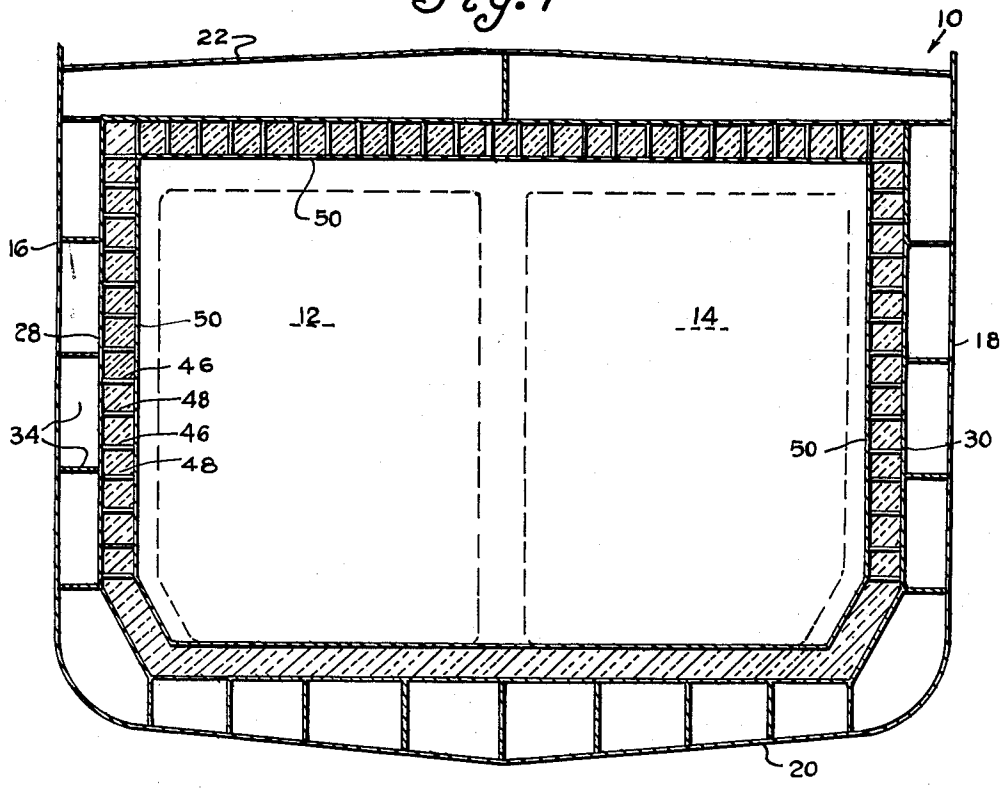
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INSULATED STORAGE TANK

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Fig. 1



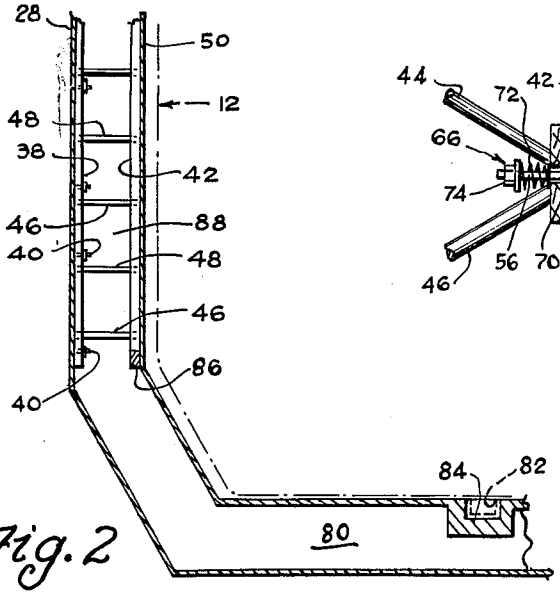




Fig. 2

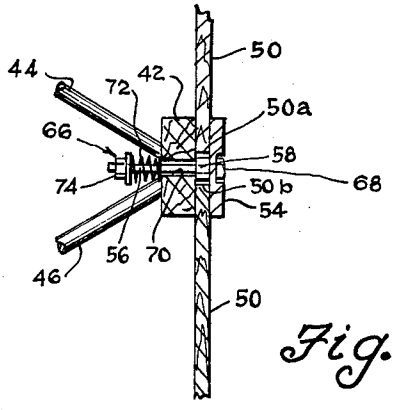



Fig. 3

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Fig. 4

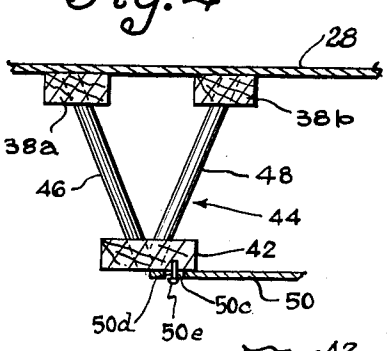






Fig. 5

Fig. 6

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3,104,025

# INSULATED STORAGE TANK

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This invention relates to an insulated structure for housing fluids and liquids having temperatures differing widely from ambient temperature and it relates more particularly to an insulated storage tank for housing a liquefied gas such as liquefied natural gas.

This invention will be described with reference to the ship transportation of liquefied natural gas in large volume from a source of plentiful supply to an area where natural gas deficiencies exist. It will be understood that the concepts described are not limited to the storage and transportation of liquefied natural gas but will have application to the storage and/or transportation of other extremely cold liquids and also to the land storage of such liquefied gases in large volume.

In the storage of a liquefied gas in large volume, it has been found to be impractical to construct a container wherein the liquefied gas is maintained under high pressure so as to enable the liquefied gas to be retained at ambient temperature. Thus, large capacity tanks for the storage or transportation of liquefied natural gas are designed for housing the material at about atmospheric pressure and preferably under slight positive pressure sufficient to minimize the danger of air being drawn into the tank.

At about atmospheric pressure, liquefied natural gas has a boiling point temperature within the range of —240° F. to about —258° F., depending upon the amount of heavier hydrocarbons present in the liquefied gas. Other liquefied gases have similar low boiling point temperatures such as —70° F. for carbon dioxide and a temperature of about —320° F. for air, nitrogen, helium and the like.

In order to reduce heat loss into the cold liquid to minimize vaporization during storage and transportation, it is desirable to provide a thermal insulating barrier between the ambient atmosphere and the liquefied gas. The capacity of the tank, the wide temperature differential and the effect of the cold on the metals employed in the ship structure and in the tanks present a number of complex and unique problems with respect to the construction of the insulated storage facility.

Steel plate ordinarily employed in the construction of a tank or the hull of a ship has been found to be incapable of use where the steel is exposed to a temperature below —100° F. because such metals lose their ductility and become embrittled at such temperatures. As a result, when the liquefied gas is to be transported or housed within the hull of a ship, it is desirable to house the liquefied gas in a separate tank or shell formed of a fluid impervious, temperature-insensitive material such as aluminum or alloys of aluminum, copper, stainless steel, or other austenitic steels which retain their ductility and strength at the low temperatures of the liquefied cargo. It is desirable also to insulate the container from the steel hull of the ship or the housing in which the separate storage tanks are arranged.

To the present, attempts have been made to make use of an insulation system which not only minimizes heat loss to the liquid and transmission of cold from the liquid to the steel walls of the ship but which also comprises a barrier to the passage of fluid in a manner to present a second line of defense which prevents the passage of the liquid into contact with the steel walls in the event of failure or escape of liquid from the separate insulated containers. For this purpose, use has been made of panels



of balsa wood or quippo joined one to another in sealing relationship across the inner surfaces of the ship structure defining the ship's hold to insulate the ship structure against the passage of liquid and in which a back pressure principle may be developed to militate against the penetration of liquid through the insulation to the steel wall of the ship. In the back pressure principle, penetration of the liquid will continue through the insulation layer until it reaches a point in the insulation where the temperature is at a level at which the liquid cannot remain in the liquefied state. Diffusion of the vapor that is formed in a direction back through the insulation layer is blocked by the wall of liquid penetrating into the insulation and diffusion in the opposite direction is blocked by the wall upon which the insulation is mounted. Thus the vapor is entrapped within the pores of balsa wood. If the permeability of the vapor through the pores is such as to prevent the escape of vapors at a rate faster than the vapors are being introduced from the liquid, a vapor pressure will build up to prevent further penetration of the liquid into the insulation layer thereby to maintain an insulated space.

While it is desirable to provide a second line of defense against penetration of the cold liquid to the steel walls of the ship, it has been found that the separate tanks can be constructed in a manner to avoid the escape of liquid such that the need for a costly second line of defense can be avoided. It therefore becomes an object of this invention to provide a less expensive insulated structure for use in the storage and transportation of cold liquids, such as liquefied natural gas.

A further object is to produce and to provide a method of producing an insulated structure of the type described which is formed of low cost and readily available materials and which can be installed in a simple and efficient manner to provide a low cost insulation system.

More specifically, it is an object of this invention to provide a system for the storage and transportation of extremely cold liquids wherein the insulation embodies low cost and readily available materials which can be advantageously combined for the safe and economical storage and transportation of liquefied natural gas.

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 ship embodying the features of this invention for the storage of liquefied gas in large volume in the insulated hold of the ship;

FIG. 2 is a cross-sectional elevational view of a fragmentary portion of the ship structure illustrating a preferred embodiment of the invention;

FIG. 3 is a sectional view showing a means for mounting the panels for independent movement within a supporting frame;

FIG. 4 is a sectional view taken along the line 4—4 of FIG. 5;

FIG. 5 is an elevational view showing a segment of the paneled insulating wall, and

FIG. 6 is a sectional view of a panel employed in the practice of this invention.

As shown in FIGS. 1 and 2, there is provided an insulated structure represented by a ship or barge **10**. The structure is provided with storage tanks **12** and **14** which, under conditions of use, may be filled with a liquefied natural gas. To insure that the tanks will be self-sufficient under the conditions existing when filled with the cold cargo liquid, it is desirable that the tanks **12** and **14** be constructed with sufficient wall thickness of a temperature-insensitive material such as aluminum and alloys of aluminum, copper, brass, stainless or other austenitic or

high nickel steels, which materials are capable of withstanding the cold temperatures without loss of strength or ductility as would otherwise characterize ordinary steel plate of which the ship's hull is constructed.

In the preferred practice of the invention, the ship or other transportation means is fabricated with an outer hull having side walls **16** and **18**, a bottom wall **20** and a top deck **22**. To protect the ship's hull from the cold of the liquid, while at the same time strengthening the ship, it is desirable to construct the ship with an inner hull spaced from the outer hull as presented by the walls **28** and **30**. A plurality of cross brace members **34** in the form of girders, I-beams and the like are secured to adjacent surfaces of the hull for purposes of strengthening the hull structure and also to define wing tanks therebetween.

Having briefly described the ship structure and the tanks mounted within the hold space of the ship, the latter of which is defined by the inner hull, reference will now be made to the concepts of this invention for mounting low cost insulation within the inner hull to provide an insulated hold space in which the tanks are mounted preferably without attachment directly to the ship structure so as to enable movement of the tanks relative to the ship in expansion and contraction while still stabilizing the position of the tanks within the insulated hold space.

The insulation section mounted adjacent the inner surface of the inner hull **28** and **30** comprises a plurality of vertically disposed, laterally spaced apart furring strips **38** secured, as by means of Nelson studs **40** or other conventional fastening means, to the inner hull. In a typical construction, the furring strips **38** will be in the form of two by four lumber arranged in pairs **39**$^{a}$ and **38**$^{b}$ on 3 foot centers with the two by four in each pair being about 12 inches apart.

Each pair of furring strips **38** is provided with a frame member **42** arranged midway between the furring strips and spaced inwardly therefrom. The furring strips and the frame members are interconnected by cross brace members **44**. Again, in a typical installation, the frame members will comprise two by six lumber spaced about 12 inches inwardly from the furring strips and connected thereto by the cross brace members illustrated as dowel pins **46** and **48** extending from the frame members to the furring strips at angles of about 67° with the face of the frame members. The cross brace members are vertically spaced apart on about 12 inch centers firmly to support the frame members in spaced parallel relation with the furring strips and the wall **30** and **28** on which they are mounted.

The frame members **42** are adapted to support thin panels **50** of a structurally strong and dimensionally stable, low cost material arranged in end-to-end and in side-by-side relationship to form a substantially continuous siding or wall defining the storage space in which the tanks **12** and **14**, etc. are mounted. It is preferred to make use of plywood panels, but use can be made of metal sheets, plastic sheets or combinations or laminates of metals, plastic and wood. The panels **50** are dimensioned to have a width corresponding to the spacing between the frame members. For example, in the illustrated modification, the panels **50** would have a width of 3 feet and a length of a conventional dimension such as 6, 8 or 12 feet. The lateral edges **50**$^{a}$ and **50**$^{b}$ of the panels are adapted to overlap the frame members to enable attachment thereto, as by nails, screws or the like, but it is preferred, because of the expansion and contraction problems due to extreme temperature change, to mount the panels as floating members free of the supporting frame members. For this purpose, as shown in FIGS. 4 and 5, the overlapping edge portions of the panels are formed with elongate, horizontally disposed slots **50**$^{c}$ slidably to receive studs **50**$^{d}$ which extend through the slot with a head **50**$^{e}$ at one end and secured to the frame member **42** at the other end. In another arrangement,



shown in FIG. 3, each frame member **42** is provided with a cover strip **54** secured as by means of a bolt and nut assembly **56** to the frame member with a spacer **58** in between to space the cover strip by an amount corresponding to the thickness of the panels **50** firmly to grip the edges of the panels between the cover strip **54** and the frame member **42**. Thus, the panels, which will be exposed to extreme temperature change of from about 80° F. when installed to about −250° F. when the tanks are filled with liquefied natural gas, will be free to move relative to the supporting structure in response to expansion and contraction but without becoming disengaged from the supporting structure.

For this reason, the frame members **42** and the facing strips **54** are deemed to have a width greater than the amount of contraction calculated to take place in the panels upon reduction in temperature so that the edges of the panels will, at all times, be retained between the frame members and cover strips, although the edges of the panels might be spaced one from the other in the assembly.

As illustrated in FIG. 5, similar cover strips **60** may be arranged to extend horizontally between the vertically disposed cover strips **54** with a vertical spacing between the horizontally disposed cover strips **60** corresponding to the lengths of the panels to overlap or cover the meeting edges of the ends of the panels. These horizontally disposed cover strips **60** can be secured, as by boiler plugs **62**, to the supporting walls **30** or **28**. The corner sections where the cover strips **60** and the cover strips **54** meet should be sealed off with a cover plate **64** more or less to conceal the joint and to provide some semblance of a temporary fluid barrier.

It is desirable resiliently to urge the cover strips in the direction frictionally to engage the surfaces of the edge portions of the panels disposed between the cover strips **54** and the frame members **42**. For this purpose, the spacer **58** would be of lesser thickness than the panels and tensioning means **66** would be introduced continuously to urge the cover strip **54** outwardly in the direction towards the frame member **42** to grasp the edge portions of the panels therebetween. One such resilient means illustrated in FIG. 3 comprises an elongate bolt member **56** having its head **68** received within a recess in the front face of the cover strip and wherein the bolt member extends slidably through an opening **70** in the frame member. The resilient means in the form of a spring **72** is positioned with one end bearing against a nut **74** on the end of the bolt while the other end bears against the back side of the frame member constantly to urge the bolt and the cover strip **54** in the outwardly direction.

Further to provide a barrier against the penetration of cold liquid through the formed siding, a thin membrane of metal, plastics, or other fluid and vapor impervious material, as represented by a film of aluminum, stainless steel, copper, polytetrafluoroethylene, polyesters, resinous treated plywood and the like can be incorporated as an inner ply and preferably as a face ply on the panels **50** and the sealing strips **54** and **60** or else as a continuous membrane covering the assembled panels. The feature of using an outer protective metal film is shown to best advantage by the numeral **76** in FIG. 6.

In a specific embodiment of the invention (see FIG. 2), use is made of a combination type of insulation construction wherein the bottom wall of the storage space is formed of a relatively thick layer **80** of thermal insulating material, preferably characterized by structural strength and dimensional stability, such as balsa wood panels or quippo. It is desirable to make use of insulation of this character for use in support of the tanks out of contact with the ship structure.

When a flooring of structurally strong and dimensionally stable material is employed, it is possible to incorporate therein means for stabilization of the position of the tanks while still permitting movement of the tanks relative to the ship structure responsive to expansions and

contractions in the metal container due to temperature change. One such stabilization means, illustrated in FIG. 2, comprises the use of keys **82** extending downwardly from the bottom wall of the tank in radial alignment with the center theerof as representative of the stabilized position for receipt in sliding engagement in corresponding keyways **84** provided in the surface of the insulated flooring. Such key and keyway construction stabilizes the position of the storage tank within the insulated space to obviate uncontrolled shifting movement of the tank responsive to the pitching and rolling movements of the ship or like housing while still leaving the tank free to expand or contract. When such flooring is employed, the lower edge of the lowermost panel **50** will be adapted to rest upon a horizontally disposed frame member **86**, such as a two by four or other strong structural material.

There will be a space **88** between the wall or siding formed of the panels **50** and the inner surface of the inner hull. Within this space **88** there is placed various types of low cost thermal insulating material adapted to insulate the hull of the vessel against the cold of the liquid in storage while, at the same time, minimizing the transfer of heat from the ambient atmosphere to the liquid in storage to cause vaporization thereof. The insulation used for insulating the space **88** can be selected of a large variety of materials, such as finely divided cork, vermiculite, silica powders, glass or rock wool insulation, diatomaceous earth and the like.

When a continuous membrane lining of a cold-resisting metal such as an aluminum alloy or stainless steel is laid over, and supported by, the assembled thermally insulated panels and insulated bottom wall, there results an insulated container for liquefied gases which necessitates no self-sufficient storage tanks such as storage tanks **12** and **14** described above. The membrane lining itself can act as the storage container, the weight of the liquid being taken by the insulated flooring and the assembled insulated panels.

It will be apparent from the foregoing that I have provided a simple and inexpensive construction for the efficient and economical insulation of a large storage space used for housing one or more tanks of large dimension for the storage of a material having a temperature differing widely from the ambient temperature. While no attempts have been made specifically to embody a second line of defense to hold back the transfer of liquid which might accidentally be released from the storage containers, it will be apparent that, in the construction defined, at least a temporary barrier will still be present to provide some factor of time in which to take care of any emergencies which might develop.

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 the construction of an insulated space of large dimension for housing one or more containers filled with a material having a temperature differing widely from ambient temperature, an enclosure defined by a bottom wall and vertically disposed walls, spaced apart furring strips fixed to the internal surfaces of the vertically disposed walls of the enclosure in which the furring strips are arranged in laterally spaced apart pairs with each of the furring strips in each pair being laterally spaced apart one from the other, frame members spaced inwardly from the furring strips and connected to the furring strips by cross brace members in which a frame member is provided for each of the pairs of furring strips and in which each frame member is connected to a pair of furring strips by horizontally disposed dowel pins extending outwardly from the frame members to the furring strips, thin panels of a structurally strong material arranged in end-to-end and in side-by-side relation and supported by the frame members to form a continuous siding in spaced relation with the enclosure walls to define a storage space for said containers, cover strips confronting the inner surfaces of the panels to overlap the adjacent edges and conceal any opening therebetween, and insulation material in the space between the siding and the enclosure walls.

2. An insulated structure as claimed in claim 1 in which the panels are dimensioned to have a width corresponding to about the spaced relationship between the frame members.

3. An insulated structure as claimed in claim 1 which includes means mounting the panels between the cover strips and the frame members but independent thereof for relative movement.

4. An insulated structure as claimed in claim 1 which includes cover plates disposed outwardly of the cover strips and dimensioned to cover the meeting intersections thereof.

5. An insulated structure as claimed in claim 1 which includes a continuous membrane of a fluid and vapor impervious material present as a lamina of said panels.

6. An insulated structure as claimed in claim 1 which includes a fluid and vapor impervious membrane covering the assembled panels and cover strips.

7. An insulated structure as claimed in claim 1 in which the bottom wall of said structure is formed of a relatively thick layer of a structurally strong and dimensionally stable thermal insulating material.

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