claim 10, characterized in that said second panel (572) has a thermal expansion coefficient that is different from that of said load-bearing elements (575) so as to give rise to gripping between said second panel and said load-bearing elements flush fitted in the latter when the tank is cooled.

12. Sealed, thermally insulated tank according to claim 2, characterized in that said non-conducting element (670) has two load-bearing structures (500) arranged in such a manner that their respective panels have said inner faces turned toward one another, the load-bearing elements (575) projecting from said inner faces being assembled in pairs in the region of their ends located opposite said panels in order to form, on each occasion, a load-bearing element of said non-conducting element.

13. Sealed, thermally insulated tank according to claim 12, characterized in that an insulating piece (680) having a thermal conductivity that is lower than that of said load-bearing elements is interposed, on each occasion, between the two assembled load-bearing elements.

14. Sealed, thermally insulated tank according to claim 12, characterized in that the load-bearing elements of the two load-bearing structures are assembled in pairs, on each occasion, by means of a linking piece (680) having a thermal expansion coefficient that is different from that of said load-bearing elements so as to give rise to gripping between said linking piece and said load-bearing elements (575) when the tank is cooled.

15. Sealed, thermally insulated tank according to claim 1, characterized in that at least one load-bearing structure (70, 170a-b, 270, 370, 470, 500, 600, 700, 800, 1300, 1477) of a non-conducting element is manufactured by means of a forming process chosen from the group comprising the processes of molding, extrusion, pultrusion, thermoforming, blow-molding, injection-molding and rotational molding.

16. Sealed, thermally insulated tank according to claim 1, characterized in that at least one insulating barrier (5, 8) consisting of said non-conducting elements (70, 170a-b, 870) is covered, on each occasion, by one of said sealed barriers (5, 8) that is formed from thin metal plate strakes (40) with a low expansion coefficient, the edges of which are raised toward the outside of said non-conducting elements, said non-conducting elements having cover panels (72, 172, 872) carrying parallel grooves (78, 178) spaced by the width of a plate strake in which weld supports (42) are slidably retained, each weld support having a continuous wing projecting from the outer face of the cover panel and on whose two faces the raised edges (43) of two adjacent plate strakes are welded in a leaktight manner.

17. Sealed, thermally insulated tank according to claim 16, characterized in that secondary retention members (82-84) integral with the load-bearing structure of the ship fix the non-conducting elements forming the secondary insulating barrier (2) against said load-bearing structure (1), and in that primary retention members (48) linked to said weld supports (42) of the secondary sealing barrier (5) retain said primary insulating barrier against the secondary sealing barrier, said weld supports retaining said secondary sealing barrier against the cover panels of the non-conducting elements of the secondary insulating barrier.

18. Floating structure, characterized in that it comprises a sealed, thermally insulated tank according to claim 1.

19. Floating structure according to claim 18, characterized in that it consists of a methane carrier.

20. Sealed, thermally insulated tank according to claim 2, characterized in that said load-bearing elements of a load-bearing structure include at least two longitudinal partitions (75, 175, 192, 193, 275, 375, 475) arranged at a distance from one another in order to define at least one cell (73, 173) of mutually constant cross section, capable of receiving the thermal insulation liner (76, 276, 376a-b, 476).