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CONTAINER FOR STORING LIQUIDS AT LOW TEMPERATURES

Filed March 3, 1965

3 Sheets-Sheet 1

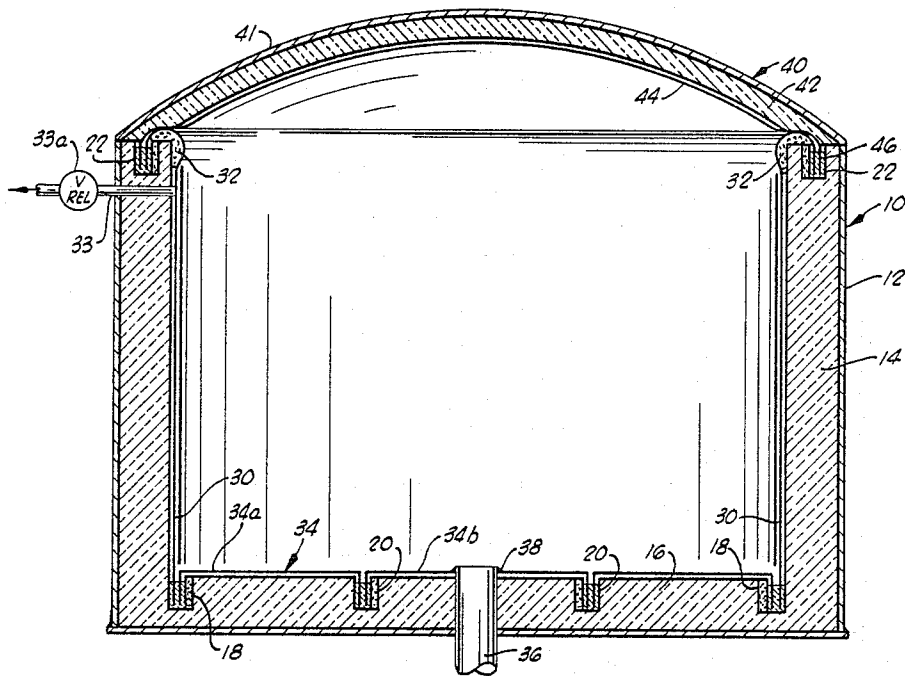


Fig. 1

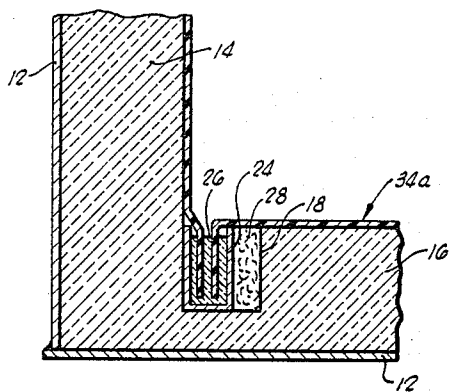


Fig. 2

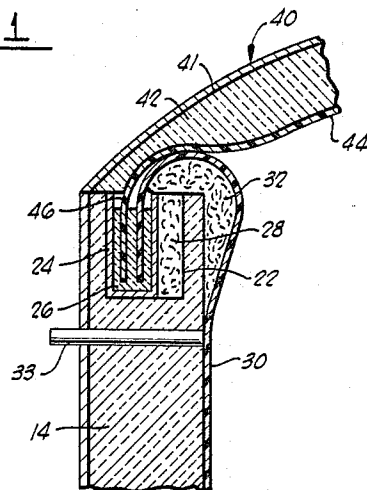


FIG. 4

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3 Sheets-Sheet 2

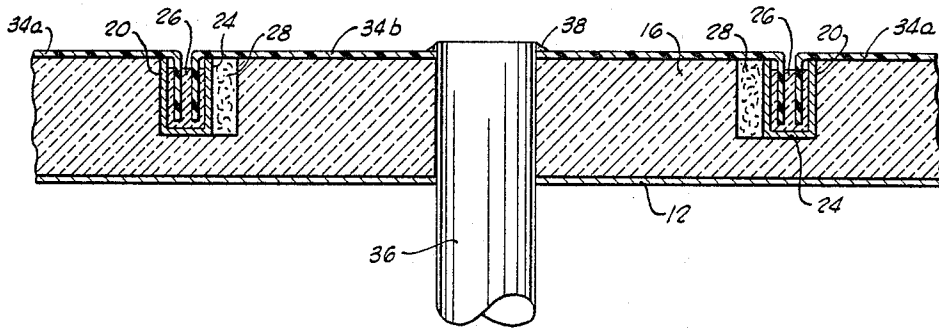


FIG. 1

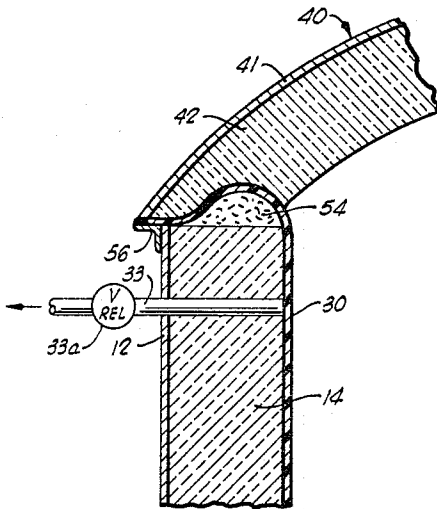


FIG. 6

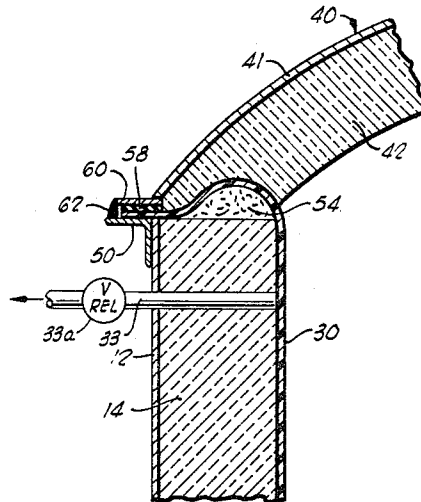


FIG. 7

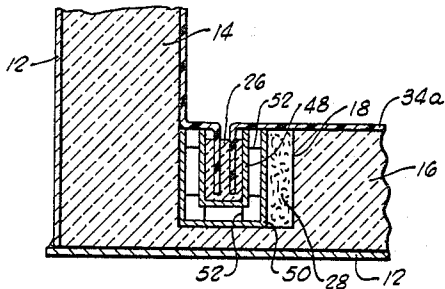


FIG. 8

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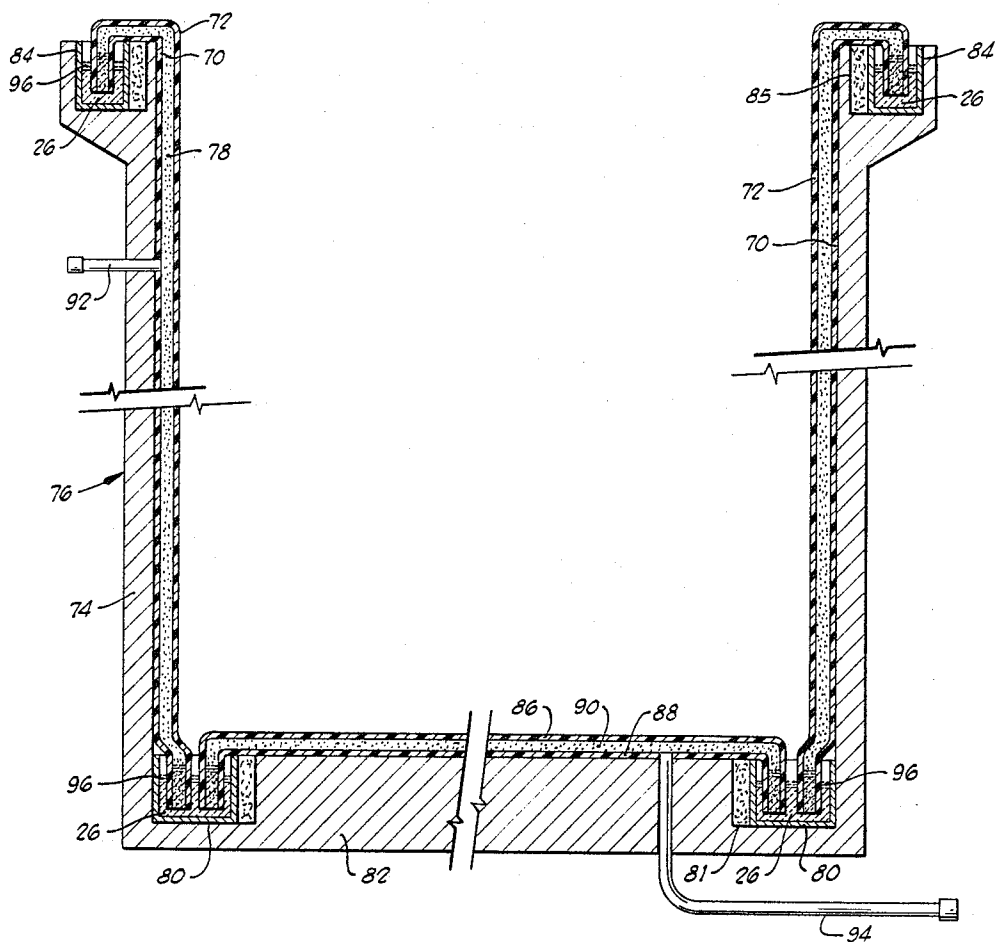


FIG. 8

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1

2

3,267,685

CONTAINER FOR STORING LIQUIDS AT LOW TEMPERATURES

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22 Claims. (Cl. 62-45)

This invention relates to a container for confining a body of liquid at relatively low temperatures, particularly, at temperatures below the freezing point of water. More specifically, but no by way of limitation, the present invention relates to a strong, relatively lightweight container which can be economically constructed in either portable or stationary form for storing liquids at a temperature below the freezing point of water.

The storage of large volumes of liquified, normally gaseous materials which, in the liquid state possess a relatively high vapor pressure, presents several problems. Two major problems which are encountered in this type of liquid storage are (a) that which arises from the requirement for a relatively efficient, thermally insulating environment for the stored liquid so that its relatively low temperature of storage can be economically maintained, and excessive evaporation or "boil off" of the liquid can be avoided, and (b) the necessity particularly where large volumes of the liquid are to be stored, of providing a storage tank which is exceptionally strong structurally in order to withstand the vapor pressures which may be developed by vaporization of the stored liquid due to heat exchange with the environment. It will be noted that these two problems are interrelated in that the efficiency of the insulating coating or barrier provided around the storage container will determine to some extent the requirement for heavy, mechanically strong structural members in the construction of the container. The efficiency of the thermal insulation provided also will be a major factor affecting the cost of any equipment, such as compressors and the like, which must be provided for preventing loss of the stored liquid due to vaporization.

As typical of liquids which present some storage difficulties as a result of the described problems may be cited liquified petroleum gases, such as liquified methane, ethane and propane, liquified inert gases such as liquified helium and liquid nitrogen, and, to some extent, anhydrous ammonia. The large current production of liquified petroleum gases, together with the seasonal market for these materials, results in the requirement that substantial quantities of the materials be stored during certain periods of the year. It has previously been proposed to store normally gaseous materials of this type both in artificial above-ground tanks and storage containers, as well as in earthen cavities or pits. One of the primary motivations in employing the latter type of storage has been the economies which are achieved thereby relative to storage in tanks or other above-ground structures. When the latter have been employed, it has been necessary to use heavy structural materials in fabricating the tanks to obtain the necessary strength to withstand the high vapor pressures, and the expense of such construction has been further increased by the necessity to provide relatively heavy insulation to reduce the rate of heat exchange between the stored liquids and the surrounding environment. Moreover, the necessity to provide liquid tight seals and joints in all locations within the tank contacted by the liquid, and vapor tight seals at other points, has further increased the cost of construction of this type of container so that, in many instances, where even relatively small volumes of the liquified gases require storage,

the use of above-ground tanks of the type described may become economically infeasible.

The present invention provides an improved container which is especially adapted for the containment of liquids which are normally stored at temperatures below the freezing point of water. Broadly described, the present invention comprises a container formed by a rigid outer shell having a side wall and a bottom, and being open at the top with such outer shell preferably being formed of a mechanically strong material, such as steel. The outer shell is lined with a rigid, thermally insulating material which also has a side wall, and includes a floor overlying the bottom of the outer shell. A groove or trough occupies a horizontal plane in the insulating material lining the outer shell, and is positioned at the junction of the side wall of the insulating material with the floor thereof, and extends completely around the side wall. The trough opens upwardly and is adapted to retain a liquid therein. A first, liquid impermeable membrane lines the side wall of the insulating material and has a lower edge which extends into the trough. A second, liquid impermeable membrane lines the floor of the insulating material and has an outer peripheral edge which extends into the trough.

In the use of the container, the trough contains a solid material having a melting point below about 25° C. with the solid material increasing the edge portions of the first and second membranes which are extended into the trough so as to form a liquid tight seal around the edges of the membranes. In a preferred embodiment of the invention, the solid material which is disposed in the trough is water. The use of ice as the material forming the seal around the edges of the membrane which are extended into the trough has many advantages, and is particularly desirable where the liquid to be stored is a normally gaseous material which has been converted to the liquid state and is stored at very low temperatures. When ice is used to entrap or seal the membranes which line the side wall and floor of the insulating material of the container, a strong liquid tight joint is formed between the membranes, and such joint can be very quickly and economically constructed. Moreover, the joint is of a semi-permanent nature since it can be opened or destroyed merely by permitting the ice to be melted so that the edges of the membranes can be easily withdrawn from the trough.

In a preferred embodiment of the invention, the upper edge of the membrane which lines the side wall of the insulating material is also retained in place by a frozen liquid seal by extending such upper edge into a trough formed in the upper portion of the side wall of the insulating material, and filling the trough with a liquid which can be converted to the solid state at a temperature which is below 25° C., and above the temperature at which liquids are to be stored in the container.

From the foregoing description of the invention, it will have become apparent that it is a major object of the present invention to provide an improved container for storing liquids at relatively low temperatures, and preferably, below the freezing temperature of water.

Another object of the present invention is to provide a high mechanical strength container capable of containing large volumes of relatively volatile liquids in a thermally insulated environment, which container can be constructed at substantially less cost than the types of containers which have previously been provided for this purpose.

An additional object of the present invention is to provide a strong lightweight container which is especially well adapted for containing normally gaseous, liquified materials, such as liquified petroleum gases, and which may be constructed in either stationary or portable form.

A more specific object of the present invention is to

3

provide a container for storing liquids at relatively low temperatures, which container is well insulated to prevent an undesirably high rate of heat exchange between the liquid contents of the container and the container environment.

An additional object of the invention is to provide a container for liquified gases which are to be stored at low temperature, which container is constructed with seals formed by a frozen, normally liquid material which is retained in the solid state by contact with liquids stored in the container, or by location in close proximity to such liquids.

In addition to the foregoing described objects and advantages, additional objects and meritorious features of the invention will become apparent as the following detailed description is read in conjunction with the accompanying drawings which illustrate certain embodiments of the invention.

In the drawings:

FIGURE 1 is a vertical sectional view which is partially schematic, and which is taken through the center of one embodiment of a liquid storage container constructed in accordance with the present invention.

FIGURE 2 is a sectional view of a detail of the construction illustrated in FIGURE 1, such detail showing one of the frozen liquid bottom seals used in the container of the invention.

FIGURE 3 is a sectional detail view illustrating a modified construction of the frozen bottom seals which may be used in the invention.

FIGURE 4 is a sectional detail view showing the frozen liquid seal used between the roof structure and the side wall of the container.

FIGURE 5 is a sectional detail view illustrating the manner in which a suction discharge conduit may be connected through the bottom of the container.

FIGURE 6 is a sectional view illustrating a modified construction of the seal between the roof structure and side wall of the container.

FIGURE 7 is a sectional view illustrating another manner of constructing the seal between the roof structure and the side wall of the container.

FIGURE 8 is a sectional view illustrating yet another modified embodiment of the invention.

Referring to the drawings in detail, and particularly to FIGURE 1, the container of the invention is designated generally by reference character 10 and includes a rigid outer shell 12 constructed of a material having a high mechanical strength, such as carbon steel. The outer shell 12 is lined with a relatively thick layer of rigid insulating material which includes a side wall 14, and a floor 16 which rests upon and lines the bottom of the outer shell 12. The insulation material can be cellular glass, cork, balsa wood, or any other relatively inexpensive, lightweight, good thermal insulator which can be suitably secured or adhered to the rigid outer shell 12.

In the illustrated embodiment of the invention, the container 10 is generally cylindrical in configuration and an annular groove or trough 18 is formed in the insulating material floor 16 around the periphery thereof at its junction with the side wall 14 of the rigid insulating material. Another annular groove or trough 20 is formed in the floor 16 of the insulating material, and is disposed radially inwardly from the trough 18. A third annular groove or trough 22 is formed in the top of the side wall 14 of the insulating material and extends completely around the container 10. Each of the grooves 18, 20 and 22 are preferably of generally rectangular cross-sectional configuration.

The specific construction of the frozen liquid seals which are used in the container of the present invention can best be understood by referring to FIGURES 2, 4 and 5 in conjunction with their schematic illustration in FIGURE 1. Within each of the annular grooves 18, 20 and 22 formed in the rigid insulation material which lines the

4

outer shell 12 is positioned an annular, liquid tight channel 24 preferably having a generally U-shaped cross-sectional configuration. The liquid tight channels 24 can suitably be constructed of metal or plastic, and are used to contain a sealant material 26 which is a liquid at ambient temperatures having a freezing point below about 25° C. The normally liquid sealant material 26 which is placed in the liquid tight channels 24 is preferably water and, in the use of the container, is converted to ice in the manner hereinafter explained. Positioned between one side of each of the liquid tight channels 24 and a parallel side of its respective groove is a relatively loose or compressible thermally insulating material 28, such as Fiberglass or the like. The compressible insulation material 28 permits expansion and contraction of the liquid tight container 24 occasioned by variations in the temperature of the fluid contents of the container 10. It will be perceived in referring to FIGURES 2, 4 and 5 that the seal arrangements associated with each of the grooves 18, 20 and 22 are substantially identical, each thus including the liquid tight channel 24, the normally liquid material 26 and the compressible insulating material 28.

The internal surface of the side wall 14 of the rigid insulating material is lined with a relatively flexible, liquid impermeable membrane 30 which can suitably be constructed of thin metal or plastic. The upper edge of the membrane 30 is extended over a rim of compressible or relatively loose insulating material 32 positioned over the inner edge of the upper end of the side wall 14. The upper edge of the membrane 30 is further extended into the normally liquid sealant material 26 in the channel 24. The bottom edge of the membrane 30 is extended into the normally liquid sealant material 26 which is carried in the channel 24 positioned in the annular trough 18. It is preferred to provide a vent pipe 33 extending through the shell 12 and insulation 14 at a point located near the top of the container for a purpose hereinafter described. The vent pipe is provided with a check valve or pressure release valve 33a.

A second, liquid impermeable, flexible membrane designated generally by reference character 34 covers the floor 16 of the rigid insulating material which lines the outer shell 12. The second membrane 34 may, like the first membrane 30, be constructed of a thin metal or plastic material. The second membrane 34 may consist of a single sheet of material which covers the entire bottom 16 of the rigid insulation material, or it may be formed as shown in FIGURE 1 for the purpose of better accommodating a suction discharge conduit 36 which is extended into the center of the bottom of the container 10. Thus, in the illustrated construction, the second, liquid impermeable membrane 34 comprises a segmented or two-part construction which includes an annular, radially outer section 34a and a central section 34b. The annular radially outer section 34a is provided with an outer peripheral edge portion which extends into the normally liquid sealant material 26 in the channel 24 carried by the annular groove 18. The inner peripheral edge of the radially outer section 34a of the membrane 34 extends into the normally liquid sealant 26 carried by the channel 24 in the groove 20. In this embodiment, the central section 34b is preferably a relatively thin metal sheet having an outer peripheral portion which extends into the sealant material 26 in the channel 24 of the trough 20. The central portion of the metallic central section 34b is secured by a suitable fluid tight seal 38 around the upper end of the discharge conduit 36.

In order to prevent evaporation of the liquid stored in the container 10, a roof structure 40 is provided and includes a rigid, outer shell 41 of metal or the like supporting a relatively rigid thermally insulating material 42. The insulating material 42 is lined with a vapor-impermeable material 44 on the concave or inner surface thereof. The vapor-impermeable material 44 can suitably take the form of a covering membrane which has a

5

peripheral edge portion 46 which depends downwardly from the roof structure. When the roof structure 40 is positioned as illustrated in FIGURE 1, the peripheral edge portion 46 of the vapor-impermeable membrane 44 is extended into the normally liquid sealant material 26 carried in the channel 24 located in the groove 22 in the side wall 14 of the rigid insulating material.

It should be pointed out that in the construction of the roof structure 40, the rigid outer shell 41 can be eliminated or omitted from the construction in some instances, such as where relatively rigid and structurally strong insulating material 42 is employed, since the weight of the liquid held within the container 10 is carried entirely by the bottom and side walls of the container and there is less need for structural strength in the roof structure 40.

In the construction of the container 19, the outer shell 12 is first shaped as desired by conventional and well known fabrication procedures. The insulating material is then positioned on the inside of the outer shell 12 to constitute a side wall and floor for the container, and to provide adequate thermal insulation for the liquid material which is to be stored at a low temperature in the container. The roof structure 40 is similarly constructed.

The liquid impermeable membranes 30 and 34 which line the side wall 14 and floor 16, respectively, of the rigid insulating material are then placed in position as illustrated in FIGURE 1. This positioning of the membranes involves the extension of the peripheral edges of the membranes into the channels 24 positioned in the respective grooves 18, 20 and 22. It is not necessary, or even desirable, in most instances, to bond or seal the membrane to the contacting surface of the rigid insulating material, since the seals at the edge of the membrane will retain it in the proper position over the lining of rigid insulating material when the container is in use. Moreover, if the membranes 30 and 34 are not sealed to their respective contacting surfaces of the insulating material, any slight leakage through pinhole breaks or apertures in the membranes does not present a problem when the liquid is removed from the container 10 by suction. This is because any tendency which the resulting reduced pressure within the container might have to vaporize the stored liquid will then not cause rupture of the membranes. In other words, if any liquid material remaining in the container and perched having infiltrated under the membranes 30 and 34 is flashed by an evacuation procedure used in removing the liquid from the container, the vapor evolved under the membranes will have sufficient room to expand and can be released through the vent pipe 33 and check valve 33a since the membranes are not bonded to the areas of the rigid insulating material with which they are in contact.

After the liquid impermeable membranes 30 and 34 have been located in their proper positions with their peripheral edges extending into their respective channels 24, the several channels are partially filled with a normally liquid sealant material 26 which can be easily converted to the solid state by a relatively slight reduction in temperature. The materials 26 employed in forming the seals used in the container 10 of the invention are those which are liquid at ambient or room temperatures, and can thus be poured into the channels 24 without requiring high temperatures to melt the material, and special handling equipment. It is further necessary that the normally liquid sealant materials 26 have a freezing point which is higher than the freezing point of the liquids which are to be stored in the container 10. Since the preferred employment of the container is contemplated to be in the storage of normally gaseous materials in the liquid state and at cryogenic temperatures, several normally liquid sealant materials will meet this latter requirement. From the standpoint of economy and ease of use, however, as well as certain operating and technical advantages, it is highly preferred that water be the

6

sealant material employed for forming the seals used in the invention.

In addition to the advantages offered by water of being relatively economical, being easily poured into the channels 24, and being liquid at ambient or room temperatures yet freezing at a higher temperature than most of the liquids which will be stored in the container, several other marked advantages accrue from the use of water as the sealant material. Thus, upon being converted to the solid state, water, unlike practically all other materials, undergoes expansion, and thus bears tightly against the confining walls of the channel 24, and also tightly grips or engages the free edges of the membranes 30 and 34 which are extended into the ice. A tight liquid and vapor-impermeable barrier or seal is formed around the edges of the membranes to prevent leakage from the container 10 of either the liquid contained therein, or vapors which might otherwise escape between the roof structure 40 and the side walls of the container.

Water also presents the advantage of being immiscible with hydrocarbon materials, and thus there is less likelihood of contamination of the stored liquids when such liquids are liquified petroleum gases and the like. Lastly, ice demonstrates a self-healing property which permits any fissures or cracks which might otherwise tend to develop in the ice seal to be immediately healed and the integrity of the seal to be maintained.

After the troughs 18, 20 and 22 have been filled with the normally liquid sealant material 26, the roof structure 40 is positioned as illustrated in FIGURE 1 of the drawings with the peripheral edge 46 of the vapor-impermeable membrane 44 extending into the channel 24 in the groove 22. The liquid to be stored can then be introduced through a suitable opening (not shown) in the roof structure 40, or in some instances, may have been positioned in the container 10 prior to installation of the roof structure 40. When the low temperature of the stored liquid is to be relied upon to convert the normally liquid sealant material 26 to the solid state, rather than the use of extrinsic refrigeration or heat exchange systems, the roof structure 40 is preferably placed in position prior to introducing the low temperature liquid into the container 10.

During storage of liquids at low temperatures within the container 10, it is contemplated that the temperature of storage or containment will be below the melting point of the normally liquid sealant material 26. As previously indicated, one of the preferred usages of the container 10 is for storing at very low or cryogenic temperatures, normally gaseous materials which develop a relatively high vapor pressure even at such low temperatures. Materials of this type include, for example, liquified natural gas, liquified ethane, liquified propane, liquified helium and liquified nitrogen. When these materials are enclosed within the container 10, and water is employed as the normally liquid sealant material 26, strong, liquid impermeable seals are established by the ice around the edges of the membranes 30 and 34 so that no leakage or escape of the liquid is possible at these points. Moreover, the ice seal established around the upper edge of the membrane 30 and the peripheral edge 46 of the vapor-impermeable membrane 44 of the roof structure 40 is such that no substantial escape of vapor from the container 10 can occur. The low temperatures at which the normally gaseous materials are to be stored will retain the water in a frozen state in the seal zones so that the integrity of the seals continues during the period of storage.

The desirability of not bonding the membranes 30 and 34 to the surfaces of the rigid insulating material with which they are in contact has previously been discussed. Where relatively low pressures are created in the container 10 by evacuation of the contents therefrom, it may, in some instances, be desirable to provide an additional space for accommodating gases produced by flashing of liquid which has leaked between one of the membranes 30 or

34 and the rigid insulating material. Additional continuous space or increased volume can be provided by using the embodiment of the seal structure illustrated in FIGURE 3.

In the modified seal structure illustrated in FIGURE 3, a liquid tight channel 48 of U-shaped cross-section is provided for containing the normally liquid sealant material 26. The channel 48 is positioned within, and spaced from, a larger channel 50 by suitable spacer blocks 52 so that a fluent material may flow completely around the outside of the channel 48 in the space between the two channels. With this arrangement, the sudden vaporization of a liquid which has leaked through the membrane 34 into the space between this membrane and the floor 16 of rigid insulating material will not result in rupture of the membrane due to insufficient space for volumetric expansion of the flashed material. Instead, the entire void space existing between the side wall 14 of the rigid insulating material and the membrane 30 is also available to accommodate the gas developed upon flashing, since this space is permitted by the seal structure of FIGURE 3 to communicate with the space between the floor 16 of the insulating material and the membrane 34. It should be noted that a similar seal structure can be provided in the trough 20 if desired. The vent pipe 33 is provided adjacent the top of the container to permit complete escape of entrapped vapor from beneath the membrane 30 if the pressure becomes excessive so as to open the pressure release valve 33a.

Where relatively high vapor pressures are not characteristic of the liquids stored within the container 10, two alternative types of seal structures for establishing the seal between the roof structure 40 and the side walls of the container may be employed. These are illustrated in FIGURES 6 and 7. In referring to these figures, it will be noted that a relatively loose, compressible insulating material 54 is again placed between the top edge of the membrane 30 and the top edge of the side wall 14 of the rigid insulating material lining the shell 12. Also, in both structures, the frozen liquid seal employed around the top of the container 10 as illustrated in FIGURE 1 has been eliminated, and instead, in the embodiment illustrated in FIGURE 6, the upper or top edge of the membrane 30 has been welded or otherwise suitably secured to a circumferential flange 56 which is secured around the upper end of the outer shell 12 of the container. The rigid insulation 42 used in the roof structure 40 is then indented or shaped to a configuration which is complementary to the contour of the membrane 30 as it passes across the top edge of the side of the container. In permanent installations where the roof can remain in place, and access other than by removal of the roof is provided to the interior of the container 10 for filling and emptying the container, the metallic shell 41 of the roof structure can also be welded to the flange 56 if desired.

In the modified embodiment illustrated in FIGURE 7, the upper edge of the membrane 30 is not welded or otherwise secured to the flange 56, but is instead sealingly retained in position on the flange 56 by a gasket 58 which extends between the upper surface of the membrane 30 and a circumferential flange 60 formed around the outer peripheral edge of the outer shell 41 of the roof structure 40. In the construction of the seal illustrated in FIGURE 6, the flanges 60 and 56 are drawn toward each other by suitable clamps to place the resilient gasket 58 in compression, and the two flanges are then welded to each other by suitable welds 62.

As has previously been pointed out, the seal structures illustrated in FIGURES 6 and 7 and employed between the roof structure 40 and the side walls of the container 10 are suitable for use where the vapor pressures developed by the stored liquid are not large, and the need for a strong vapor seal at this point is accordingly reduced. Commensurate with this condition, the vapor-impermeable membrane 44 can be eliminated from the

inner surface of the insulation 42 which lines the roof structure 40 as is illustrated in FIGURES 6 and 7.

In another embodiment of the present invention, the wall structure of the container 10 is modified to provide more effective thermal insulation in the manner illustrated in FIGURE 8. In this embodiment, instead of employing a single liquid impermeable membrane 30 lining the side wall 14 of the rigid insulating material, two superimposed vapor impermeable membranes 70 and 72 are extended along the side wall 74 of a rigid outer shell, designated generally by reference character 76, and are spaced apart by a porous, relatively rigid insulating material 78. The lower edges of the membrane 70 and 72, and of the insulating material 78, are extended into a channel 80 positioned in grooves or troughs 81 formed in the bottom 82 of the rigid outer shell 76. The upper edges of the membranes 70 and 72 and the insulating material 78 positioned therebetween are extended into a channel 84 supported in a groove 85 which extends around the upper peripheral edge of the rigid outer shell 76.

A similar double membrane structure is provided for lining the bottom 82 of the rigid outer shell 76. The double membrane structure lining the bottom of the shell thus includes an upper membrane 86, a lower membrane 88 and a porous, relatively rigid insulating material 90 positioned between the two membranes. The peripheral edges of the membranes 86 and 88 and the insulating material 90 are extended into the channel 80 similarly to the membranes 70 and 72 and insulating material 78 used to line the side wall 74 of the shell 76.

A vacuum conduit 92 extends through the side wall 74 of the shell 76 and through the membrane 70 to facilitate exaction of the air filling the pores of the porous insulating material 78. A similar vacuum conduit 94 extends through the upper membrane 86 and along the side wall of the container to a position of accessibility adjacent the top of the container. By means of the vacuum conduits 92 and 94, the gas filled interstices of the porous insulation between the superimposed membranes can thus be evacuated to provide highly effective thermal insulation for the liquid stored in the container.

In order to prevent sublimation of the ice seals formed around the ends of the superimposed membranes as the space therebetween is evacuated, a relatively non-volatile, non-sublimable liquid which is immiscible with, and less dense than, water is initially placed in the channels 80 and 84 before filling the channels with water preparatory to forming the ice seals. This material can be selected from a number of suitable materials. For example, relatively high boiling, non-volatile hydrocarbons, such as petroleum waxes and the like, are suitable. As the channels 80 and 84 are filled with water, the non-sublimable liquid is displaced by the water by a difference of density and stratifies on top of the water. Then as the water is later frozen to provide the ice seals hereinbefore described, the protective layer of non-sublimable material is positioned on top of the ice as indicated by reference character 96 in FIGURE 8. The material thus forms a barrier preventing sublimation of the ice and consequent destruction of the integrity of the ice seals as the air between each of the pairs of superimposed membranes is evacuated.

It should be noted that if additional mechanical strength and thermal insulation is required, the superimposed membrane structure illustrated in FIGURE 8 can be used to line containers which are constructed with a thick layer of rigid insulation as illustrated in FIGURES 4 through 7. In other words, if the embodiments of the invention illustrated in the latter figures, the lining comprising superimposed or double layered membranes having an evacuated space therebetween can be used in place of the membranes 30 and 34 if more efficient thermal insulation is required. Any suitable type of roof structure can be used in conjunction with the open top container illustrated in FIGURE 8, and can include an in-

insulating lining of the evacuated double membrane type described.

The employment of the liquid impermeable membranes, the relatively inexpensive, yet rigid, efficient insulating material forming the side wall 14 and floor 16 of the container, and the outer metallic shell 12 permit the container 10 to be constructed much more economically than conventional fabricated containers of the type heretofore in use. Moreover, the container is of relatively light weight and can be made portable when relatively small volumes of liquid are to be stored. The roof structure 40 and membranes 30 and 34 of the container can be easily removed in disassembling the container, since both are retained in position primarily by the normally liquid seal structures heretofore described which, of course, are rendered inoperative when the temperature within the container rises above the freezing point of sealant material.

Although certain preferred embodiments of the invention have been hereinbefore described as exemplary of its practice and to provide guidelines for those desiring to practice the invention, the described and depicted structures do not constitute the exclusive means of practicing the invention, or the only form which it may take. Thus, the basic principles herein described may be embodied in other structures of different shape, constructed of different materials and used in slightly different ways than those to which specific reference has been made. Insofar as such modifications in structure and use are substantial equivalents of the embodiments of the invention described in the foregoing specification, it is intended that they shall be considered as circumscribed by the spirit and scope of this invention and by the appended claims.

What is claimed is:

1. A container for storing liquids at low temperatures comprising:

- a rigid outer shell;
- thermally insulating material lining said outer shell;
- a plurality of liquid impermeable membranes lining said thermally insulating material; and
- a frozen seal structure between said liquid impermeable membranes and preventing fluid flow between said membranes, said seal structure including
- a sealant material sealingly engaging portions of said membranes and having a melting point below about 25° C. and above the temperature at which said liquids are to be stored, and

trough means for retaining said sealant material in a substantially horizontal plane whereby said sealant material can be positioned for sealing engagement with said portions of the membranes by pouring the sealant material into trough means in liquid form.

2. A container as defined in claim 1 wherein said sealant material is water.

3. A container for storing liquids at low temperatures comprising:

- a rigid outer shell having a side wall and a bottom, and open at the top;
- thermally insulating material lining said outer shell and covering the side wall and bottom thereof;
- a liquid impermeable membrane overlying the portion of said insulating material covering the side wall of said shell and having a lower peripheral edge portion;

liquid impermeable membrane means overlying the portion of said insulating material lining the bottom of said shell and having a peripheral edge portion;

trough means in said insulating material adjacent the intersection of the portion of said insulating material covering the side wall of the shell and the portion of said insulating material covering the bottom of the shell, said trough means receiving the peripheral edge portions of said liquid impermeable membrane and said liquid impermeable membrane

means, and being adapted to retain a liquid in contact with said portions.

4. A container as defined in claim 3 and further characterized to include ice in said trough means sealingly engaging said peripheral edge portions.

5. A container as defined in claim 3 and further characterized to include a roof structure extending across and closing the top of said rigid outer shell; said roof structure including a rigid, thermally insulating material having an outer peripheral edge extending at least to the insulating material lining said rigid outer shell.

6. A container as claimed in claim 3 and further characterized to include a discharge conduit extending through the bottom of said shell and said thermally insulating material and sealingly engaging at its outer periphery said impermeable membrane means.

7. A container as defined in claim 3 wherein said liquid impermeable membrane means includes a plurality of juxtapositioned liquid impermeable membranes overlying, and collectively covering, all of the portion of said insulating material lining the bottom of said shell, and further characterized to include

seal means sealingly joining said juxtapositioned membranes and comprising

- a normally liquid, frozen sealant material sealingly engaging portions of each adjacent pair of said juxtapositioned membranes; and
- means for retaining said frozen sealant material in a fixed position relative to the insulating material lining the bottom of said shell.

8. A container as defined in claim 3 wherein said liquid impermeable membrane has an upper edge, and said container is further characterized as including

- a channel in the upper portion of the insulating material and receiving the upper edge of said liquid impermeable membrane; and

- a normally liquid, frozen material in said channel and engaging the upper edge of said liquid impermeable membrane.

9. A container as defined in claim 3 wherein said trough means comprises:

- a trough in the portion of said insulating material lining the bottom of said outer shell; and
- a channel in said trough and receiving said portions of said liquid impermeable membrane and said liquid impermeable membrane means and adapted to retain a liquid in contact with said peripheral edge portions.

10. A container as defined in claim 5 wherein said roof structure comprises:

- a rigid outer shell;
- a rigid thermally insulating material lining said outer shell; and
- a substantially vapor impermeable material lining said rigid, thermally insulating material.

11. A container as defined in claim 10 wherein said vapor impermeable material comprises a substantially vapor impermeable membrane.

12. A container as defined in claim 11 wherein said liquid impermeable membrane has an upper edge and said container is further characterized as including

- means for sealingly interconnecting the upper edge of said liquid impermeable membrane and said vapor impermeable membrane.

13. A container as defined in claim 12 wherein said means for sealingly interconnecting said membranes comprises

- trough means extending around said container in the upper portion of said first mentioned insulating material and receiving the upper edge of said liquid impermeable membrane and a portion of said vapor impermeable membrane; and
- sealant material in said trough means and sealingly engaging a portion of said membranes therein, said sealant material having a melting point below about

11

25° C. and above the temperature at which said liquids are to be stored.

14. A container as defined in claim 9 wherein said channel is of smaller cross-sectional area than said trough, and said trough means is further characterized to include

means spacing the walls of said channel from the walls of said trough to permit fluid flow around said channel and between the undersides of said liquid impermeable membrane and said liquid impermeable membrane means.

15. A container for storing liquids at relatively low temperatures comprising:

a rigid outer shell having sides, a bottom and an open upper end;

rigid, thermally insulating material lining said outer shell and having a side wall and a floor;

an upwardly opening channel for containing a liquid occupying a horizontal plane in said insulating material at the junction of said side wall with said floor and extending completely around the side wall;

a first liquid impermeable membrane lining the side wall of said insulating material and having a lower edge portion extending into said channel; and

a second liquid impermeable membrane lining the floor of said insulating material and having an outer peripheral edge extending into said channel.

16. A container as defined in claim 15 wherein said channel contains a solid material having a melting point below about 25° C., said solid material encasing and forming a seal with the edge portions of said first and second membranes which are extended into said channel.

17. A container as defined in claim 15 and further characterized as including seal means in the side wall of said rigid insulating material and around the open upper end of said outer shell, said seal means engaging said first liquid impermeable membrane and supporting said first membrane in a downwardly hanging relation thereto.

18. A container as defined in claim 16 and further characterized in including

means for by-passing fluid around said channel between spaces existing between said rigid insulating material and each of said membranes.

19. A container for storing liquids at temperatures below about 25° C. comprising:

a rigid outer shell having a side wall and a bottom;

a first pair of superimposed impermeable members forming a partial interior lining for said container and extending parallel to the side wall of said shell, said superimposed impermeable members each having an upper edge and a lower edge;

means spacing said first pair of superimposed members from each other;

means for evacuating the space between said first pair superimposed members;

a second pair of superimposed impermeable members forming a partial interior lining for said container and extending parallel to the bottom of said shell, the superimposed impermeable members in said second pair each having an outer peripheral edge;

12

means spacing said second pair of impermeable members from each other;

means for evacuating the space between said second pair of superimposed members; and

a frozen seal structure between said pair of superimposed impermeable members and preventing fluid flow between said pairs of superimposed impermeable members, said frozen seal structure including

a frozen sealant material sealingly engaging the lower edges of said first pair of superimposed impermeable members and the peripheral edges of said second pair of superimposed impermeable members, said sealant material having a melting point below about 25° C. and above the temperature at which said liquids are to be stored, and

means for retaining said sealant material in a substantially horizontal plane whereby said sealant material can be positioned for sealing engagement with said superimposed impermeable members by pouring the sealant material into said retaining means in liquid form.

20. A container as defined in claim 19 wherein said frozen sealant material is ice.

21. A container as defined in claim 20 and further characterized to include a channel around the upper portion of the side wall of said shell and receiving the upper edges of said first pair of superimposed members; and a normally liquid, frozen material in said channel and engaging the upper edges of said first pair of superimposed members.

22. A container as defined in claim 20 wherein said frozen seal structure is further characterized in including a material less sublimable than ice on the surface of the ice for deterring sublimation of the ice as the spaces between said first and second pairs of superimposed impermeable members are evacuated.

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