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3,085,708

MEMBRANE TYPE STORAGE TANK

Filed Dec. 19, 1960

2 Sheets-Sheet 1

FIG. 1

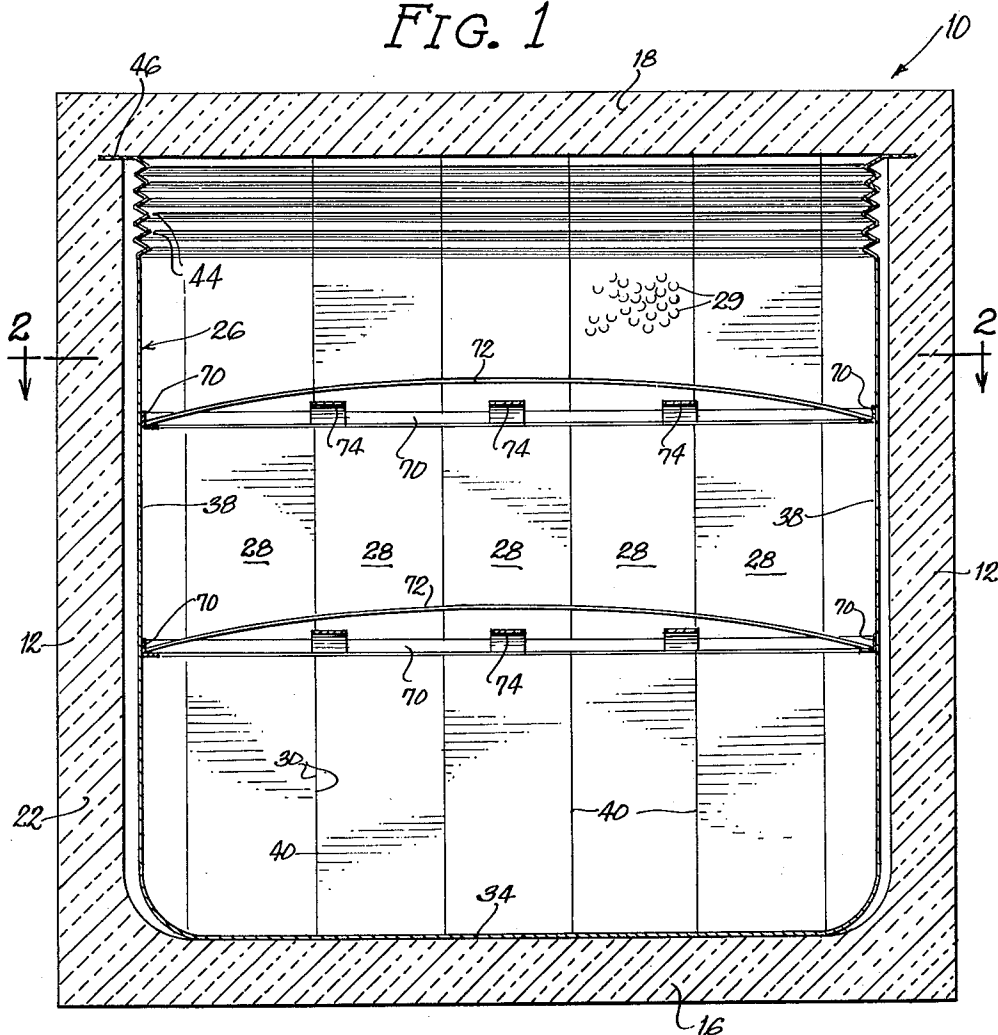
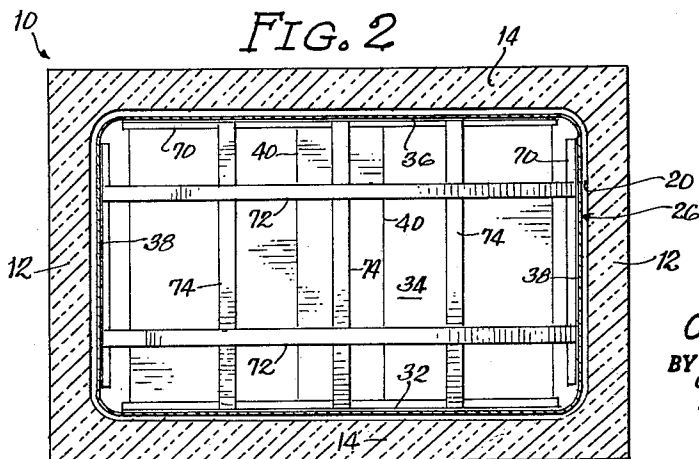


FIG. 2



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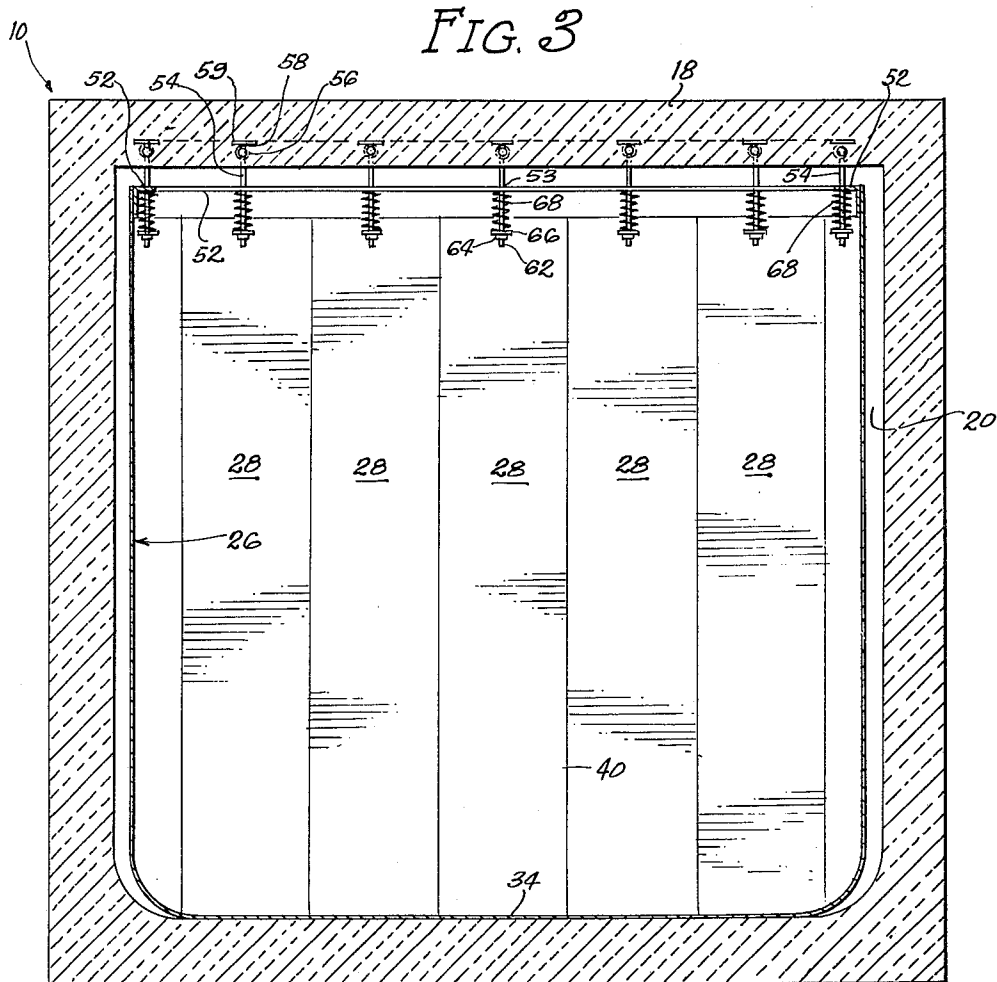
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MEMBRANE TYPE STORAGE TANK

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13 Claims. (Cl. 220-9)

This invention relates to a storage facility designed for use with liquids or fluids having a temperature differing widely from the ambient temperature and it relates more particularly to a tank of large capacity for the storage and transportation of a low boiling liquefied gas, such as liquefied natural gas.

In my Patent No. 2,954,892, issued October 4, 1960, entitled "Vessel for Storing Cold Liquids," description is made of a facility for the land storage of large volumes of cold liquefied gas. The liquid is adapted to be confined within an enclosure formed of a continuous lining formed of a thin film of fluid and vapor impervious material, hereinafter referred to as a membrane, which is incapable of self-sufficiency under load but which is forced by the load of the liquid in storage against the insulation layer for support.

A membrane type tank of the type described offers considerable advantage over the construction of conventional tankage for housing large volumes of extremely cold liquid. It does away with the high cost of a self-sufficient tank housed within an insulated space. For example, in the manufacture of a self-sufficient tank of aluminum plate, or stainless steel, high nickel steel, or other metal capable of retaining strength and ductility at the cold temperatures of the liquid (-240° F. to -258° F. for natural gas, depending upon the amount of higher boiling hydrocarbons in the natural gas), the cost of self-sufficient tanks for housing as much as 30,000 barrels is in the order of hundreds of thousands of dollars. Further, such self-sufficient tanks cannot be rigidly tied into the insulated structure for support because of the necessity to permit relative movements between the tank and the supporting structure due to the differences in expansion and contraction in response to the great differences in temperature change since the tank will be subject to a temperature change of from 80° F., when empty, to about -250° F. when filled, whereas the supporting structure will have to be insulated from the tank so that it will remain at about ambient temperature. In a tank of 100 feet by 100 feet by 60 feet, the change in dimension in the tank may range from 6 to 10 inches in the various directions.

In a membrane type tank, it is sufficient to make use of a thin film of a fluid and vapor impervious material formed as a lining about the inner surface of an insulated space which is characterized by structural strength and dimensional stability to maintain the liquid load when the lining is forced into engagement with the insulated surface for support. Under such circumstances, the lining merely functions as a liquid and fluid impervious barrier to confine the liquid within the insulated space but it contributes little by way of structural strength or support of the liquid load. Thus the lining or membrane can be fabricated at low cost of a minimum amount of material, representing a many-fold savings over and above the self-contained storage tanks.

The construction of a membrane type tank is faced by a number of problems which are not present in a self-sufficient tank. Because of the lack of self-sufficiency, it is desirable to provide means for supporting the membrane as a lining about the insulated space in a manner to prevent collapse when the liquid is removed. Another problem which is also faced by a self-sufficient tank, but in a different way, is the need to permit freedom of the film or membrane for expansion and contraction movements

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relative to the supporting insulation layer due to temperature change but while still maintaining proper stabilization of the lining.

In my aforementioned patent, the membrane is formed of interconnected segments which are individually supported from the insulation at spaced apart points with corrugations extending lengthwise and crosswise in each of the segment to make additional amounts of material available throughout the entire area of the lining for expansion and contraction without substantial change in dimension. The joinder of the individual segments into a continuous fluid and vapor impervious lining and the support thereof can be achieved but with great difficulty and at considerable expense.

It is an object of this invention to produce and to provide a method for producing a membrane type tank for the storage and/or transportation of an extremely cold liquid and it is a related object to produce and to provide a method for producing a tank of the type described which is formed of relatively low cost and readily available materials; which can be mounted in position of use to form a continuous fluid and vapor impervious lining at minimum expense; which embodies a simple and efficient means to prevent collapse; which embodies a simple and inexpensive means for support in a manner which permits freedom of movement relative to the housing in expansion and contraction due to temperature change, and which is simple in construction and easy in operation to provide a sturdy storage facility of large capacity.

These and other objects and advantages of this invention will hereinafter appear and for purposes of illustration, but not of limitation, an embodiment of the invention is shown in the accompanying drawings in which:

FIG. 1 is a schematic sectional elevational view of a storage tank embodying the features of this invention;

FIG. 2 is a sectional view taken substantially along the line 2-2 of FIG. 1, and

FIG. 3 is a sectional elevational view similar to that of FIG. 1 but showing a further modification in the construction thereof.

The invention will be described with reference to the storage of liquefied natural gas in large volume. Under such conditions, it is practical only to store the liquid at atmospheric pressure or slightly above. At atmospheric pressure, the liquefied gas will be at a temperature of about -240° F. to -258° F. depending upon the amount of heavier hydrocarbons present since liquefied methane, the major component of natural gas, has a boiling point of -258° F. at atmospheric pressure. It will be understood that the concepts of this invention will have application also to the storage of other cold fluids and liquefied gases.

In accordance with the practice of this invention, there is provided a structurally strong and dimensionally stable housing 10, illustrated as a rectangular housing having vertically disposed side walls 12, front and back walls 14, a bottom wall 16 and a top wall 18. For purposes of illustration, the walls are shown as being constructed of a thermal insulating material 22 to define an insulated storage space 20 therebetween but it will be understood that the housing can be constructed of an outer shell or frame of a structurally strong material, such as metal plate, with or without reinforcement, with a thick layer of insulating material separating the metal frame from the insulated storage space 20.

The insulation layer 22 constituting the entire structure of the housing or a part thereof is preferably fabricated of a structurally strong and dimensionally stable insulating material, such as panels or plies of a porous wood like balsa wood, quippo, etc., or of rigid foams of plastic, glass or cement, either in the form of panels or foamed in place insulation, or of panels of honeycomb with the

cells extending horizontally endwise between the inner and outer surfaces. The inventive concept can best be illustrated with reference to a housing of rectangular shape but it will be apparent from the description that tanks of other shapes in horizontal cross-section, but preferably with flat walls, can be employed.

Supported within the insulated space 20 and adjacent the inner surfaces of the insulation layers is a lining 26 of a fluid and vapor impervious material which completely covers the inner surfaces of the vertical and bottom walls of the housing 10 to a height greater than the level of liquid adapted to be housed within the tank. An important concept of this invention resides in the construction and in the mounting of the lining formed of the thin membrane-like material.

The portions of the lining covering the front, back and bottom walls (or the side and bottom walls if the former are of substantial width) are formed of continuous strips 28 of the fluid and vapor impervious sheet stock dimensioned to have a length which corresponds to the width of the bottom wall 16 plus the height to which the lining is adapted to cover the front and back walls plus an additional amount for expansion and contraction. The strips 28 are arranged in side-by-side relation with the adjacent edges 30 being joined one to another in sealing relation, as by welding, to define the continuous front, bottom and back wall portions 32, 34 and 36 respectively of the membrane container. Thus the two opposite walls 14 of greatest dimension and the bottom wall 16 are lined with membranes which extend continuously downwardly along one wall, across the bottom wall and upwardly along the opposite wall. It will be apparent that the strips can be joined one to the other in sealing relationship while within the housing or separate and apart therefrom where joiner, as by welding, can be more easily and effectively carried out to preform the lining covering the three large walls of the insulated space. Similarly, the linings for the side walls 12 are formed of continuous strips dimensioned to have a length corresponding to the height to which the lining rises in the tank, plus the additional amount for expansion, and arranged in side-by-side relation for joiner of the adjacent edges in sealing relation to provide a continuous cover 38 over the side walls of the insulated space. The adjacent lateral edges of the panels 38, 32 and 36 are joined one to the other in sealing relation and the bottom edges of the panels 38 are joined to the lateral edges of the panel section 34 to define a fluid and vapor impervious enclosure therebetween.

In this construction, the only welds that are required to be made are along the seams 40 between the lateral edges of the adjacent strips of lining material, most, if not all, of which can be preformed outside of the tank where access can be made to all such surfaces more easily and effectively to join the edges in sealing relation. In the event that the panels 38 for the side walls are preformed separate and apart from the panels covering the front, back and bottom walls, joiner can be effected while in position of use merely by joining the lateral edges of the lining covering the three side and bottom walls with the adjacent lateral edges and the lower edges of the lining dimensioned to cover the end walls to effect a complete fluid and vapor impervious lining about the insulated space.

The strips of fluid and vapor impervious material used to form the membrane should be of a material which is temperature-insensitive and which retains its strength and ductility and is not embrittled at the cold temperature of the liquid. For this purpose, use can be made of film or sheet stock of from .006 to .030 inch formed of such metals as aluminum and alloys of aluminum, copper, brass, stainless steel or other austenitic steels or high nickel steels, or plastic film stock such as glass fiber reinforced polyester sheets, polyesters and the like.

Means are provided adjustably to suspend the lining from its upper edge into the insulated space to position the lining within the insulated space 20 with the walls of the lining adjacent the inner surfaces of the housing walls but free therefrom to permit relative movement in expansion and contraction.

To compensate for expansion and contraction in the horizontal direction, the panels can be formed with periodic laterally spaced apart vertically extending corrugations (not shown) or else corrugated at their edges where they are joined one to another but it is preferred to compensate for such change in dimension by the formation of the panels with a dimpled construction 29 throughout or with a cross-ribbed checker-board construction for making additional material available in all directions in amounts to compensate for the expansion and contraction adapted to take place without substantial dimensional change.

The modification shown in FIG. 1 illustrates one means for suspension and for compensating for contraction and expansion of the membrane in the lengthwise direction. In this modification, the upper edge portion of each of the panels before or after joiner, are formed with a plurality of horizontally disposed, vertically spaced apart corrugations 44 dimensioned to make an amount of material available calculated to exceed the amount of contraction otherwise taking place throughout the length of the strips so that the bottom portion of the lining will be able to remain at rest at all times on the bottom wall of the supporting housing. Beyond the corrugated portion, the upper edge of the panels is formed with means for fixing the position of the lining as by attachment to the housing. By way of example, the upper edge is turned to an outwardly extending flange 46 adapted to be engaged in the housing wall for support and in a manner to suspend the remainder of the lining within the insulated space.

In another modification, shown in FIG. 3, the formed lining is suspended within the insulated housing from a resilient means connected to the top wall of the tank. In the illustrated modification, the mounting means comprises angle irons 52 or other rigid structural members which are horizontally disposed and attached to the upper edge portion of the membrane or lining about the insulated space. The structural members have a plurality of spaced apart openings 53 through which elongate rods 54 may extend. The upper end of each of the rod members is pivotally connected to the top wall of the housing as by means of an eye 56 engaged upon a hook 58 of a bracket 59 rigid with a horizontally disposed beam 60 fixed to the upper portion of the insulated space. The through-extending end portion of each of the rods 54 is threaded, as at 62, for enabling a washer 66 and a nut 64 threadably to be received on the end thereof. A compression spring 68 is disposed between the washer and the structural member 52 in a manner resiliently to urge the supporting structure 52 in the upward direction. By adjustment of the nut member on the rod, it becomes possible to raise or lower the structural member 52 by an amount to compensate for the expansion and contraction found to take place. Sufficient flexibility exists by reason of the resilient support to take care of any additional contraction or expansion which might take place. The force for deformation of the springs is calculated to be less than the force required to rupture the lining. It is desirable, though not essential, to make use of an additional element within the container for urging the membrane outwardly into position of use and to prevent collapse upon removal of liquid. For this purpose, use can be made of a spider construction of the type described in my previously issued Patent No. 2,954,892.

A further means, illustrated in FIGS. 1 and 2 of the drawings, comprises light weight, horizontally disposed beams 70 fixed to the inner surfaces of the panels in vertically spaced apart relation to provide relatively rigid,

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structurally strong, horizontally disposed ledges in the side panels as well as in the front and back panels. Extending crosswise between opposite ledges are one or more bowed strips 72 of wood or other relatively rigid resilient material which are effective as spreader bars constantly to urge the opposite ledges in the direction away from each other and towards engagement with the insulating supporting wall. In the assembled relation, there will be spreader bars 72 extending crosswise between the opposite side walls and other spreader bars 74 extending lengthwise between the front and back walls.

It will be apparent from the foregoing that I have provided a simplified means for the construction of a membrane enclosure for use in an insulated storage tank which is adapted to house liquids, and especially extremely cold liquids like liquefied natural gas. The use of continuous strips of membrane material to extend lengthwise over opposite walls and across the bottom wall markedly simplifies the construction and materially improves its operation since the number of joints along the adjacent edges of the strips is materially reduced by comparison with the preformed panel construction of the type heretofore employed.

It will be understood that changes may be made in the details of construction, arrangement and operation without departing from the spirit of the invention, especially as defined in the following claims.

I claim:

1. In a membrane tank for liquid storage comprising a rigid housing of structural strength having vertically disposed walls, a bottom wall and a top wall defining a storage space therebetween, a thin collapsible membrane container of fluid and vapor impervious material supported from the upper edge portion for suspension within said storage space to line the walls of said housing and against which the membrane rests in response to liquid load in storage while remaining free thereof for relative movements responsive to expansion and contraction, the improvement wherein the said membrane container comprises elongate strips of said fluid and vapor impervious material extending continuously across the bottom wall of the housing and up opposite vertical walls to a level above the liquid level and in which the strips are arranged in side-by-side relation with the adjacent edges joined in sealing relation to form a continuous panel dimensioned to have a width corresponding to the width of said vertical walls, and other elongate strips extending continuously from the bottom wall to the level of the liquid in the container and arranged in side-by-side relationship with the lateral edges joined in sealing relation to form other panels dimensioned to have widths corresponding to the others of said vertical walls, with the edges of one panel being joined with the edges of adjacent panels in sealing relation to define the membrane container therebetween and in which said strips are of dimpled construction substantially throughout their area for expansion and contraction without dimensional change.

2. A membrane tank as claimed in claim 1 in which the membrane container is formed of strips of temperature insensitive material which do not lose their strength and ductility at extremely low temperature.

3. A membrane tank as claimed in claim 1 in which the rigid housing comprises an insulated housing formed of thermal insulating material having structural strength

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and dimensional stability for support of the membrane container under load.

4. A membrane tank as claimed in claim 3 in which the thermal insulating material comprises panels of balsa wood.

5. A membrane tank as claimed in claim 1 in which the panels forming the membrane container have vertically disposed, laterally spaced apart corrugations for enabling expansion and contraction in the crosswise direction without dimensional change.

6. A membrane tank as claimed in claim 1 in which the panels of the membrane container are cross ribbed for expansion and contraction without dimensional change.

7. A membrane tank as claimed in claim 1 in which the panels of the membrane container are corrugated in the edge sections where the strips are joined one to the other for expansion and contraction in the crosswise direction without dimensional change.

8. A membrane tank as claimed in claim 1 which includes means in the upper end portion of the panels of the membrane container for enabling expansion and contraction in the lengthwise direction without dimensional change.

9. A membrane tank as claimed in claim 8 in which the means permitting expansion and contraction without dimensional change comprises horizontally arranged vertically spaced apart corrugations.

10. A membrane tank as claimed in claim 8 in which the means in the upper end portion of the panels for enabling expansion and contraction without dimensional change comprises a frame fixed to the upper portion of the housing, hanger rods suspended from said frame and shiftable relative thereto in the vertical direction, means securing the upper end portions of said panels to said hanger rods, and means resiliently urging said rods towards a raised position.

11. A membrane tank as claimed in claim 10 which includes means for adjusting said resilient means on said hanger rods to adjust the position of the panels in the vertical direction.

12. A membrane tank as claimed in claim 1 which includes means within the housing constantly urging the vertically disposed panels of the membrane container in the direction towards the supporting wall of the housing.

13. A membrane tank as claimed in claim 12 in which the means constantly urging the panels outwardly in the direction of the supporting walls of the housing comprises horizontally disposed vertically spaced apart ledges on the inner surfaces of the vertically disposed panels, resilient spreader bars dimensioned to have a length greater than the distance between opposite walls and bowed to extend between said opposite walls with the ends bearing against said ledges.

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