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[54] **MARINE TRANSPORTATION OF LIQUEFIED GASES**
12 Claims, 3 Drawing Figs.

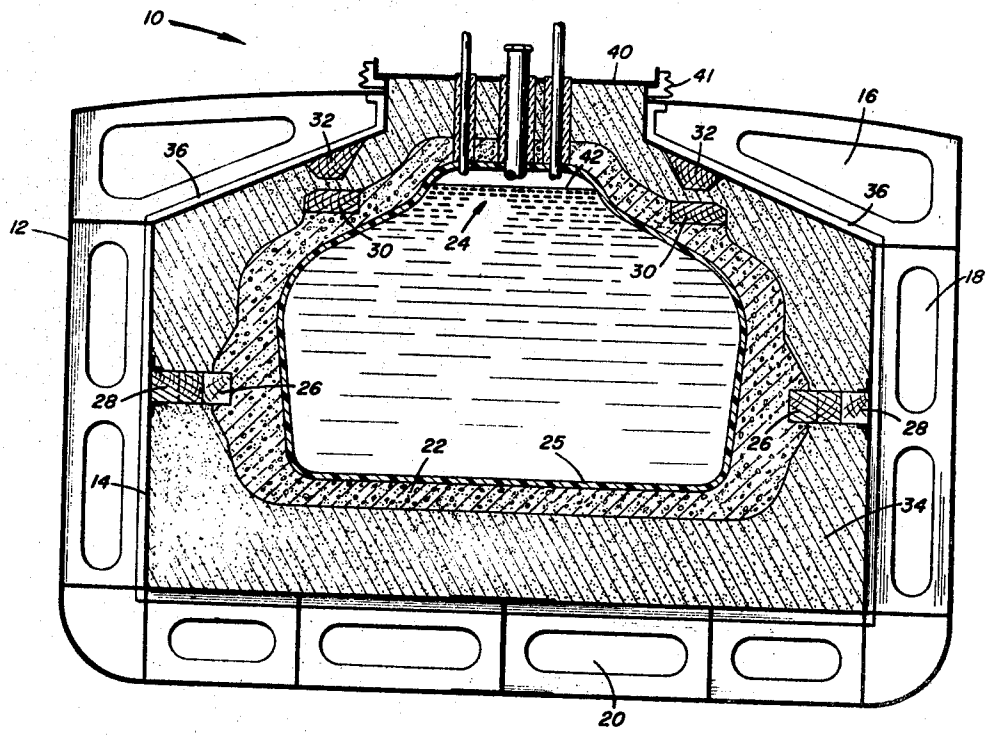
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[50] Field of Search ..... 114/74, 74 (A); 220/9, 9 (A1), 15

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ABSTRACT: A ship of simplified construction for the marine transportation of liquefied gases at cryogenic temperatures is equipped with at least one concrete tank. In a first embodiment, the concrete tank is surrounded by a layer of sand. A second embodiment contemplates both a layer of sand surrounding the concrete tank and a further layer of insulating material within the tank. In a third embodiment, a layer of insulating material is provided within the concrete tank. A fourth embodiment of the invention relates to a concrete tank surrounded by a layer of insulating material which abuts the hull of the ship. And in a fifth embodiment of the invention, the entire hull of the ship is concrete and forms at least one containment tank. In the fifth embodiment, there may be provided a layer of insulating material within each tank.



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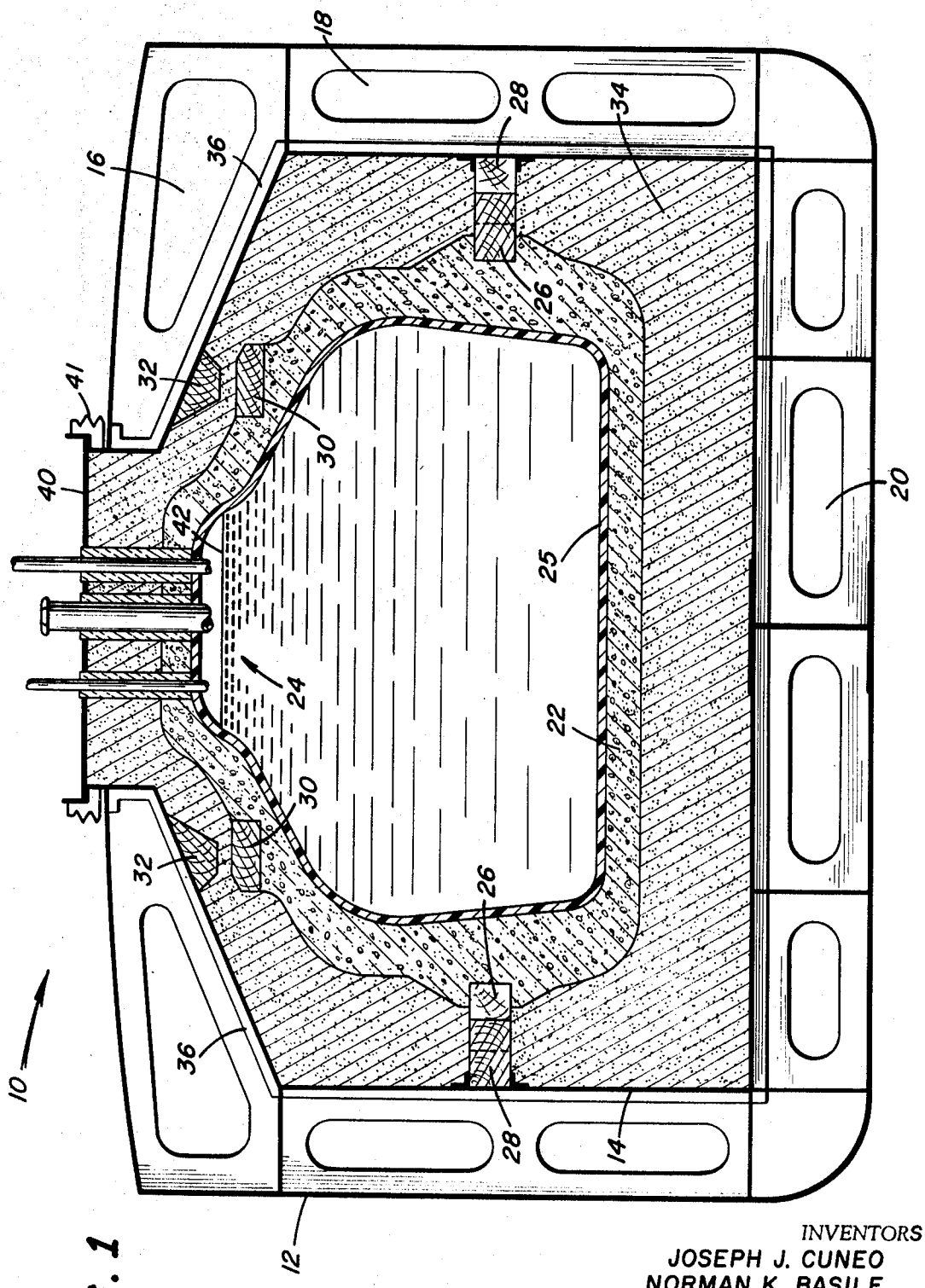


FIG. 1

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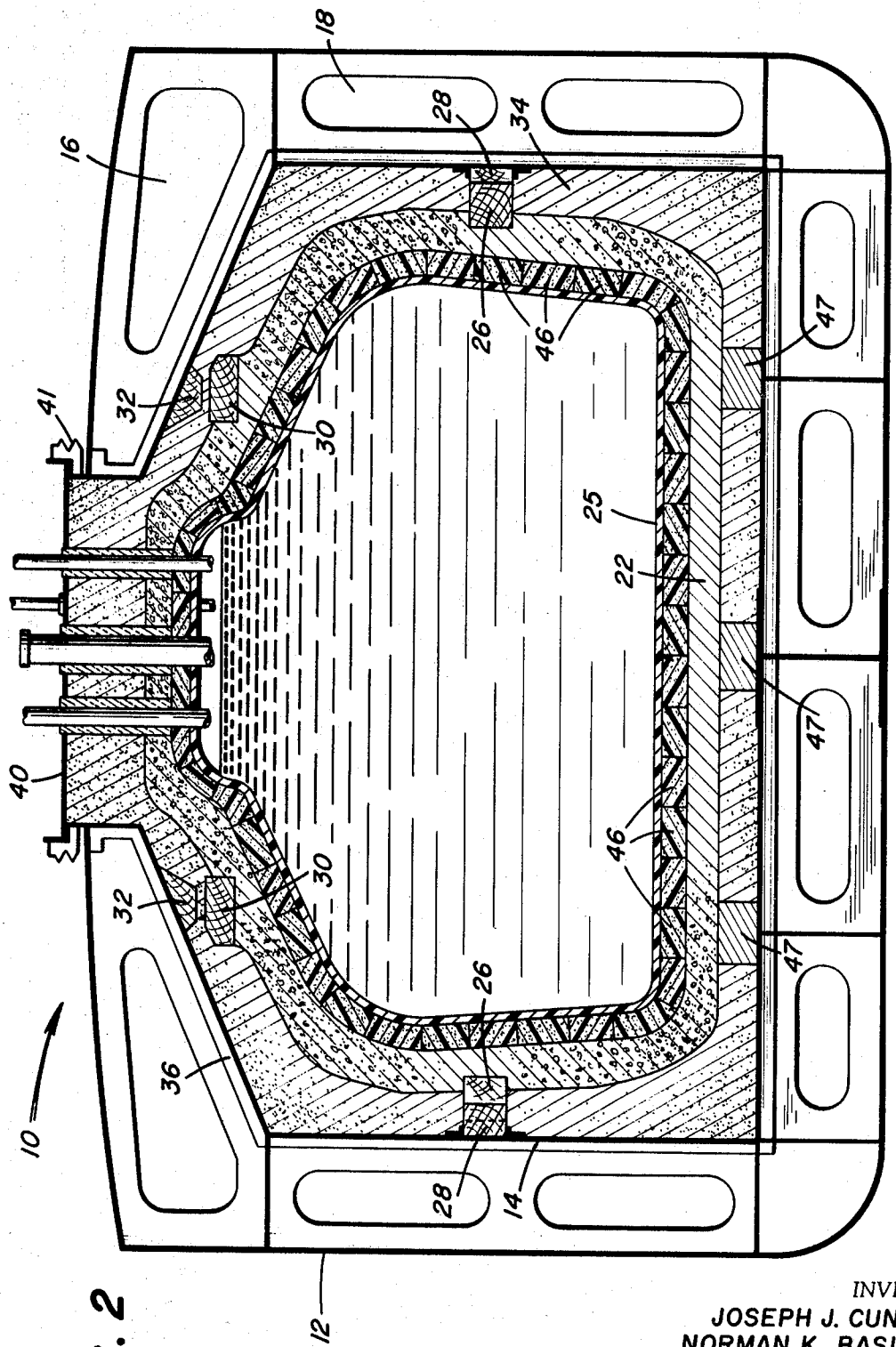


FIG. 2

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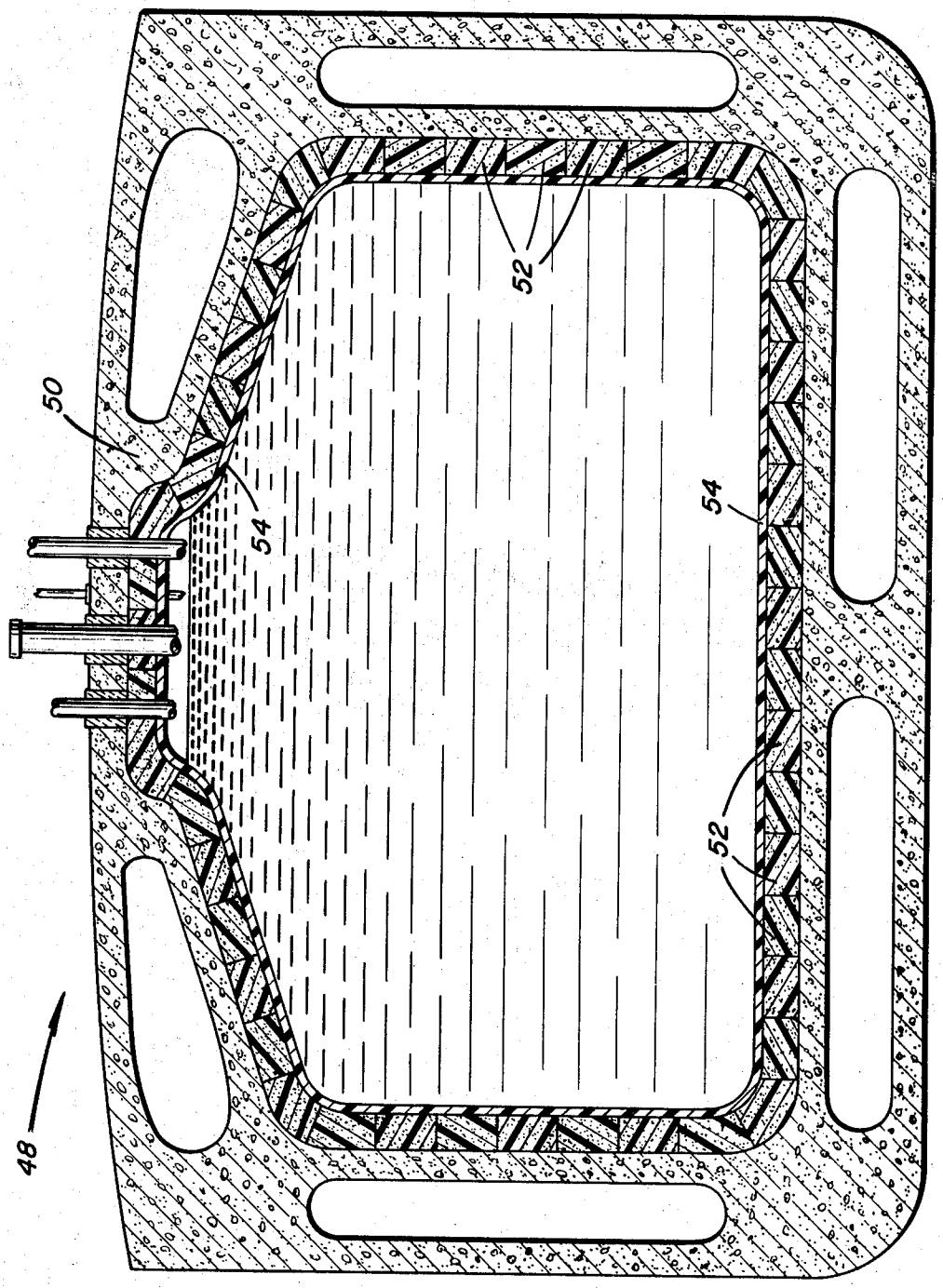


FIG. 3

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MARINE TRANSPORTATION OF LIQUEFIED GASES

BACKGROUND OF THE INVENTION

In the field of transporting liquefied materials at cryogenic temperatures (of the order of −250° F.), many problems present themselves. It is well known that carbon steel, used extensively in ship building, is relatively weak at cryogenic temperatures. Therefore, the transportation of cryogenic material must be done in such a manner that the carbon steel hull of the ship is protected from the low-temperature material transported thereby.

In the past, tanks having double barrier construction have been positioned within the hull of the ship and have been used to transport cryogenic material. These tanks have necessarily been made of materials other than carbon steel in view of the strength properties of this steel at low temperatures. Specifically, these tanks have been designed of nickel-steel or aluminum alloys and have served, quite effectively, for cargo containment and for protecting the hull of the associated ship from exposure to extremely low temperatures. The double barrier construction is employed so that if the inner barrier should fail, due to faulty welds, overstress or other causes, there remains a second barrier to contain the cargo and prevent exposure of the ship's hull to the extremely low-temperature material housed in the container.

While the double barrier nickel-steel or aluminum alloy tanks have been quite satisfactorily employed in the past, there are certain disadvantages which are associated therewith. Particularly, a major disadvantage is that materials of the nickel-steel and aluminum alloy varieties tend to be quite costly. Further, the double barrier tank tends to be somewhat complex in its construction and also tends to be adversely affected by thermal stress caused by nonuniform cooling thereof. And still further, while it is thought to be improbable, it is always possible that both of the walls of the double barrier construction would fail, thereby exposing the hull of the vessel to the cryogenic temperature of the transported material.

SUMMARY OF THE INVENTION

The present invention relates to the concept of transporting cryogenic fluids, such as methane, nitrogen, oxygen, and the like, at approximately saturation temperatures corresponding to atmospheric pressure within one or more steel reinforced concrete tanks contained within the hold of the ship. It is contemplated that large bulk quantities, up to approximately 50,000 tons, be transported.

By storing the cryogenic fluid in a concrete tank, many advantages result. Particularly, the concrete tank has excellent strength properties at cryogenic temperatures. Therefore, the problem involved in the prior art, namely the concern with the container material becoming brittle and weak at cryogenic temperatures, is avoided.

It is therefore one object of the invention to provide a chamber for the transportation of cryogenic material, which chamber is extremely strong at cryogenic temperatures.

In view of the fact that the concrete tank exhibits superior strength properties, the construction of the ship may be simplified.

It is therefore another object of the present invention to provide a ship which is relatively simple in construction and which effectively serves to transport cryogenic material.

While the concrete tank partially serves to insulate the cryogenic temperature of the transported material from the hull of the ship, additional insulation may be advantageous. It is therefore contemplated that an insulating space be provided between the concrete hull of the ship and that this insulating space be filled with an insulating material such as dry sand. This arrangement forms the first embodiment of the present invention. To ensure that the cryogenic material housed within the concrete tank does not escape from said tank, it is contemplated that there be provided a liquid and gas impervious liner on the inner wall of the tank.

It is therefore a further object of the invention to provide a system for transporting a cryogenic material in an oceangoing vessel which serves to safely house the material while efficiently isolating the cryogenic temperature associated with the material from the hull of the ship.

It should here be noted that the layer of dry sand serves additional functions. The sand serves to support the concrete tank so that the tank is prevented from shifting within the hold of the ship. Also, the sand serves to minimize the structural requirements of the tank. By providing a layer of sand, the sand static head balances the static and dynamic forces associated with the cargo and serves to transmit these forces to the structure of the ship.

It is therefore an additional object of the invention to provide a system for transporting cryogenic material in an oceangoing vessel in such a manner that the containment tank is fixed within the hold of the ship and is not subjected to excessive static and dynamic forces form the transported material.

While, in most instances, the invention as described above will prove adequate for insulating the hull of a ship from the cryogenic temperature of the material transported thereby, there are instances, such as those wherein the ambient temperature is extremely low, wherein further means may be provided for maintaining the hull of a ship at relatively elevated temperatures. It is therefore contemplated by the present invention that there be formed a series of channels associated with the hull of the ship, channels which are conveniently formed by stiffener members, for conducting warm fluid therethrough. This fluid can be of many types, such as hot water, oil, or antifreeze fluid.

It is therefore a further object of the present invention to provide positive means for maintaining the hull of the ship at relatively elevated temperatures.

There are instances wherein the cargo volume of a vessel for transporting cryogenic material is an extremely important factor. It is therefore the desire to provide means for increasing the cargo volume of such a vessel without necessitating an increase in the size of the associated ship.

Along the lines of the preceding paragraph, it should be noted that one function of the sand layer intermediate the concrete container and the hull of the ship is to insulate the hull from cryogenic temperatures. It is therefore contemplated by the present invention that this sand layer be reduced in width, or removed, and be supplemented by, or replaced by insulating means having insulating properties superior to sand.

It is well known that polyurethane is a better thermal insulator than is sand. Therefore, a given width of polyurethane is more effective than a corresponding width of sand. By using polyurethane blocks as an insulating medium, as a substitute for, or in addition to the sand layer, the cargo volume of the fluid-containing vessel may be increased.

Therefore, in addition to the first embodiment of the invention, wherein the concrete tank is surrounded by a layer of dry sand, additional embodiments of the present invention are contemplated. These embodiments employ insulating systems of the foam block variety and are three in number.

In the second embodiment of the present invention, it is contemplated that a layer of dry sand be supplied between the concrete tank and the hull of the ship and also that a layer of insulating material such as, for example, a layer of polyurethane blocks, be provided on the inner wall of the concrete tank. In this manner, both the sand and the polyurethane serve to insulate the hull of the ship from the cryogenic temperature associated with the transported material.

In the third embodiment of the present invention, the sand layer is entirely replaced by a series of polyurethane insulating blocks lining the inner wall of the concrete tank. In this mode, it is necessary that there be provided a set of foundations for supporting the tank; while in the first and second modes, the sand itself could perform this supporting function.

In the fourth embodiment of the invention, the sand barrier is entirely replaced by a series of polyurethane insulating blocks, these blocks, rather than lining the inner wall of the tank, lining the hull of the ship. Here again, foundation blocks are necessary to support the tank.

It should be noted that when the cryogenic material is separated from the concrete tank by an insulating layer, there is a reduction of thermal stress in the walls of the concrete tank.

It should also be noted that while the exclusive use of polyurethane blocks is extremely efficient, the exclusive use of sand is far less expensive. Therefore, an economic balance must be drawn between the high-insulating properties of polyurethane and the low-cost property of sand. In this In this manner, the ratio of layer thicknesses may be determined.

It is therefore another object of the present invention to provide a concrete tank for the transportation of cryogenic material, wherein said tank is of maximum dimensions.

It is a further object of the invention to provide a concrete tank for the transportation of cryogenic material, wherein said tank receives a minimum of stress from said cryogenic material.

In still a fifth embodiment of the present invention, it is contemplated that the entire hull of the ship be constructed of reinforced concrete. By so constructing a ship, the entire hull is of a material having excellent strength properties at cryogenic temperatures and the hold containment serves as a natural second barrier. Consequently, there is no need for sophisticated ship construction.

It is therefore still another object of the invention to provide a ship for the marine transportation of cryogenic material, said ship being of simplified construction.

In accordance with the latter embodiment of this invention, it is contemplated that the inner wall of the concrete hull, that forming the tank, may be provided with a set of polyurethane insulating blocks. In this manner, there is an insulation between the cryogenic material and the concrete hull, and thus there is a reduction in the thermal stress experienced by the hull.

It should be noted that in each of the above-noted embodiments of the present invention, it is contemplated that there be provided a gas and liquid impervious nonstructural liner positioned intermediate the tank and the cryogenic material. This liner may be made of any material which is liquid and gastight at cryogenic temperatures and which remains impervious to the particular cargo being transported. An example of such a material is polyethylene.

From the above, it is evident that the present invention solves many of the problems which plague the prior art. A concrete tank is used to house cryogenic material. This tank has properties making it extremely strong at cryogenic temperatures, and consequently, the construction of the associated ship is substantially simplified.

The concrete tank is lined with a liner made of a material which is both gastight and liquidtight at cryogenic temperatures. Thus, the liner forms a first barrier to the passage of the cryogenic material from the tank. The tank itself forms a temporary second barrier.

The invention further contemplates the use of an insulating system formed of either sand or blocks of insulating material, or both.

In addition to the above, the present invention also contemplates an all-concrete ship. In this manner, cargo containment is extremely safe—the entire ship is of a material resistant to cold. Thus, many of the backup systems become unnecessary, and the construction of the ship is simplified.

The above-enumerated objects of the invention as well as many of the attendant advantages thereof will become more readily apparent when reference is made to the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view through the hull of a ship adapted for transporting cryogenic material and constructed in accordance with the first embodiment of the present;

FIG. 2 is a cross-sectional view through the hull of a ship constructed in accordance with the present invention and serving to illustrate additional embodiments of the invention; and

FIG. 3 is a cross-sectional view through a vessel constructed in accordance with a further embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

With reference first to FIG. 1, illustrating the first embodiment of the present invention, a ship for transporting cryogenic material is shown generally at **10** and comprises an outer hull **12** and an inner hull **14**. Intermediate the two hulls **12** and **14** are upper wing ballast tanks **16**, side ballast tanks **18** and bottom ballast tanks **20**. The inner and outer hulls are connected and structurally reinforced, both in the longitudinal and transverse directions, by conventional framing techniques.

Located within the inner hull **14**, and spaced therefrom, is a reinforced concrete tank **22**. The upper region of the concrete tank **22** is formed in such a manner that the tank is inclined toward the centerline, or, put another way, is in the shape of a bottleneck **24**. It should be noted here that numerous concrete tanks of varying dimensions may be employed in a single ship; therefore, total container requirements can always be met. The tank **22** is provided with a series of pipes for filling and emptying the tank, for venting and for the performance of other conventional functions.

The concrete tank forms a volume in which fluid at cryogenic temperatures may be housed. Forming a barrier between the inner wall of the tank **22** and the cryogenic material is a gas and liquid tight flexible liner **25** which may be, for example, of polyethylene.

The tank **22** is provided with two-chock systems. A conventional series of chock pairs **26, 28** is distributed around the surface of the tank on fixed geometric centerlines to restrain the tank from longitudinal and transverse movement while permitting the tank to expand and contract relative to the structure of the ship about these fixed geometric centerlines. If the space **34** is filled with sand, chock pairs **26, 28** are optional because the sand will perform the same function. The second chock system consists of conventional buoyancy chock pairs **30, 32**. The buoyancy chocks are also optional.

Intermediate the concrete tank **22** and the inner hull **14** is a layer of heavy material which may be, for example, dry sand. Sand has been found well suited to meet the needs of the present invention since it is an effective support and insulator and since it is relatively inexpensive.

The functions of the sand are numerous. Particularly, the sand acts to transmit the static and dynamic forces of the cargo stored in the concrete tank **22** to the structure of the ship **10**. As a consequence, the tank design load may be minimized. Further, the sand functions as an insulator serving to isolate the cryogenic temperature of the transported material from the hull of the ship. Also, the thickness of the sand layer in the space **34** functions to regulate the boiloff rate of the material within the concrete tank. And finally, the sand in the space **34** ensures that the tank **22** is held firmly in position relative to the vessel **10**.

It is quite common in ships to provide stiffeners for reinforcing the hulls thereof. These stiffeners can be designed so as to form channels, such as that indicated at **36**, adjacent the inner hull **14**. It is contemplated by the present invention that channels **36** be used as conduits for fluid serving to heat the hull **14** at times when the ambient temperature is relatively low. Such use of the channels **36** ensures that the steel hull **14** is maintained at a temperature above that near which the structure of the steel becomes weakened. Naturally, when the ambient temperature is not dangerously low, the stiffener circulation system would remain idle.

The tank **22** is sealed but for a plurality of pipes provided at its upper region. These pipes serve many well-known functions, such as tank loading, tank unloading, venting, etc. It is contemplated that they be provided in such a manner that the

cryogenic liquid housed within the tank, the fully loaded level of which is shown at 42, be maintained at a predetermined pressure (usually between 1 and 4 p.s.i.g.).

It will be noted that the layer of sand covers the top of the tank 22. Thus, the cryogenic temperature of the transported material is insulated from the external environment. It will also be noted that the sand which covers the tank 22 is itself covered by a hatch cover 40. This hatch cover is constructed in a well-known manner and is secured in place by a conventional gas and liquidtight expansion joint 41. To ensure insulation between the external environment and the cryogenic temperature of the transported material, the pipes emergent from the tank 22 are insulated, in a well-known manner, from the hatch cover 40.

In operation, the unloaded ship 10 is prepared for loading by the controlled admission of cargo into the tank 22. The boiloff resulting from the cool-down operation is removed from the tank 22 by means of the tank vent pipe.

At the conclusion of a voyage, the liquid housed in the concrete tank 22 is removed. However, a small portion of liquid (between 2 percent and 6 percent of the internal depth of the tank) is allowed to remain in the bottom of the tank 22 to maintain the tank in a cooled state. In order to compensate for the loss of weight due to the removal of the cryogenic fluid, the ballast tanks 16, 18 and 20 can be filled with water.

As noted above, a small portion of the cryogenic liquid is allowed to remain in the tank 22 after the tank has been unloaded. The reason for this is twofold. First, the presence of liquid in the tank in a cooled condition. Therefore, when the tank 22 is refilled, to begin a new voyage, the problem of gasification, common when a warm tank is filled with cryogenic fluid, is avoided. And second, if the liquid in the tank is methane, a sufficient amount thereof may be retained to permit the use of the boiloff as a portion of the propulsion fuel for the vessel 10.

As also noted above, the top of tank 22 is tapered. By so shaping the tank, the free surface area is reduced and thus the adverse free surface effect on ship stability is minimized.

There are situations in the field of marine transportation wherein volume utilization is of ultimate importance. It is therefore necessary, in many cases, to provide a container tank having maximum volumetric dimensions. FIG. 2 is illustrative of a tank having excellent volume capabilities.

With reference now to FIG. 2, wherein like elements are similarly referenced, the second, third and fourth embodiments of the present invention are described. The ship is shown at 10 and has an outer hull 12 and an inner hull 14. Again, the ship 10 is provided with a concrete tank 22 which is spaced from the inner hull 14.

In the second embodiment of the present invention, the entire inner surface of the concrete tank 22 is provided with blocks of insulating material such as polyurethane blocks 46, and the inner surface of these blocks 46 is covered by a liquid and gastight liner, such as a polyethylene liner 25. The space 34 is filled with dry sand. This second embodiment of the present invention combines the advantage that sand is relatively inexpensive with the advantage that polyurethane is an excellent thermal insulator. It is contemplated that the respective widths of the sand layer and the polyurethane insulation system be determined by economic considerations. It should be evident that this embodiment of the invention, as shown in FIG. 2, permits excellent utilization of the hold cubic and permits a large tank volume. Also, the concrete tank is insulated from the cryogenic material.

The concrete tank of FIG. 2, due to the fact that a portion of the sand support system has been removed, may be provided with a set of conventional wooden foundation blocks 47. These blocks 47 serve to transmit the vertical loads caused by the cargo tank itself and the material which it houses to the bottom structure of the ship.

In the third embodiment of the present invention, it is contemplated that a system of insulating blocks 46 serves as the sole means for insulating the cryogenic temperature associated with the transported material from the hull of the ship. The blocks 46, in this embodiment, entirely cover the inner wall of the tank 22. A liquid and gas impervious liner 25 is also provided, this liner covering the inner surface of the insulating block system. It should be evident that this embodiment provides for excellent use of the hold cubic and permits a large tank volume. Also, the concrete tank is insulated from the cryogenic material. In this embodiment, it is necessary that foundation blocks 47 be provided.

There are numerous instances in which it is desirable to provide access to the containment tank. In this manner, the tank is available for inspection, servicing and other operations. Consequently, the fourth embodiment of the present invention contemplates appending the insulating blocks directly to the inboard side of the ship's hull. Within this insulating block system is located the concrete tank of the present invention, the inner wall of this tank being lined with a liquid and gastight liner. Since in the fourth embodiment of this invention no sand is provided, it is necessary that there be provided conventional foundation blocks to support the tank.

As noted above, there is a fifth embodiment of the present invention, this embodiment being depicted in FIG. 3 and relating to a simplified ship whose entire hull structure is of concrete. More particularly, and with reference to FIG. 3, there is shown a vessel 48 having a hull 50 made entirely of steel reinforced concrete. Within the reinforced concrete hull 50 is a polyurethane block insulation system 52. There is also provided a gas and liquidtight liner 54 of polyethylene which forms a seal between the polyurethane system 52 and the liquid within the hollow of the hull 50. This concept permits maximum utilization of the internal cubic of a vessel and presents the most simplified construction for a system adapted to transport cryogenic fluids. Again, as in the embodiments shown in FIGS. 1 and 2, there are provided a series of side, bottom and upper wing ballast tanks for ballasting the ship during the unloaded leg of its voyage.

In view of the substantial quantities of materials to be transported and in view of the temperatures of these materials, it may be desirable to prestress the concrete tanks constructed in accordance with the present invention. This may be simply accomplished by preloading the reinforcing rods in tension during tank construction.

While the present invention has been described with particular reference to the figures, it should be noted that the above description is given for illustrative purposes only, and that it is the intent that the present invention not be limited thereto, but only be limited as set forth in the appended claims.

We claim:

1. A ship system adapted for the marine transportation of liquefied gas at substantially cryogenic temperature and atmospheric pressure, and including: a steel hull; at least one concrete tank permanently located within, spaced from, and capable of contracting and expanding independent of said hull, said tank being for the containment of liquefied gas; liquid and gas impervious liner means for physically isolating said liquefied gas from the hull of the ship; and insulation means for thermally isolating said liquefied gas from the hull of the ship.

2. The invention as recited in claim 1, wherein the space between the concrete tank and the hull of the ship is filled with dry sand.

3. The invention of claim 2, wherein said liquid and gas impervious liner means isolates the liquefied gas from the inner wall of said tank.

4. The invention as set forth in claim 2, wherein said tank is shaped such that its upper region, relative to its lower region, is tapered about its centerline.

5. The invention recited in claim 2, and further comprising means for limiting the motion of said concrete tank within the hull of said ship.

6. The invention of claim 2, and further comprising means for positively heating the hull of said ship.

7. The invention as set forth in claim 3, wherein said insulation means is positioned intermediate the inner wall of said tank and the liquid and gas impervious liner.

8. The invention recited in claim 7, wherein said insulation means abuts the inner wall of said tank and wherein the liquid and gas impervious liner abuts the inner surface of said insulating means.

9. The invention as recited in claim 2, wherein said insulation means is located in the space between the concrete tank and the hull of the ship.

10. The invention recited in claim 9, wherein said insulation means abuts the hull of said ship and wherein the liquid and gas impervious liner abuts the inner wall of said concrete tank.

11. The invention recited in claim 1, wherein said ship is provided with a plurality of holds within its hull for housing a plurality of concrete tanks.

12. The invention as recited in claim 1, wherein said insulating material is polyurethane and wherein said liquid and gas impervious liner is polyethylene.