

[54] **MEMBRANE TANK FOR LIQUEFIED GASES**

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[30] Foreign Application Priority Data

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[58] Field of Search..... 62/45; 220/9 LG; 114/74 A

[56] References Cited

UNITED STATES PATENTS

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[57] ABSTRACT

The dimensions of the membrane tank are so selected that when it is cooled by liquefied gas charged therein and contracted, the flat portions may just contact with the inner surfaces of an insulating material lined over the inner wall of a shell structure. Restraining forces are applied to the membrane tank when the latter is installed into the insulating material structure. When the liquefied gas is charged into the membrane tank, the bending stresses generated are almost zero and the tank is subjected only to the hoop tensions.

3 Claims, 8 Drawing Figures

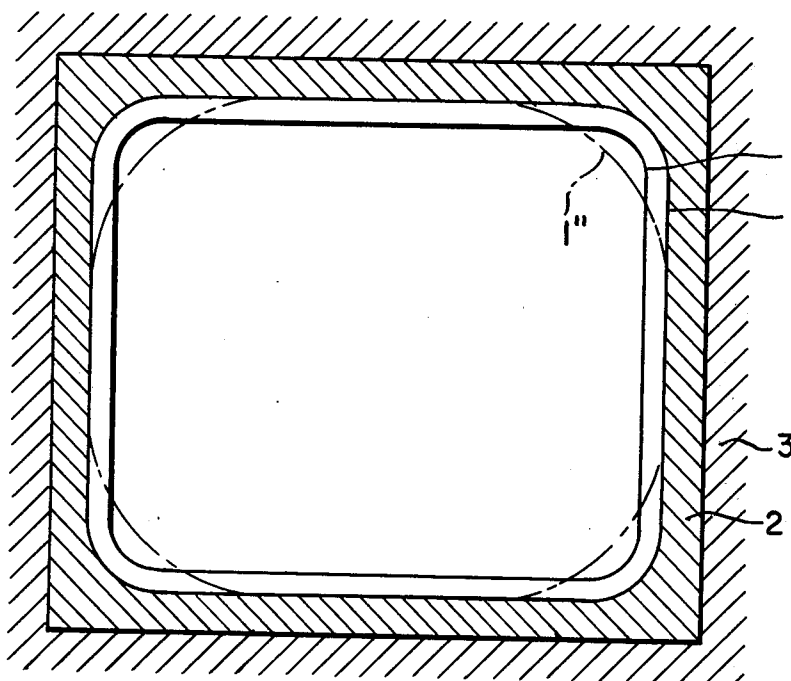


Fig. 1

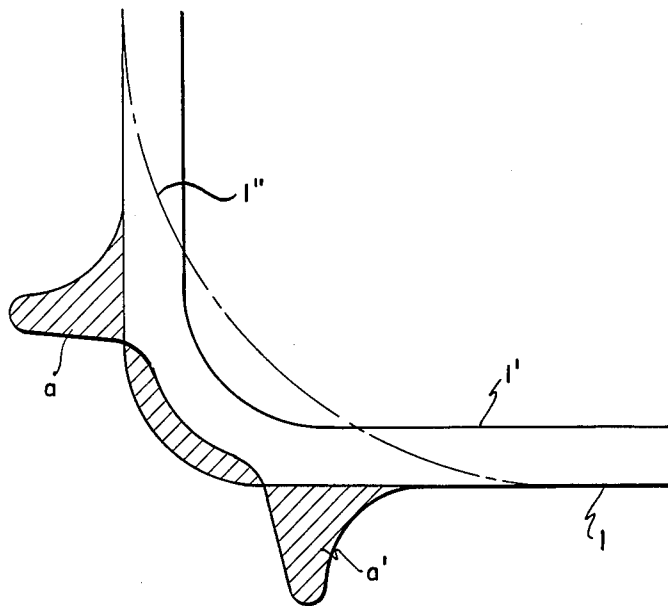
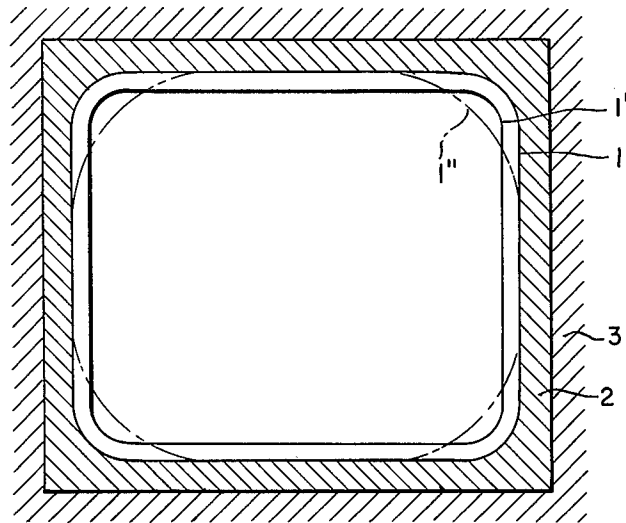


Fig. 2

Fig. 3

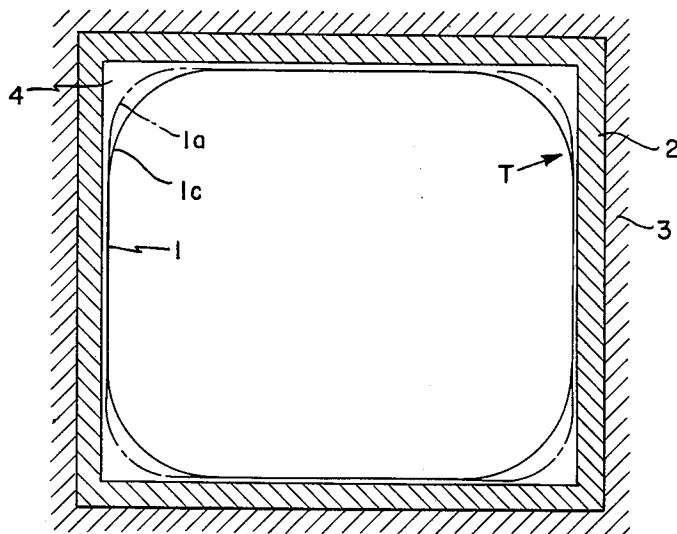


Fig. 4

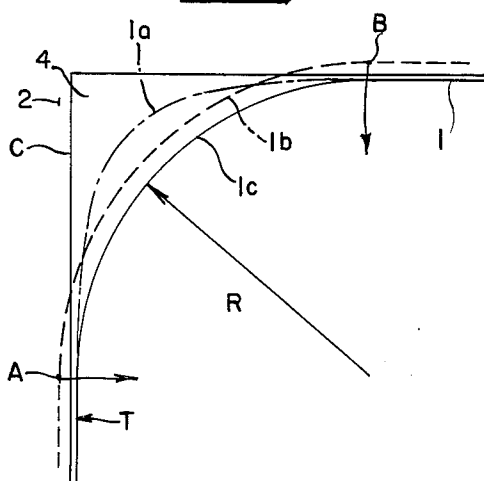


Fig. 5

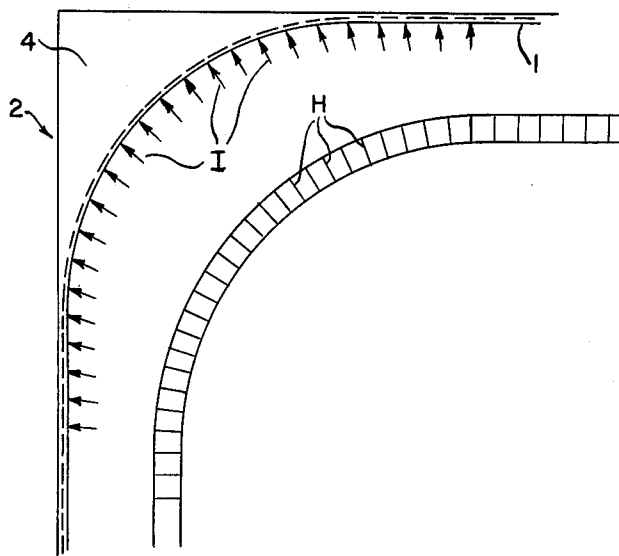


Fig. 6

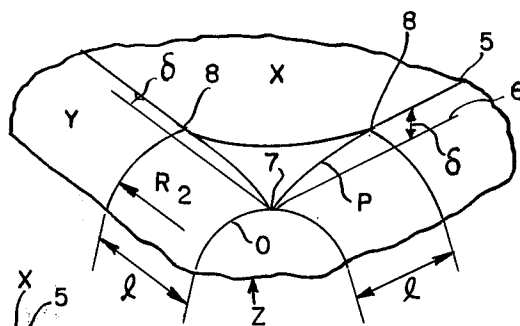
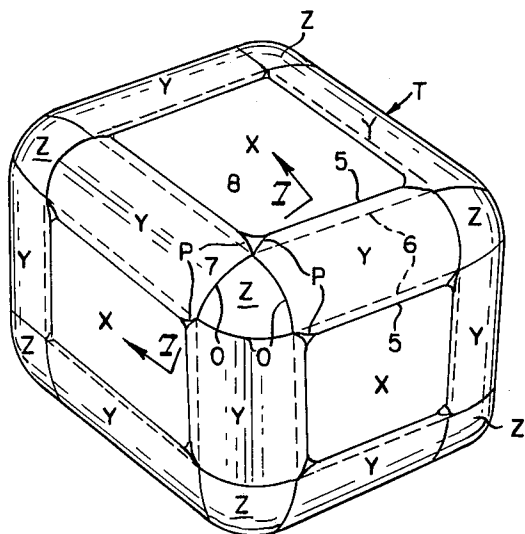


Fig. 7

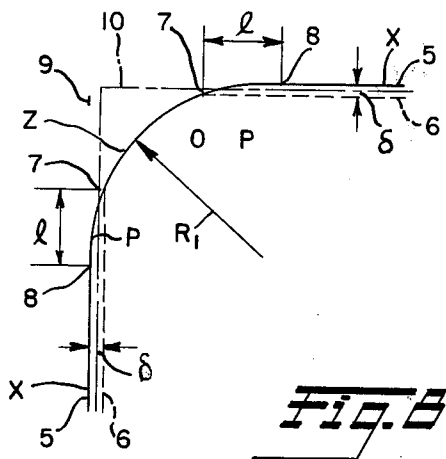


Fig. 8

MEMBRANE TANK FOR LIQUEFIED GASES

The present invention relates to a membrane tank for liquefied gases.

The conventional liquefied gas storage tanks are generally divided into a self-supporting type and a membrane type. In case of the self-supporting storage tanks, the tank shell is so designed and fabricated as to withstand the hydraulic pressure as well as gas pressure of liquefied gas stored in the tank. As a result, the tank shell is complex in structure, and requires a large amount of very expensive material, and welding. Furthermore the liquefied gas storage tanks using materials difficult for welding will be very expensive. In the case of the membrane storage tanks, the hydraulic pressure as well as gas pressure are supported by a shell structure lined with insulating material, so the construction can be very thin and simple. Furthermore, the fabrication cost is inexpensive because the amount of expensive material and welding can be reduced. However the membrane tank fabrication method is extremely difficult because complicated creases must be provided in order to absorb the contraction of the membrane tank due to the contact with low temperature liquefied gas. Furthermore the damages of the membrane tank tend to start from the creased portions.

To overcome these problems, there has been proposed the so-called flat membrane tank type in which the deformation or contraction of the membrane tank is absorbed by the deformations of the cylindrical ridge portions thereof, but there is a disadvantage in that local bending stresses are produced because the deformations are concentrated at the cylindrical ridge portions.

In view of the above, the primary object of the present invention is to provide a liquefied gas membrane storage tank which generates only hoop tension but almost no bending stress when the membrane tank is cooled to a temperature of liquefied gas stored therein, so that the stress generated can be prominently reduced and can be uniformly distributed.

The objects, features and advantages of the present invention will become more apparent from the following description of preferred embodiments, in conjunction with the accompanying drawing.

FIG. 1 is a cross sectional view of a conventional flat membrane tank for liquefied gas;

FIG. 2 is a fragmentary view thereof, in enlarged scale, used for the explanation of the stress distribution at the corner thereof;

FIG. 3 is a cross sectional view of a first embodiment of the present invention;

FIG. 4 is a view used for the explanation of the deformation thereof;

FIG. 5 is a view illustrating the stress distribution thereof;

FIG. 6 is a perspective view of a second embodiment of the present invention;

FIG. 7 is a fragmentary view thereof, in enlarged scale, illustrating a spherical vertex portion and a cylindrical connecting portion substantially in the form of a triangle; and

FIG. 8 is a sectional view taken along the line VIII-VIII of FIG. 6.

Prior to the description of the preferred embodiments of the present invention the prior art so-called flat membrane tank will be briefly described in order to point out the disadvantage thereof which are solved by

the present invention. Referring to FIG. 1, a flat membrane 1 is placed on the inner wall of a shell 3, having in between an insulating material 2. The ridges of the membrane are cylindrical and vertices of the membrane are spherical. When low temperature liquid is charged, the flat membrane 1 is contracted as shown by the lines 1' and then pressed against the insulating material 2 under the hydraulic and gas pressures of the liquid as shown by the chain lines 1''. The deformation of the membrane tank due to the low temperature and pressure of the liquid is absorbed by the deformations of the ridges. Since the flat membrane tank of the type described is very simple in construction, it is advantageous from the standpoint of material and manufacture, but it has a disadvantage that local bending stresses are generated as shown and a and a' in FIG. 2 because the deformation of the membrane tank mainly occurs at its ridges.

Referring to FIGS. 3-5, the first embodiment of the present invention will be described.

The insulating material 2 which also serves to transmit the inner pressure of the membrane tank T to the shell 3 is lined over the inner walls of the shell 3. The outer dimensions of the membrane tank T are so determined that at room temperature they are larger than the inner dimensions of the insulating material 2 as indicated by the broken lines 1b in FIG. 4 but when the membrane tank T is cooled to a temperature equal to that of the low temperature liquid charged into the tank the membrane tank T is so contracted that the flat portions thereof contact with the inner surfaces of the insulating material 2. The ridges of the membrane tank T are cylindrical. When the membrane tank T is installed, the restraining forces are applied to the tangent lines, that is the boundary lines A and B in FIG. 4 between the flat faces and the ridges so that the ridges are deformed as indicated by the chain lines 1a in FIG. 4 while the flat portions are pressed against the inner surfaces C in FIG. 4 of the insulating material 2.

Since the insulating material 2 is lined over the inner walls of the tank shell 3, there is a sufficient space 4 at every corner into which the deformed ridge portion of the membrane tank 3 extends as indicated by the chain lines 1a. Even after the restraining forces are relieved, the flat portions are pressed against the inner surface of the insulating material 2 so that the deformed ridge portion may remain in the space 4 at room temperature and the bending stresses are generated.

When the membrane tank T is cooled by the low temperature liquid, it is contracted so that the deformed ridge portion is gradually retracted inwardly. At the temperature of the low temperature liquid the flat portions just contact with the inner surfaces of the insulating material 2 and the ridge portion is curved with a predetermined radius as indicated by the solid line in FIG. 4. Therefore no bending stress is generated, so that the membrane tank T is subjected only to the hoop tension H. However because of the expansion of the membrane tank T due to the hydraulic pressure or inner pressure I of the low-temperature liquid, very small bending stresses are generated, but they are negligible in practice. In order to eliminate completely the bending stresses, the radius of curvature of the membrane is further decreased.

Next referring to FIGS. 6-8, the second embodiment of the present invention will be described. According to the second embodiment of the present in-

vention oppose to the first embodiment, no restraining force is applied to the vertex portion to deform the latter when the membrane tank is installed within the shell.

The convex cylindrical ridge portion Y where the adjacent flat surfaces X meet has a radius R_2 , and the convex spherical vertex portion 0 has a radius R_1 , smaller than R_2 . The adjacent flat portion X, the cylindrical ridge portions Y and the spherical vertex portion 0 are connected to each other through a triangular connecting portion P. The outer dimensions 5 of the flat surface X at room temperature are greater than the radius of the spherical vertex portion 0 by δ . The value of δ is determined depending upon the dimensions and material of the membrane tank T. For example when the membrane tank T is contracted by ϵ_r at a temperature of liquid stored therein, δ is so selected as to be equal to δ_r in order to substantially eliminate the bending stress at the cylindrical edge Y. The distance l between the vertex 7 of the connecting portion P on the side of the spherical vertex portion 0 and the vertex 8 on the side of the flat portion X is taken as $l \approx \frac{1}{2} R_1$ to facilitate the fabrication, and the connecting portion P has a surface substantially similar to a conical surface so that it may be easily developed and do not cause undue stress.

When the restraining force is applied to the membrane tank T so as to decrease its outer dimensions 5 to the dimensions indicated as the broken lines 6 in FIG. 8 to install the membrane tank within the shell, the outer dimensions of the membrane tank can be easily deformed even though the force is not directly applied to the spherical vertex portion 0. When the forces are applied to the membrane tank T, the cylindrical ridge portions Y is deformed, but no force is transmitted to the spherical vertex portion 0 because the deformation is absorbed by the connecting portions P. In other words no force is needed to be applied to the spherical vertex portion when the membrane tank T is installed within the shell or the insulating material. In the membrane tank T installed within the shell, no high bending stress is generated even at room temperature. When it is cooled to a temperature of a low-temperature liquid stored, it is contracted so that substantially no bending stress is generated and the membrane tank is subjected only to the hoop tension.

The insulating material is so lined on the inner surfaces of the shell so as to provide a space at every corner so that the membrane tank of the second embodiment may be installed in a manner described substantially similar to that described in the first embodiment. That is, the ridge portions of the membrane tank may be freely deformed within these spaces. The effect of the second embodiment installed are similar to that of the first embodiment.

It is understood that in addition to the preferred embodiments described above various modifications may be effected without departing from the true spirit of the present invention.

The advantages of the membrane tank in accordance with the present invention may be summarized as follows:

i. In the membrane tank installed almost no bending

stress is produced, and the membrane tank is subjected only to the hoop tension. The thickness of the wall of the membrane tank can be therefore reduced considerably, and the damage to the membrane tank can be avoided. The membrane tank has sufficient strength and can be fabricated in a simple manner at a low cost.

ii. Since the spaces are provided at every corners of the insulating material lined on the inner walls of the shell, the externally extended deformations of the cylindrical ridge portions of the membrane tank can be allowed when the membrane tank is to be installed within the shell. Furthermore the radius of the cylindrical ridge portions may be reduced.

iii. The spaces may be used for the piping system associated with the membrane tank and access for the maintenance and inspection.

iv. According to the second embodiment, the thermal contraction of the membrane tank can be absorbed by the connecting portions with a conical surface, so that the forces are applied only to the cylindrical ridge portions and not to the spherical vertex portions of the membrane tank when the latter must be reduced in size so as to be installed within the shell. Furthermore even when the restraining force is applied, there arises no problem on the strength of the membrane tank, and the less restraining force will be required. The membrane tank can be fabricated at low cost because the spherical vertex portions may be fabricated in a simple manner.

v. The contraction of the cylindrical ridge portions can be relieved in the spaces at the corners of the insulating material, and the installation of the membrane tank within the insulating material may be much facilitated.

What is claimed is:

1. A storage container for liquefied gas comprising an outer shell, an inner lining of insulating material engaging the inner walls of said shell, and a flexible membrane tank within said inner lining, said tank including flat side, top and bottom portions and flat end portions, the side and top and bottom portions being connected by arcuate ridge portions each having a convex cylindrical surface, the dimensions of each flat portion of the tank being larger at room temperature than the corresponding portions of the lining, said dimensions being such that when the membrane tank is assembled within the lining, the flat portions of the tank engage the corresponding flat portions of the lining, with the arcuate ridge portions received within corners formed between adjacent side portions of the lining, said arcuate ridge portions retracting inwardly when the tank is cooled by liquefied gas placed therein.

2. A tank as set forth in claim 1 wherein a space is provided between the lining and each ridge portion, the radius of curvature of the ridge portions being decreased when the tank is installed within the lining.

3. A tank as set forth in claim 1 wherein said tank is provided with convex spherical vertex portions when radius of curvature is less than the ridge portions, and the adjacent flat portions and spherical vertex portions are connected through a cylindrical connecting portion having a surface similar to a conical surface.

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