United States Patent [19]

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[11] **3,827,136**

[45] **Aug. 6, 1974**

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

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[22] Filed: **Mar. 15, 1973**

[21] Appl. No.: **341,724**

[30] **Foreign Application Priority Data**

Mar. 25, 1972 Japan 47-29417

[52] **U.S. Cl.** .... **29/455,** 29/460, 29/469, 114/74 A, 220/9 LG

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

[58] **Field of Search** .... 29/455, 460, 469; 114/74 A; 220/9 LG, 9 A, 1 B

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Primary Examiner—Charlie T. Moon
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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 constructing an assembly including said inner membranous vessel and a carrying structure composed of a roof portion of said heat insulating layer, a roof portion of said outer vessel and a saddle frame for supporting bottom edge portions of said inner membranous vessel separately from said outer vessel having a hold space, mounting said assembly into said hold space, urging flat side wall portions of said inner membranous vessel toward the inside of the tank 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 the construction period of the tank is shortened and 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.

6 Claims, 2 Drawing Figures

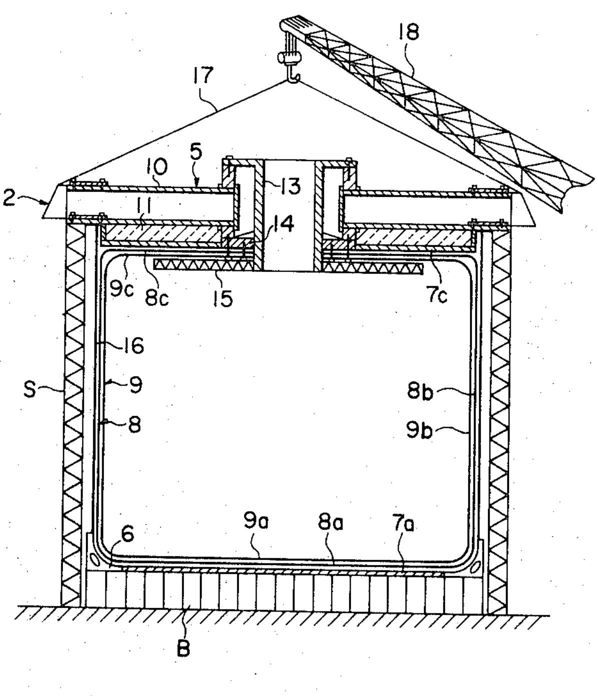


FIG. 1

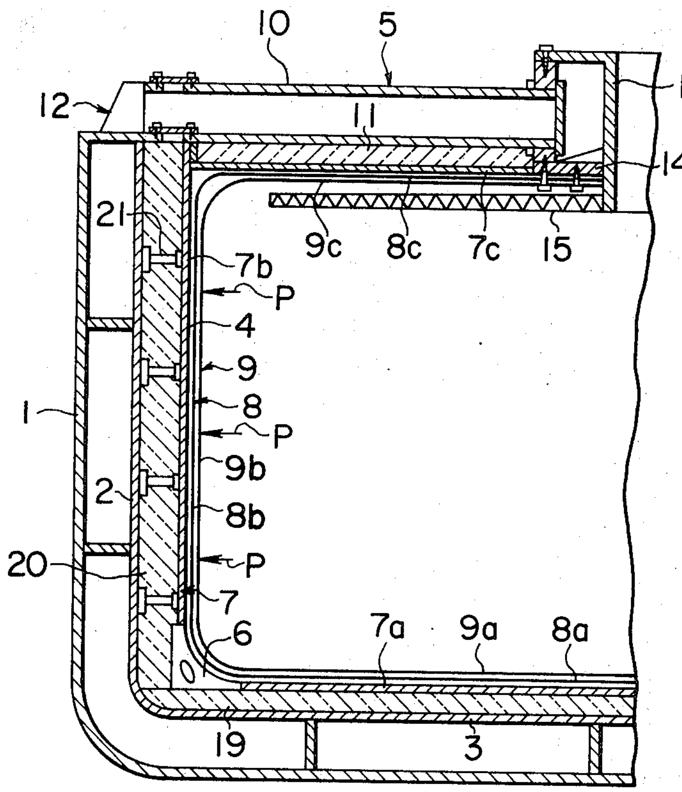
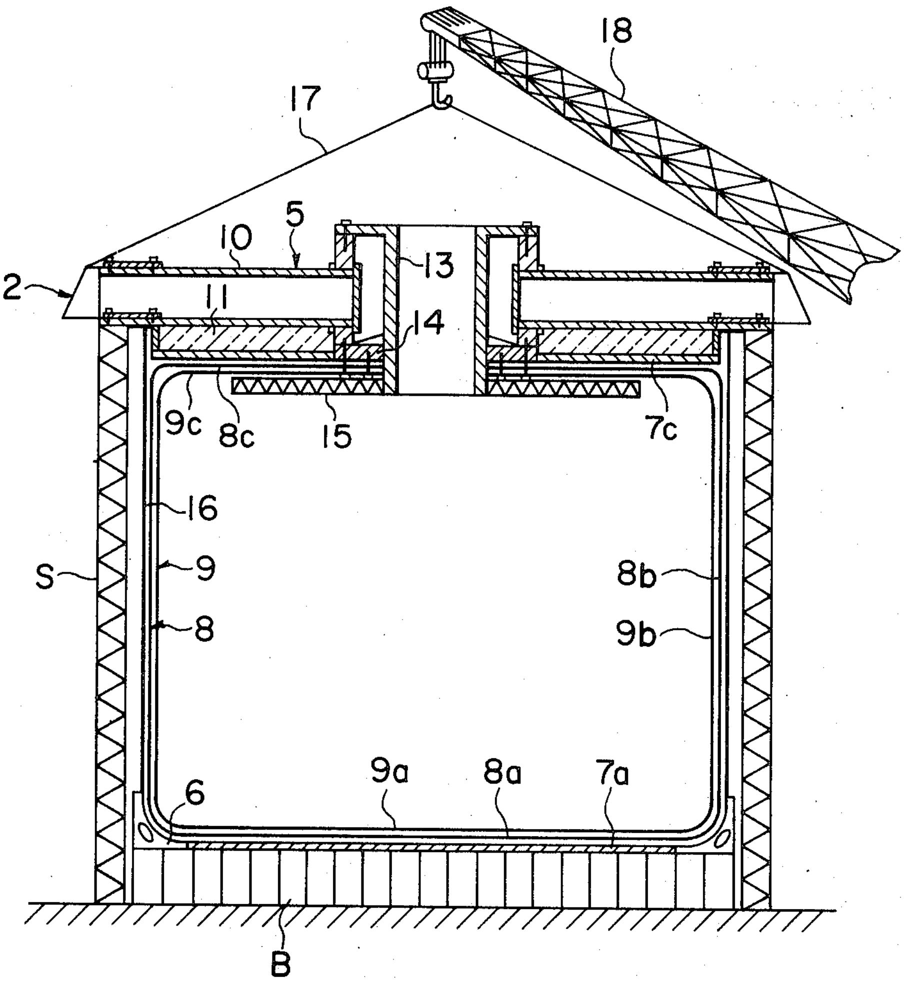


FIG. 2



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 for containing a low temperature liquefied gases such as natural gases or petroleum gases which are in gaseous state at room temperature and can be liquefied at low temperature under atmospheric pressure, and more particularly, a method of constructing a low temperature liquefied gas tank of a membrane type including an inner membranous vessel provided at the inside of an outer vessel via a compression resistant heat insulating layer.

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 membrane type of the above-mentioned structure has been constructed in a manner that the outer vessel is first constructed and after the completion thereof, the heat insulating layer and the inner membranous vessel are constructed in the outer vessel by consuming many days of construction, and therefore, there has been a problem that the various works of construction must be arranged in series thereby making the period of construction elongated, and nevertheless, there occurs some interference of works, making the construction work complicated and difficult.

In view of such a problem, it has been proposed to construct an assembly of an inner membranous vessel and a heat insulating layer enclosing it separately from an outer vessel and to mount the assembly into the outer vessel. However, in this case, it is required to leave a relatively large clearance between the outer vessel and the assembly to make it practical to mount the assembly into the outer vessel, and therefore, after the insertion of the assembly into the outer vessel, the space left between the two must be filled up with proper means. Furthermore, in a low temperature loaded condition when the inner membranous vessel is loaded with low temperature liquefied gases, the inner membranous vessel would contract by a relatively large amount with respect to the supporting surface provided by the heat insulating layer, and as a result, the inner vessel is actually supported by the heat insulating layer in a condition expanded by the internal pressure applied by the low temperature liquefied gases as much as an amount corresponding to the contraction thereof in a low temperature operating condition.

Therefore, the thin plate forming the inner membranous vessel is not only subject to a compression force applied in the direction of its thickness but also a tensile force acting along the surface thereof. Furthermore, since the inner vessel is subject to changes of operating conditions such as from a normal temperature unloaded condition to a low temperature loaded condition by way of a low temperature unloaded condition, or vice versa, and accordingly, makes complicated deformations under application of thermal stresses, it is not favorable to apply any restriction to the inner vessel which will prevent such deformations. It has been proposed to provide complicated corrugations or convexes and concaves at wall portions of the inner vessel so that the contraction at low temperature is absorbed by such corrugated portions and the inner membranous vessel comes just in close contact with the inner surface of the heat insulating layer in a low temperature loaded condition. However, it requires a complicated and difficult work to provide complicated corrugations or convexed and concaved portions at the wall portions of the inner vessel and there is a drawback that the overall manufacturing cost of the tank is very much heightened.

SUMMARY OF THE INVENTION

Therefore, it is the object of this invention to solve the above-mentioned problems and to provide an improved method of constructing a low temperature liquefied gas tank of a membrane type based upon a principle of constructing an outer vessel and an inner vessel separately, the later being thereafter inserted into the former by which the tank is constructed very simply and easily, and in the tank constructed by which method, the inner membranous vessel is in the most faborable stress condition in a low temperature loaded condition without being provided with complicated corrugations or convexed and concaved portions.

The above-mentioned 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, comprising the steps of constructing an assembly including said inner membranous vessel and a carrying structure provided at a roof portion of said inner membranous vessel at a construction stage separately from said outer vessel adapted to present a hold space for receiving said assembly, and mounting said assembly into said hold space, characterized by constructing said carrying structure by a roof portion of said heat insulating layer and a roof portion of said outer vessel having a rigid structure, urging flat side wall portions of said inner membranous vessel, after said assembly has been positioned in said hold space, 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.

Since, according to the method of this invention, the assembly composed of the inner membranous vessel and the carrying structure provided at the roof portion of said inner membranous vessel is constructed separately from the outer vessel on a construction stage preferably to also have a saddle-like frame, the inner vessel is approachable at opposite sides thereof in construction, and therefore, the welding of the thin plates forming the inner membranous vessel and the inspection of the welded portions are made very easy. Since in this case the assembly is inserted into the hold space defined by the outer vessel, the inside surface thereof being as yet covered with no heat insulating layer, the insertion of the tank into the hold space is very easily done. After the assembly has been positioned in the hold space, flat side wall portions of the inner membranous vessel are urged toward the inside of the vessel by proper expansion means acting in reaction to the inner wall of the outer vessel as much as an amount corresponding to the contraction of the inner membranous vessel in a low temperature operating condition, and by filling up the space thus formed, the inner vessel is adapted to have a peripheral length larger than that of the inner surface of the heat insulating layer. In this very simple manner, the inner membranous vessel is provided with a marginal slack to compensate the contraction thereof in a low temperature operating condition.

Furthermore, since the assembly is provided beforehand with the roof portion of the heat insulating layer as well as the roof portion of the outer vessel having a rigid structure, when the assembly has been mounted into the hold space of the separately constructed outer vessel, the top portion of the tank is substantially completed and no work for further construction of this portion is required, thereby largely shortening the over-all period of construction.

According to a little modification of this invention, it is further proposed that the tank assembly is so adapted that the carrying structure is lowered an amount after the bottom of the inner membranous vessel has just been placed upon a compression resistant heat insulating layer provided over the bottom of the outer vessel before the carrying structure reaches its final mounting position, said amount being predetermined to correspond to the contraction of the inner membranous vessel in a low temperature operating condition. In this case, the flat side wall portions of the inner membranous vessel are also urged toward the inside of the tank, after the final mounting of the carrying structure, as much as an amount corresponding to the contraction of the inner membranous vessel in a low temperature operating condition, and by keeping this inwardly urged condition, the space left between the side wall portions of the inner membranous vessel and the outer vessel is filled with a compression resistant heat insulating material to form said heat insulating layer. When the assembly or actually the inner membranous vessel is compressed vertically in the process of construction at normal temperature, margins of the inner vessel thus caused are gathered at curved shoulder edge portions and compensate vertical contraction in a low temperature operating condition. By the side wall portions of the inner vessel being urged toward the inside of the tank to form a marginal slack to compensate the horizontal contraction in a low temperature operating condition before the space left between the outer and inner vessels is filled with a heat insulating material to form a compression resistant heat insulating layer, the inner vessel is relieved from being caused stress concentrations due to constraction in a low temperature loaded condition without being formed with complicated corrugations or convexed and concaved portions.

According to a further modification of this invention, it is proposed that, when the compression resistant heat insulating layer is formed at the outside of said inner membranous vessel, the inner vessel is packed with a positive pressure to resist the outside pressure exerted by the heat insulating material to form the heat insulating layer. By applying such a positive pressure at the inside of the inner vessel, it is avoided that the side wall portions of the inner vessel are urged toward the inside of the tank by the pressure applied by the heat insulating layer beyond a position predetermined by the expansion means, whereby the safety of the construction work is improved.

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 the 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. A foaming concrete including foamed sulfur or foamed glass as the reinforcing material may be used to be molded on the site.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is the 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** shows the assembly in section for use in the tank shown in FIG. **1** in the process of construction.

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.

Referring to FIG. **1**, the hull **1** of a tanker ship is constructed as a dual-walled hull including a side wall portion **2** and bottom portion **3** and cross and longitudinal bulkhead (not shown) defining a hold space **4.** FIG. **2** shows a tank assembly **5** adapted to be inserted into the hold space **4**, while in FIG. **1**, the tank assembly is shown as having been already mounted within the hull **1.**

In construction of the assembly **5** outside the hull, a saddle frame **6** is laid upon a base panel B at a predetermined position, and then a protecting plate **7*a*** made of plywood, etc., is extended over the flat surface of the base panel so as to be confined by the saddle frame to form a base of the assembly. Then, upon the base are laid bottom panel members **8*a*** and **9*a*** of an outside inner vessel **8** to be positioned in contact with the inner surface of the heat insulating layer (hereinunder called first inner vessel) and of an inside inner vessel **9** provided at the inside of said first inner vessel (hereinunder called second inner vessel), respectively, both panel members including curved edge and corner portions of cylindrical and spherical shapes, respectively, and furthermore, along proper construction scaffolds S are arranged side wall portions **8*b*** and **9*b*** of the first and second inner vessels, respectively, to construct a double-layered inner membranous vessel. In this case, the adjacent edge portions of the bottom panel members 8*a*, 9*a*, and the side wall portions 8*b*, 9*b* are connected with each other by welding. The first and second inner vessels 8 and 9 are each formed of a thin plate of low temperature resisting characteristic such as nickel steel, stainless steel, aluminum, etc., and they are arranged regarding their thickness such that, when, for example, the second inner vessel 9 has a thickness of 3–8 mm, the first inner vessel 9 has a thickness of 1–2 mm. Though in this case the first inner vessel is made thinner than the second inner vessel, the relation of the thickness may be reversed.

Separately from the construction of the above-mentioned bottom and side wall portions of the inner vessel, a top portion of the inner vessel or the assembly is prepared in the following manner: The top portion includes a carrying structure 12 composed of a tank cover 10 having a rigid structure, a heat insulating layer 11 extended over the inner surface of the tank cover and a protecting plate 7*c* extended further over the heat insulating layer 11. The carrying structure 12 is provided with a rigid dome 13 at a central portion thereof. Over the inner surface of the protecting plate 7*c* are extended top panel members 8*c* and 9*c* of the first and second inner vessels 8 and 9, said panel members being fluid-tightly mounted at a flange 14 provided at a lower end portion of the dome 13 and having curved edge and corner portions formed in cylindrical and spherical shapes, respectively. The carrying structure 12 is further provided with a plurality of cantilevers 15 extending radially outwardly from a lowermost end portion of the dome 13 to hold the top panel members 8*c* and 9*c* from falling down. The top portion of the assembly prepared in the above-mentioned structure is suspended by a crane and positioned above the side wall and bottom portions of the inner vessel separately prepared on the base panel B as mentioned before. Then, adjacent edge portions of the side wall portions 8*b*, 9*b* and top panel members 8*c*, 9*c* are connected with each other by welding. Thus, the tank assembly 5 is completed. Since in this case the tank assembly is supported by the construction scaffolds S in a fully extended condition as shown in FIG. 2, there is no danger that there occurs a buckling of the side wall portions of the inner vessels.

By constructing the assembly 5 separately from the hull outside the hull, the welding and the inspection thereof in construction is made very easily, whereby the reliability of the tank is much more improved. Before the tank assembly is suspended to be mounted into the hold space of the hull, the saddle frame 6 is suspended from the tank cover 10 by proper suspension means 16 to protect the inner vessels 8 and 9 from collapsing.

After the completion of the tank assembly 5, it is suspended by crane 18 by way of suspension means 17 and is lowered into the hold space formed in the hull 1 and is placed on a bottom heat insulating layer 19 provided at the bottom portion of the hold space. When the tank assembly is inserted into the hold space, the side wall heat insulating layer is not as yet formed, and therefore, the insertion of the assembly into the hold space is easily done.

After the tank assembly has been completely inserted into the hold space, the tank cover 10 having a rigid structure is firmly connected to a deck portion of the hull. In this connection, the tank assembly is so adapted that the inner vessels 8 and 9 are formed as oversized a little as compared with the height of the hold space so that when the tank assembly is fully inserted into the hold space, the inner vessels are somewhat compressed in the vertical direction to form a marginal slack to compensate the contraction of the inner vessels in a low temperature operating condition, said marginal slack being generally gathered at curved shoulder edge portions.

Then, a protecting plate 7*b* is placed in the space to form a side wall heat insulating layer 20 so as to be in contact with the side wall portion 8*b* of the first inner vessel, and the protecting plate 7*b* together with the side wall portions 8*b* and 9*b* of the first and second inner vessels, respectively, is urged toward the inside of the tank as much as an amount corresponding to the contraction of the inner membranous vessels in a low temperature operating condition. Thus urging operation is done by arranging a number of expansion means 21 such as oil hydraulic jacks within the space to act against the flat wall portion of the inner hull 2. In this urging operation, the protecting plate 7*b* serves to uniformalize respective urging forces exerted by the expansion means, or otherwise, if the expansion means 21 are directly applied onto the wall portion 8*b* of the first inner vessel, local stress concentrations will be caused in the membranous vessels and they will be broken.

After the side wall portions of the inner vessels have been urged toward the inside of the tank as much as a predetermined amount to compensate the contraction, a heat insulating material is charged into the space to form the heat insulating layer 20 gradually from the bottom portion to the top portion thereof, while keeping the inwardly urged condition of the inner membranous vessels. In the process of charging the heat insulating material, the protecting plate 7*b* serves also as a weir plate to prevent leaking out of the filling material onto the surface of the first inner vessel 8. The protecting plate 7*b* serves of course as a protecting plate for protecting the first inner vessel from directly contacting with the heat insulating layer in a low temperature operating condition. In the process of filling up the space to form the heat insulating layer 20, each jack 21 is removed every time when the level of the filling material has reached the jack, after the filling material has solidified.

Furthermore, when the space to form the heat insulating layer 20 is being filled with a heat insulating material, the inner vessel may preferably be packed with a positive pressure P of about 0.3 kg/cm^2 so as to prevent that the protecting plate and side wall portions of the first and second inner vessels are urged toward the inside of the tank beyond a position determined by the expansion means due to the filling-up pressure of the heat insulating material.

The suspension means 16 provided to connect the saddle frame 6 and the tank cover 10 in the process of suspending the tank assembly may preferably be removed at a proper time before the filling up of the heat insulating material is started.

As a heat insulating material to be favorably used for filling up the space to form the side wall portion of the heat insulating layer, there is proposed bead of foamed sulfer mixed with foam concrete as a binding agent. Such material is further improved to be resisitve against shocks or collapsing by being mixed with reinforcing material such as glass wool, pearlite, etc. Since sulfer is easily foamed by being mixed with a foaming agent and heated up beyond the melting temperature, the heat insulating layer is formed by having sulfuric material foamed and solidified on the site.

In operation of the low temperature liquefied gas tank of a membrane type constructed according to the method described above, when the second inner vessel **7** is loaded with low temperature liquefied gases, the first and second inner vessels **8** and **9**, as having contracted, just fit the space defined by the protecting plated **7**_b_ and therefore, the inner membranous vessels are supported in the most favorable 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, comprising the steps of constructing an assembly including said inner membranous vessel and a carrying structure provided at a roof portion of said inner membranous vessel at a construction stage separately from said outer vessel adapted to present a hold space for receiving said assembly, and mounting said assembly into said hold space, characterized by constructing said carrying structure by a roof portion of said heat insulating layer and a roof portion of said outer vessel having a rigid structure, urging flat side wall portions of said inner membranous vessel, after said assembly has been positioned in said hold space, 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 said inner membranous vessel is compressed in the vertical direction as much as an amount 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 assembly is constructed at said contruction stage equipped with a base panel and scaffolds in a manner that a panel member to form the bottom portion of said inner membranous vessel and having curved edge and corner portions is placed on said base panel with interposition of a saddle frame and a protecting plate, panel members to form the side wall portions of said inner membranous vessel are held by said scaffolds, and said carrying structure provide further with a panel member to form the roof portion of said inner membranous vessel formed with curved shoulder edge portions is supported by said scaffolds, and the adjacent edge portions of said side panel members and said bottom and roof panel members are connected with each other by welding.

4. A method according to claim **3**, wherein said saddle frame and said carrying structure is connected with each other by suspension means at least when said assembly is suspended to be mounted into said hold space.

5. 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.

6. A method according to claim **1**, wherein said inner membranous vessel is packed with a positive 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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