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[54] **METHOD OF CONSTRUCTING A LOW TEMPERATURE LIQUEFIED GAS TANK OF A MEMBRANE TYPE**

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[51] **Int. Cl.** **B21d 39/00,** B23p 19/04

[58] **Field of Search** .... 29/455, 460; 114/74 A; 220/9 LG, 9 A, 1 B

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[57] **ABSTRACT**

A method of constructing a low temperature liquefied gas tank of a membrane type comprising an inner membranous vessel provided at the inside of a rigid outer vessel with interposition of a heat insulating layer, characterized by the steps of constructing said inner membranous vessel in said outer vessel, urging flat side wall portions of said inner membranous vessel, after the completion thereof, toward the inside of said inner membranous vessel as much as to form a marginal slack corresponding to the contraction of said inner membranous vessel in a low temperature operating condition, and filling up the space left between said outer vessel and said inner membranous vessel with a compression resistant heat insulating material while keeping said inwardly urged condition of said inner membranous vessel, whereby said inner membranous vessel is constructed so as to favorably fit the space defined by the inner surface of said heat insulating layer when it has contracted in a low temperature operating condition.

7 Claims, 2 Drawing Figures

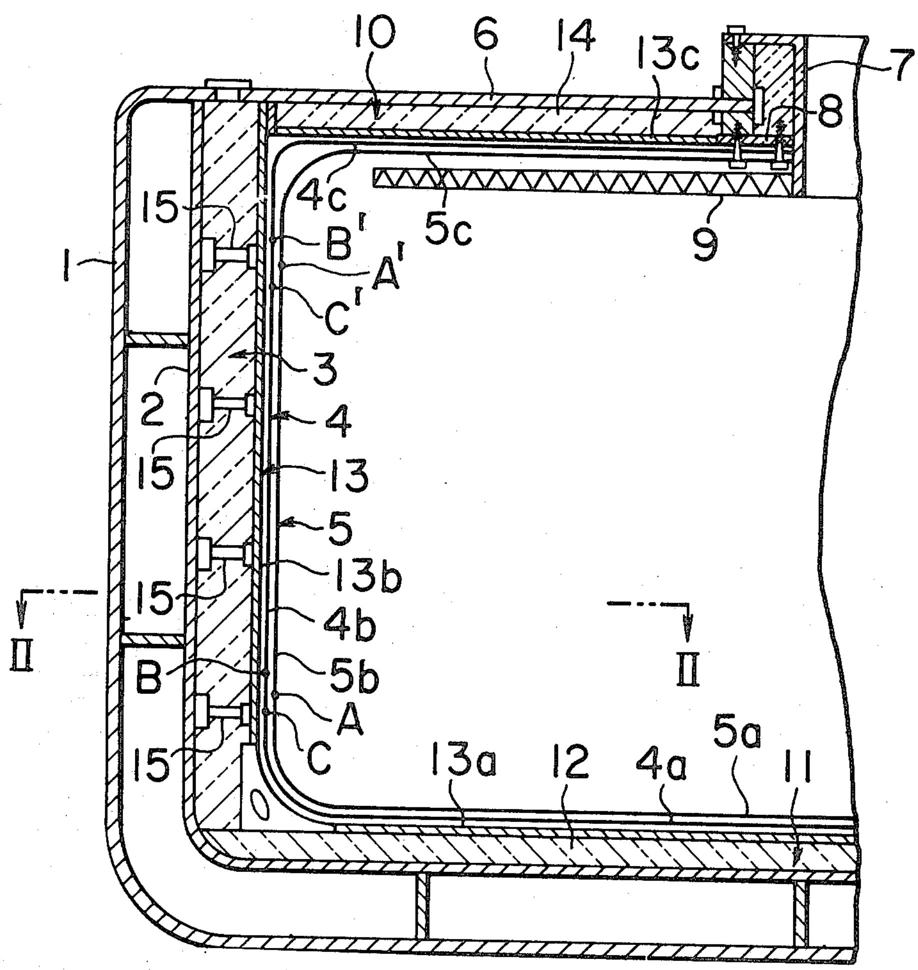

FIG. 1

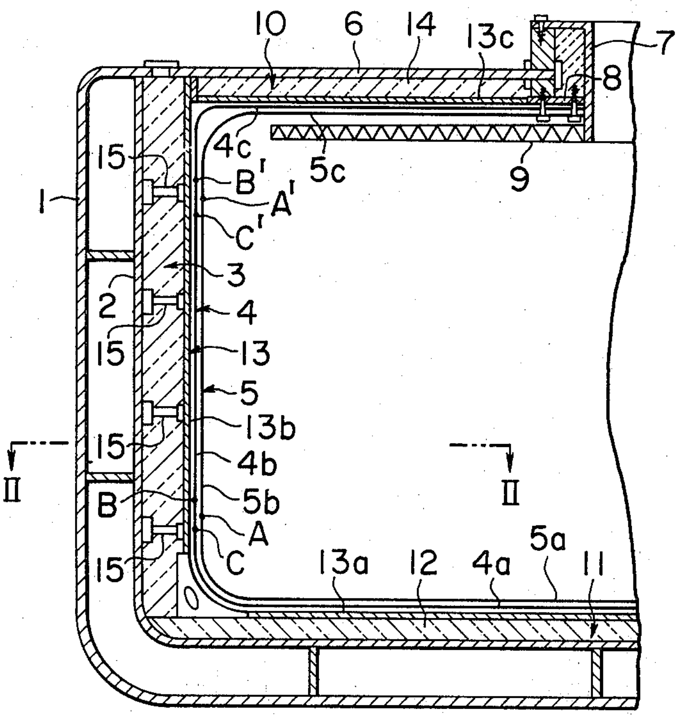
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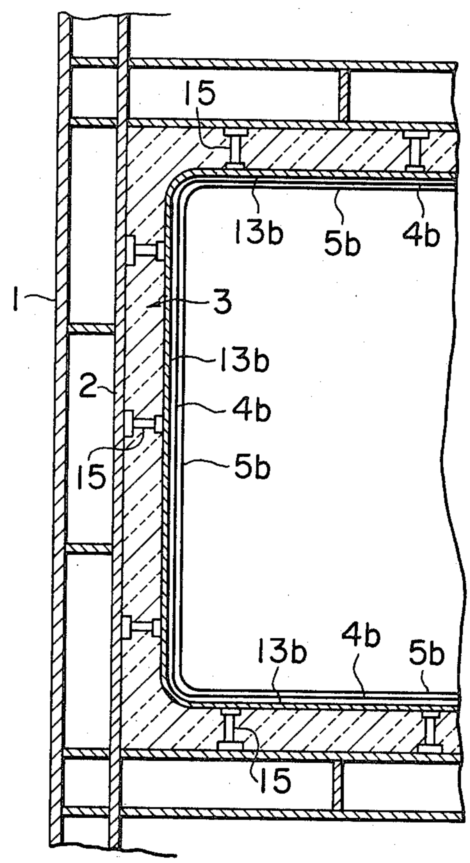
FIG. 2



METHOD OF CONSTRUCTING A LOW TEMPERATURE LIQUEFIED GAS TANK OF A MEMBRANE TYPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method of constructing a low temperature liquefied gas tank of a membrane type for containing low temperature liquefied gases such as natural gases or petroleum gases which are in a gaseous state at room temperature and can be liquefied at low temperature under atmospheric pressure.

2. Description of the Prior Art

A tank of this kind is generally composed of an outer vessel of a rigid structure, a heat insulating layer provided at the inside of said outer vessel and an inner membranous vessel provided further at the inside of said heat insulating layer, i.e. a vessel made of a thin plate and adapted to be readily deformed by an internal pressure and to come in close contact with the surface of the heat insulating layer so as to transmit the internal pressure applied by the low temperature liquefied gases loaded in the inner vessel to the outer vessel by way of the heat insulating layer thereby to support the load finally by the outer vessel.

Conventionally, the low temperature liquefied gas tank of a membrane type of the abovementioned structure has been constructed in a manner that the outer vessel is first constructed and then the heat insulating layer is constructed at the inside of the outer vessel by employing various kinds of heat insulating materials having compression resisting characteristic or by forming the heat insulating layer as a composite layer composed of heat insulating materials and reinforcing members so as to obtain as a whole a compression resisting heat insulating layer, and finally a thin plate of a low temperature resisting material such as nickel steel, stainless steel or aluminum is extended over the inside surface of the heat insulating layer to form a fluid-tight membranous vessel. According to the conventional method of construction, the tank can be constructed to have an inner membranous vessel closely fitting over the inside surface of the heat insulating layer, or in other words, the inner membranous vessel can be ideally so formed that the thin plate forming the inner membranous vessel is subject only to a compression force acting in the direction of its thickness under application of hydraulic pressure exerted from the inside of the inner membranous vessel. However, in a low temperature loaded condition when the membranous inner veseel is actually loaded with low temperature liquefied gases, the inner membranous vessel will contract with respect to the supporting surface provided by the heat insulating layer due to the low temperature caused by the low temperature liquefied gases loaded therein, while it is expanded by the internal pressure exerted by the low temperature liquefied gases loaded therein so much as to compensate the contraction due to low temperature, and therefore, the inner membranous vessel is actually supported by the heat insulating layer under application of a compression force acting in the direction of the thickness of the thin plate forming the inner vessel as well as a tensile force acting along the surface of the thin plate forming the inner vessel.

As mentioned above, the inner vessel of the low temperature liquefied gas tank of a membrane type is subject to changes of conditions from a normal temperature unloaded condition to a low temperature loaded condition by way of a low temperature unloaded condition according to loading or unloading of low temperature liquefied gases, or vice versa, and according to such changes of conditions, the inner vessel undergoes complicated deformations under the action of thermal stress. Therefore, it is not favorable to apply any restriction to the inner vessel which will prevent the deformations of the inner vessel since such a restriction will cause a stress concentration of the inner vessel. To avoid such a stress concentration, it is proposed to form the wall of the inner vessel in a shape of some complicated corrugation or as being formed with convexes and concaves in a normal temperature unloaded condition so that in a low temperature loaded condition the corrugated or convexed and concaved wall portions of the inner vessel contract to prevent smooth membranous wall portions which come in close contact with the inside surface of the heat insulating layer to be uniformly supported thereon. However, in this case, it requires a difficult work to form the inner vessel to have corrugated wall portions or convexed and concaved wall portions of a complicated structure, and therefore, there is a drawback that the overall construction cost of the tank becomes high.

SUMMARY OF THE INVENTION

Therefore, it is the object of this invention to provide a novel method of constructing a low temperature liquefied gas tank of a membrane type by which the inner membranous vessel is constructed, in a very simple manner, so as to subject to the most favorable stress condition in a low temperature loaded condition without being provided with complicated corrugations or convexed and concaved portions.

The abovementioned object is accomplished, according to this invention, by a method of constructing a low temperature liquefied gas tank of a membrane type, said tank comprising an outer vessel of a rigid structure, a heat insulating layer provided at the inside of said outer vessel, and an inner membranous vessel provided further at the inside of said heat insulating layer, characterized by the steps of constructing said inner membranous vessel in said outer vessel, urging flat side wall portions of said inner membranous vessel, after the completion thereof, toward the inside of said inner membranous vessel as much as to form a marginal slack corresponding to the contraction of said inner membranous vessel in a low temperature operating condition, and filling up the space left between said outer vessel and said inner membranous vessel with a heat insulating material of compression resisting characteristic while keeping said inwardly urged condition of said inner membranous vessel.

According to the method of this invention, it is accomplished to make the peripheral length of the inner membranous vessel larger than that of the inner surface of the heat insulating layer by the very simple method of urging flat side wall portions of the inner membranous vessel toward the inside of the vessel and filling up the space left between the outer vessel and the inner membranous vessel with a heat insulating material while keeping the inwardly urged condition of the inner membranous vessel. Since in this case the inner membranous vessel is constructed prior to the formation of the heat insulating layer, the inner vessel can be approached at both sides thereof in the process of construction, whereby it is very easy to do welding for construction of the inner vessel as well as the inspection of the welded portions, and the quality of welding as well as the accuracy of inspection are also improved. This advantage is especially marked in case of a double-layered inner membranous vessel, i.e. the case where the inner vessel is made of two membranous vessels piled one over the other, or more correctly, one enclosing the other, the outer one (hereinunder called as the first inner vessel) being in direct contact with the heat insulating layer, the inner one (hereinunder called as the second inner vessel) being adapted to contain low temperature liquefied gases therein, wherein said first inner vessel is also serving as a secondary barrier wall against leakage of the second or inside inner vessel. Generally, the secondary barrier wall is provided at or adjacent the inner surface of the heat insulating layer to prevent invasion of the liquid leaked out of the inner vessel into the heat insulating layer, and has a relatively complicated structure. By employing the double layered inner membranous vessel as mentioned above, no particular secondary barrier wall is required.

As a little modification of the method of this invention, after the inner vessel has been constructed in the outer vessel, the roof portion of the inner vessel is also urged downward to form a marginal slack for allowing contraction in a low temperature operating condition. In this case, it is convenient that the inner vessel is formed as oversized regarding its height by an amount corresponding to the inwardly urging of the roof portion and the inwardly urging is automatically accomplished by mounting a pre-constructed roof portion of the tank including roof portion of the outer vessel and a roof portion of the heat insulating layer to its normal mounting position. In this case, the flat side wall portions of the inner membranous vessel are also urged toward the inside of the vessel just as described before, and the space left between the outer vessel and the inner membranous vessel is filled with a heat insulating material of compression resisting characteristic while keeping the inwardly urged condition of the inner vessel.

The heat insulating materials to be used to form the heat insulating layer may be selected out of various kinds of materials according to the portions where the heat insulating layer is to be formed. As a side wall portion of the heat insulating layer, a material such as pearlite concrete, etc., which has compression resisting characteristic and can be constructed on the site by molding or plastering, may conveniently be used. However, a material which can most favorably be employed for the method of this invention is sulfur or a sulfuric heat insulating material. Since sulfur becomes fluidal by being heated up to a relatively low temperature, it can be readily formed into a wall or layer on the site by molding or plastering. Furthermore, sulfur is superior in heat insulating and compression resisting characteristics, can withstand low temperature, is unhygroscopic, and anti-corrosive since it is hardly oxidized below normal temperature, and does not creep. Thus, as a whole, sulfur has a very low aging factor and can serve stably over a long period of operation.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a cross-sectional view of a part of a tanker ship incorporating a low temperature liquefied gas tank of a membrane type constructed by the method of this invention; and

FIG. **2** is a section along line **II — II** in FIG. **1.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following, description is made with reference to the accompanying drawing to show an embodiment of the method of this invention applied for the construction of a low temperature liquefied gas tank of a tanker ship, especially a low temperature liquefied gas tank of a double-layered membrane type.

In FIGS. **1** and **2**, reference numerals **1** and **2** designate an outer and an inner hull of a tanker ship, respectively, and at the inside of the inner hull, there is provided a heat insulating layer **3,** and further at the inside of the heat insulating layer, there is provided a first inner vessel **4** of a membrane structure, and at the inside of said first inner vessel, there is finally provided a second inner vessel **5** of a membrane structure. The first and second inner membranous vessels **4** and **5** are made of thin plates of a low temperature resisting material such as nickel steel, stainless steel, aluminum, etc., and the first inner vessel **4** is made of a thinner plate than the second inner vessel **5** such that, for example, when the second inner vessel **5** is made of a plate having thickness of 3 – 8 mm, the first inner vessel **4** is made of a plate having thickness of 1 – 2 mm. However, such a condition about the thickness of the plate is not dominating, and the relation of plate thickness between the first and second inner vessel may be inverted in some cases.

Although the tanker ship is shown as of a type having a single deck **6** in FIG. **1,** this invention may of course be applied to a tanker ship of a double deck type. The first and second inner vessels **4** and **5** are adapted to be freely slidable over the inner surface of the heat insulating layer **3,** and at their upper central portions are fluid-tightly mounted to a flange **8** provided at a lower end of a rigid dome **7.** The roof portions of the first and second inner vessels are carried by a number of cantilevers **9** extending from the lower end of the rigid dome **7** in a manner of being freely slidable over the inside surface of a heat insulating wall **10** provided below the single deck **6.** Thus, the first and second inner vessels **4** and **5** are in a condition of being freely suspended at their roof portions.

The first and second inner vessels **4** and **5** are respectively formed substantially in a polygonal shape, and in each case the edge portion of the polygonal vessel is formed as a part of a cylinder and the corner is formed as a part of a sphere. The edge and corner portions, except those portions positioned adjacent the bottom of the vessels, are adapted to support the internal pressure applied at the inside of the vessels by a hoop tension of the membrane forming the cylindrical and spherical portions. However, as far as no leakage occurs at the second inner vessel **5,** the first inner vessel **4** is subject to no fluid or hydraulic pressure. Since in this case the first inner vessel **4** is made of a thinner plate than the second inner vessel **5,** the radii of curvature at the cylindrical edge portions and spherical corner portions of the first inner vessel **4** are selected to be shorter than those of the second inner vessel **5** in order to limit the hoop tension applied to those portions below a proper value.

The low temperature liquefied gas tank of a membrane type having the abovementioned structure is constructed, according to the method of this invention, in the following manner: First, the hull portion of the tanker ship is constructed except the deck portion, and a bottom heat insulating wall portion **11** is formed over the bottom portion of the hull. The bottom heat insulating layer may be formed of pearlite concrete, foamed polyurethane, a composite heat insulating material including a honeycomb structure packed with glass wool, a sulfuric heat insulating material substantially made of sulfur or any other compression resisting heat insulating material. Over a layer **12** formed of such a heat insulating material, is extended a protecting plate **13**, espectially a bottom portion **13***a* thereof made of plywood, etc., and thereabove is placed bottom panel members **4***a*, **5***a* of the first inner vessel **4** and the second inner vessel **5**, respectively. The edge portions of these panel members may be extended so far as shown by points A and C (actually horizontal lines) in FIG. **1**.

Next, a scaffold for the purpose of construction is built at the portion where the side heat insulating layer **3** is to be formed, and by using the scaffold as a jig or employing other proper jigs in addition, thin plates to form the side wall portions **4***b*, **5***b* of the first and second inner vessels **4** and **5** are held at predetermined positions. Then, at point A (actually a horizontal line, likewise in the following) in FIG. **1**, the thin plates forming the bottom portion **5***a* and the side wall portion **5***b* of the second inner vessel **5** are connected with each other. In this case, it is favorable that the thin plates to form the first inner vessel **4** are prepared to be lacking in the region between points A and C as shown in FIG. **1** to allow easy welding at point A and the inspection thereof from the opposite sides thereof. After the welding of the second inner vessel **5** at point A and the inspection thereof have been completed, the lacking region left between the bottom portion **4***a* and the side wall portion **4***b* of the first inner vessel **4** is patched with a belt of the same thin plate material having a width corresponding to the space between points B and C and the belt plate is welded to the bottom portion **4***a* and the side wall portion **4***b* at points B and C, respectively, and thereafter, the welded portions are inspected.

In parallel with the abovementioned process, and actually outside the hold space of the tanker ship, the deck **6** is prepared to be provided with a heat insulating layer **14** and a top protecting plate **13***c* mounted at the inside thereof and further to be mounted with top panel members **4***c*, **5***c* of the first and second inner vessels **4** and **5**, the both panel members including cylindrical edge portions and spherical corner portions to form a shoulder portion of the tank. In this case the deck is prepared to further include the cantilevers **9** radially mounted at the bottom end portion of the rigid dome **7** thereby to prevent falling down of the top panel members. Then, the deck portion is suspended by a crane and transferred to a position just above the hold space and is lowered and provisionally mounted at a predetermined position which is higher than the final mounting position by an amount corresponding to the amount of contraction at low temperature of the first and second inner vessels. In this provisionally mounted condition, the top portions **4***c* and **5***c* are connected with side wall portions **4***b* and **5***b* at points A′, B′ and C′, respectively, in the same manner as the bottom portions **4***a*, **5***a* have being connected with the side wall portions **4***b*, **5***b*. Thereafter, the side wall protecting plate **13***b* is extended, and the deck portion **6** is lowered from the provisionally mounted position to the final and normal mounting position and fixed there.

Alternatively, the deck structure may be mounted to the normal position from the beginning. In this case, when the top portion and the side wall portion of the inner vessel are to be connected, the edge portions of the top and side wall portions are overlapped one over the other as much as a predetermined amount, and by pulling apart the overlapped edge portions by means of proper jigs to cancel the overlapping, and in that condition the adjacent edges are welded together. As a further modification, the side wall protecting plate **13***b* may be extended together with the side wall portions **4***b*, **5***b* of the inner vessels. In this case, the protecting plate **13***b* is formed to be lacking at the portions corresponding to the spaces between points B and C and points B′ and C′, and after the welding and inspection thereof of the inner vessels have been finished, the lacked portions of the protecting plates are repaired by belts of the same material.

After the first and second inner vessels have been constructed, several expansion means such as oil-hydraulic jacks **15** are arranged in the space to form the side wall heat insulating layer **3** to urge the side wall portions **4***b* and **5***b* of the first and second inner vessels and the protecting plate **13***b* altogether toward the inside of the tank as much as an amount corresponding to the contraction of the inner vessels in a low temperature operating condition. In this case, the protecting plate **13***b* serves as a means for uniformerizing the urging force applied by the expansion means to the inner membranous vessels so that no local urging, accordingly stress concentration, is caused to the inner membranous vessels.

After the side wall portions of the inner membranous vessels have been urged toward the inside of the tank by a predetermined amount in the abovementioned manner, a heat insulating material is charged into the space left between the inner hull **2** and the protecting plate **13***b* while keeping the inwardly urged conditions of the side wall portions, and the heat insulating layer **3** is gradually formed from the bottom portion thereof toward the top portion.

In this case, the protecting plate **13***b* serves also as a weir plate for keeping the heat insulating material to be filled, which is generally in a powdered or fluidal condition, from leaking out onto the surface of the first inner vessel **4**. The protecting plate **13***b* serves of course finally as a protecting plate which protects the first inner vessel from directly contacting with the heat insulating layer, the inner surface of which may not necessarily be smooth in all cases. In the process of filling up the space to form the heat insulating layer **3**, everytime when the level of the charged heat insulating material reaches one of the expansion means **15**, the expansion means is removed after the heat insulating layer has been solidified or fixed. In order to avoid that the protecting plate and the side wall portions of the inner vessels are urged toward the inside of the tank beyond the position determined by the expansion means due to the pressure applied by the charged heat insulating material, it is favorable that the inside space of the inner membranous vessel is kept at a positive pressure of about 0.3 kg/cm^2. The scaffold provisionally mounted in the space to form the heat insulating layer **3** may be removed before the filling up of the space is started.

As a material preferably used to fill up the space to form the heat insulating layer **3,** is proposed bead of foamed sulfur mixed with foaming concrete as a binding agent. Such a material is further improved of its anti-shock or anti-collapsing characteristic by being mixed with glass wool, pearlite or other reinforcing materials. Furthermore, since sulfur is easily foamed when it is mixed with a foaming agent and heated up beyond the melting temperature, a sulfuric foamed heat insulating layer can be formed as foamed on the site.

When the low temperature liquefied gas tank of a membrane type constructed in the abovementioned manner is filled with low temperature liquefied gases, the inner membranous vessels **4** and **5,** as having contracted, present dimensions just fitting a space defined by the protecting plates **13***b* and **13***c*, and therefore, the inner membranous vessels are supported by the supporting surface at the best condition in a low temperature loaded condition.

I claim:

1. A method of constructing a low temperature liquefied gas tank of a membrane type, said tank comprising an outer vessel of a rigid structure, a heat insulating layer provided at the inside of said outer vessel, and an inner membranous vessel provided further at the inside of said heat insulating layer, characterized by the steps of constructing said inner membranous vessel in said outer vessel, urging flat side wall portions of said inner membranous vessel, after the completion thereof, toward the inside of said inner membranous vessel as much as to form a marginal slack corresponding to the contraction of said inner membranous vessel in a low temperature operating condition, and filling up the space left between said outer vessel and said inner membranous vessel with a heat insulating material of compression resisting characteristic while keeping said inwardly urged condition of said inner membranous vessel.

2. A method according to claim **1,** wherein a top wall portion of said inner membranous vessel is also urged toward the inside of said inner membranous vessel prior to the urging of the flat side wall portions as much as to form a marginal slack corresponding to the contraction of said inner membranous vessel in a low temperature operating condition.

3. A method according to claim **1,** wherein said flat side wall portion of said inner membranous vessel is urged by way of a protecting plate to which is applied an urging force exerted by expansion means acting in a space to form said heat insulating layer.

4. A method according to claim **2,** wherein said top wall portion of said inner membranous vessel is prepared as mounted beforehand to a top portion of said outer vessel, said top portion of said outer vessel being adapted to be provisionally mounted at a position located above its final mounting position while said top wall portion of said inner membranous vessel is connected with said flat side wall portions of said inner membranous vessel, and thereafter lowered to said final mounting position to be firmly mounted there.

5. A method according to claim **1,** wherein said inner membranous vessel is assembled of substantially flat side wall portions, a bottom wall portion including curved edge and corner portions adapted to be connected with said side wall portions, and a top wall portion including curved edge and corner portions adapted to be connected with said side wall portions, wherein the connecting portions between said side wall portions and said bottom and top wall portions are located at positions to be approachable from the inside of said inner membranous vessel as well as from a space to form said heat insulating layer.

6. A method according to claim **5,** wherein said inner membranous vessel is formed as a double-layered membranous vessel including first and second membranous vessels, said first inner vessel enclosing said second inner vessel, wherein the joining of the side wall portions and the bottom and top wall portions of said second inner vessel is made while the first inner vessel is adapted to be lacking in the portion thereof located adjacent the joining portions of said second inner vessel, said lacking portions being supplemented after the completion of the joining process of the second inner vessel.

7. A method according to claim **1,** wherein said inner membranous vessel is filled with compressed air of a pressure enough to support the side wall portions thereof against the pressure applied by the heat insulating material charged into the space to form said heat insulating layer when said heat insulating layer is being formed.

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