July 28, 1959 J. J. HENRY 2,896,416

MEANS FOR THE TRANSPORTATION AND STORAGE OF COLD BOILING LIQUEFIED HYDROCARBON GAS

Filed Aug. 5, 1957

3 Sheets-Sheet 1

FIG. 1

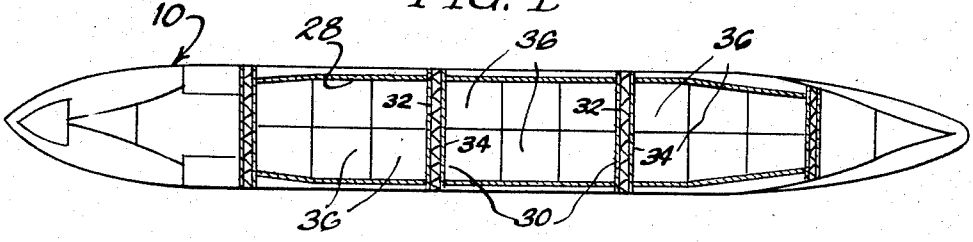
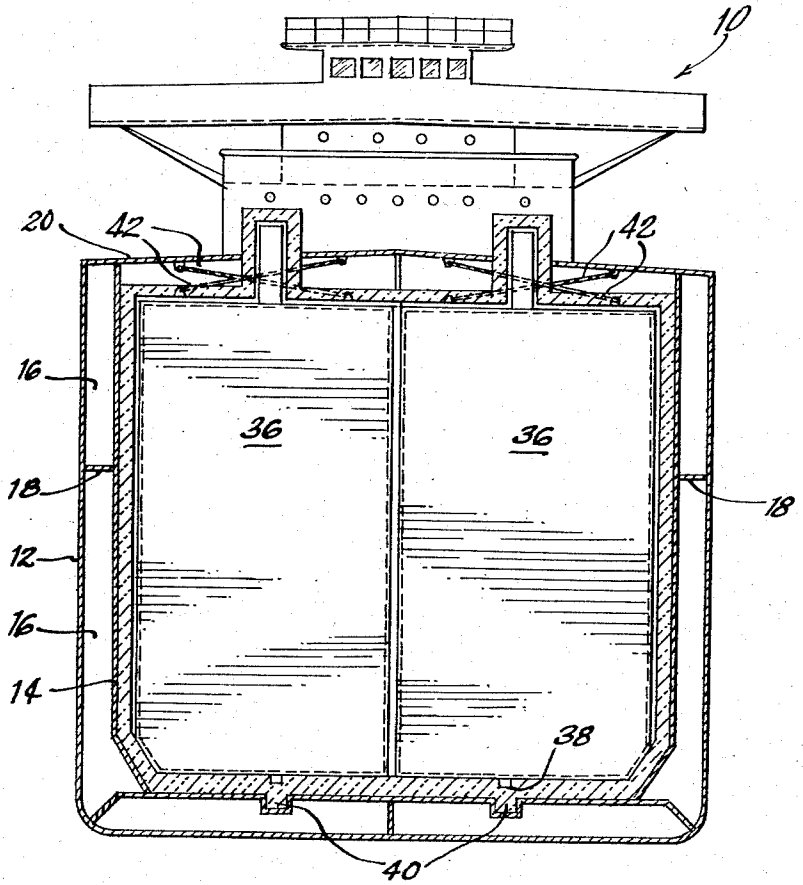


FIG. 2



INVENTOR.
James J. Henry
BY
Dorn, McDougall, Williams & Kerch
Attorneys

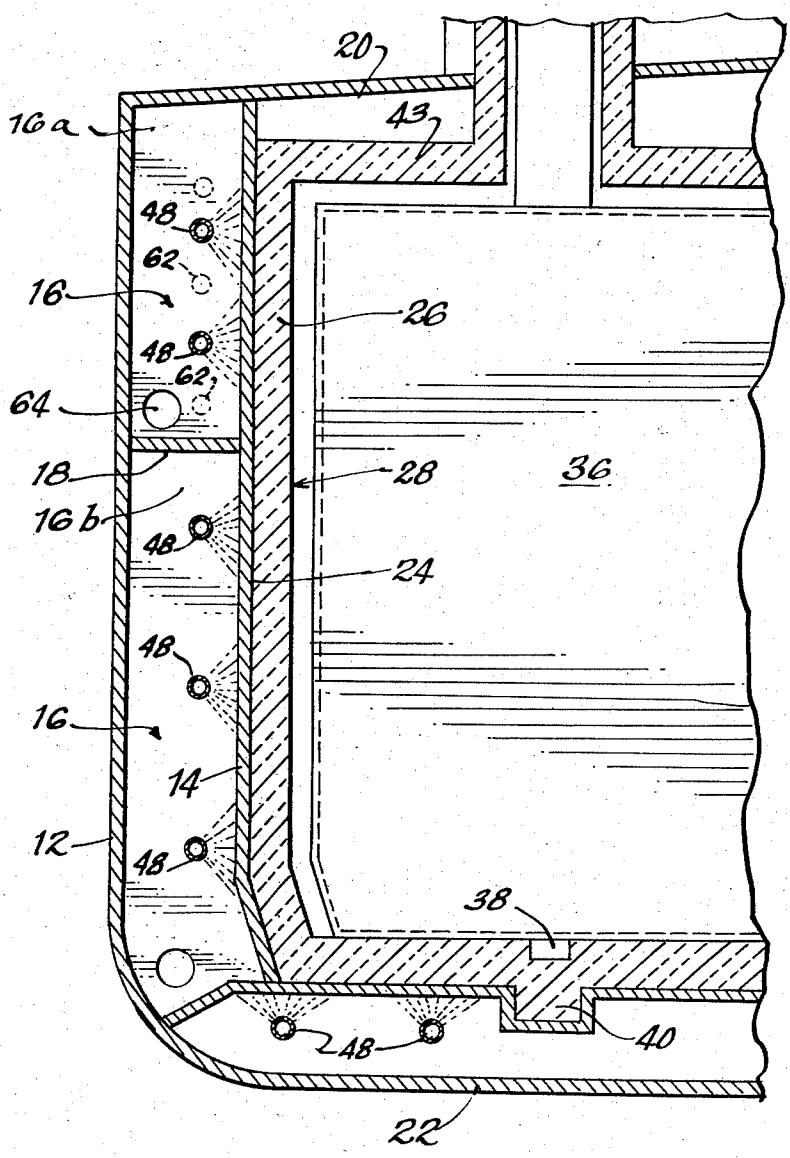
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3 Sheets-Sheet 2

FIG. 3



INVENTOR.
James J. Henry

BY
Dorne, McDougall, Williams & Kerek
Attorneys

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MEANS FOR THE TRANSPORTATION AND STORAGE OF COLD BOILING LIQUEFIED HYDROCARBON GAS

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FIG. 4

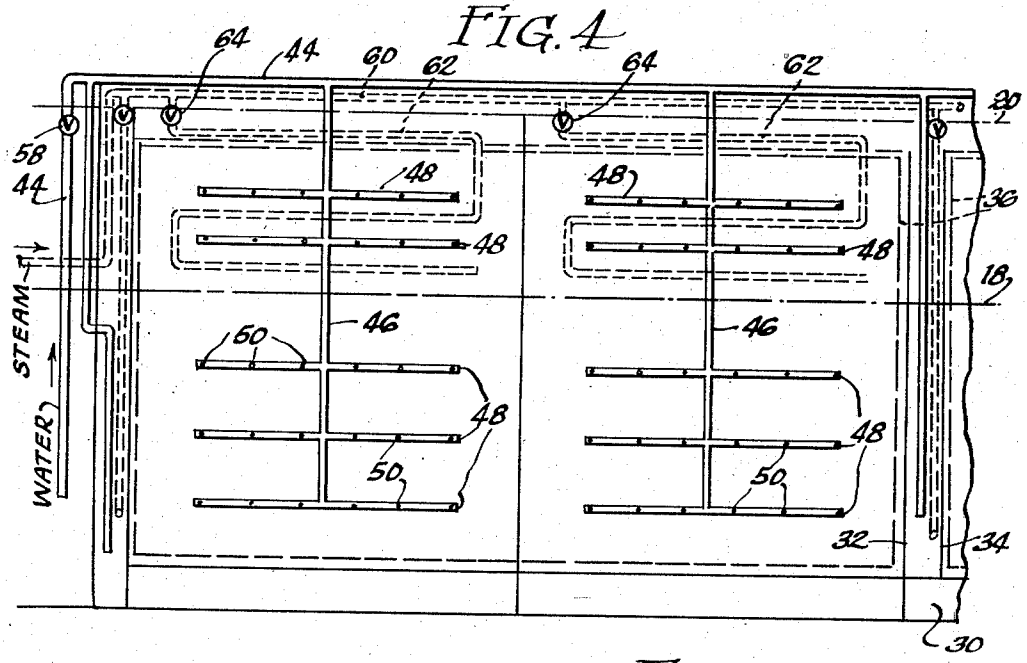


FIG. 5

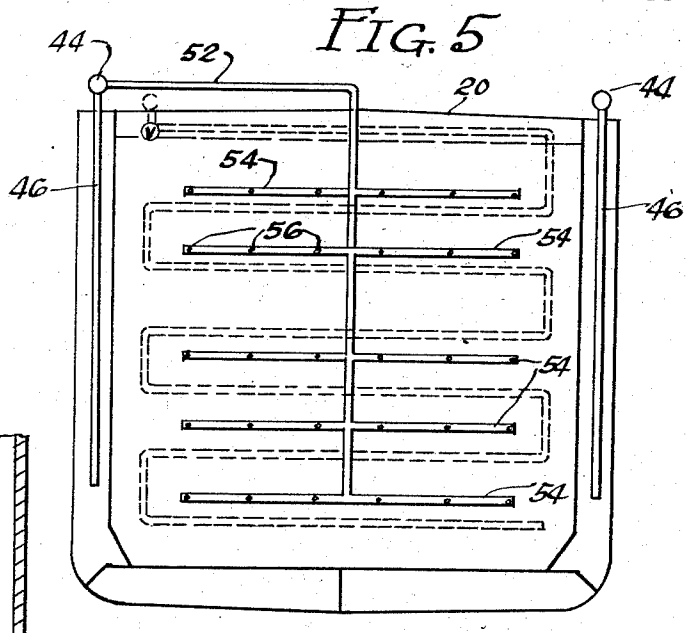
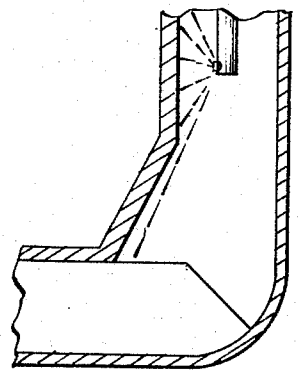


FIG. 6



INVENTOR.
James J. Henry
BY
Toms, McDougall, Williams & Hersh
Attorneys

United States Patent Office 2,896,416 Patented July 28, 1959

2,896,416

MEANS FOR THE TRANSPORTATION AND STORAGE OF COLD BOILING LIQUEFIED HYDROCARBON GAS

James J. Henry, New York, N.Y., assignor to Constock International Methane Limited, Nassau, Bahamas, a corporation of Bahamas

Application August 5, 1957, Serial No. 676,158

12 Claims. (Cl. 62—45)

This invention relates to the storage and transportation of a liquefied gas having a boiling point below —40° F. at atmospheric pressure. It relates more particularly to the construction and operation of storage tanks on ship for the water transportation of such low boiling liquefied gas.

In the preferred concept of this invention, means are provided for the storage and transportation of a liquefied hydrocarbon gas and particularly liquefied natural gas composed mostly of methane and having a boiling point in the range of —240° F. to —258° F. at atmospheric pressure, depending upon the amount of higher boiling hydrocarbons present in a sweetened gaseous composition. While the invention will hereinafter be described with reference to the handling of liquefied natural gas or methane, it will be understood that the concepts described in tank construction and in ship construction will have application to use with other liquefied low boiling gases such as propane, ethane, nitrogen, hydrogen, helium and the like hydrocarbon and non-hydrocarbon gases, and that the concepts described will have applications also for land storage of liquefied gases of the type described.

It would require tremendous pressures to maintain the methane gas in a liquefied state at ambient temperature. Construction of containers capable of withstanding such pressures would necessitate the utilization of tanks of small capacity and of high strength with the result that considerable space and weight would be represented by the tanks themselves leaving very little volume for the storage and transportation of the liquefied methane gas. Utilization of containers or tanks of large capacity demands the elimination of pressures in excess of a few pounds per square inch. Thus calculations have been based upon the transportation and storage of the liquefied methane gas at about atmospheric pressure and thus at a temperature of about —258° F.

The storage and transportation of a liquefied gas at a temperature of —258° F. presents many problems. Means must be provided for insulating the tank to minimize the amount of liquefied gas that is volatilized off in response to the natural transfer of heat through the insulated tank walls into the body of the liquefied gas contained therein. Means should be provided to protect the ship's steel from contact with the cold boiling liquid or from corresponding refrigerated temperatures since the metal is incapable of retaining its strength characteristics under such cold temperature conditions. Means should be provided for control of temperature adjacent the walls of the tanks to add heat in the event of failure of the insulation, or to add heat for the purpose of avoiding the accumulation of ice and the like on the outer walls of the tanks.

Thus it is an object of this invention to produce a new and improved tank structure and ship structure for the storage and transportation of a cold boiling liquefied gas, such as natural gas.

Another object is to produce a new and improved tank structure and ship structure embodying the features previously described to protect the ship structure and the tanks in the event of failure of the insulation; to control the transfer of heat and cold into and out of the tanks; to conduct cold away from the surfaces of the tanks; to maintain control of the temperatures of the elements of the tanks, and to provide safety features for the water transportation of the cold boiling liquefied natural gas in large volumes at atmospheric pressure and at a temperature of about —258° F.

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 an elevational plan view in miniature lengthwise through a ship embodying the features of this invention for the transporation of liquefied natural gas;

Fig. 2 is a sectional elevational view in cross-section taken crosswise of the ship shown in Fig. 1;

Fig. 3 is a fragmentary sectional elevational view of a portion of the ship structure;

Fig. 4 is an elevational view of the elements located in one section of the wing tanks of the ship;

Fig. 5 is an elevational view in cross-section through a cofferdam; and

Fig. 6 is an enlarged sectional elevational view through a corner section of a wing tank.

In Patent No. 2,798,364, description is made of a ship structure wherein a plurality of internally insulated tanks having the liquefied hydrocarbon gas directly in contact with the insulation lining are floated on water partially filling the hold of the ship buoyantly to support the tanks in the hold in a manner to minimize the exposure of the tanks to shocks, stresses or strain responsive to the rolling and the pitching of the ship. The water in which the tanks are floated functions additionally to maintain temperature control of the tanks, especially when introduced from spray heads directed to deposit the water onto the outer walls of the tank in the upper ends thereof.

This invention is directed to an improvement over the invention described and claimed in the aforementioned copending application in that use is made of a different concept in tank structure and operation, as will hereinafter be described, and to different concepts of temperature control for safe-guarding the tanks and the ship structure, as will also hereinafter be described. This invention is a continuation-in-part of the invention described and claimed in my copending application Ser. No. 582,965, filed on May 7, 1956, and entitled "Ship." In the practice of this invention, the ship **10** is constructed with an outer hull **12** formed of steel plates and an inner hull **14** also formed of steel plates. The inner hull **14**, which is spaced a short distance from the outer hull **12**, defines the hold of the ship with the space between the inner and outer hulls forming the wing tanks **16**. Deck plates **18** between the upper deck **20** and the ship's bottom **22** separate the wing tank into an upper wing tank **16a** and a lower wing tank **16b**. The inner hull **14** functions not only to strength the ship structure but it also provides a relatively smooth inner surface **24** on which thermal insulating material **26** can be built up to provide an insulated hold **28**. In addition, as will hereinafter appear, the inner hull and the wing tanks **16**, represented by the space between the inner and the outer hulls, makes it possible to embody means for the protection of the outer hull from the cold of the liquefied natural gas thereby to provide additional insurances against the limited possibilities of deterioration of the ship in use.

The hold **28** is divided crosswise by cofferdams **30** into a plurality of substantially rectangular cells of substantial dimension extending from the top deck down to the bottom wall of the inner hull. The cofferdams **30** are preferably formed of a pair of metal walls **32** and **34**

spaced one from the other by an amount which enables free access to the interior thereof for inspection or for replacement and repair of equipment. The spaced relation between the walls of the cofferdam will correspond, for the most part, to the spaced relationship between the inner and outer hulls, such for example as a spacing of from 2½ to about 4 feet in a ship having a capacity of 50,000 to 300,000 barrels for the liquefied natural gas. Suitable metal beams or plates are provided for interconnecting the walls and the inner and outer hulls for reinforcement and support.

At least one and preferably a nest of metal tanks **36** are housed within each cell for the storage of the liquefied natural gas. For most efficient utilization of space, it is preferred to make use of tanks of rectangular or other polygonal shape substantially completely to fill the cells, but cylindrical tanks or tanks of other shapes can be used.

The liquefied natural gas is housed within the inner tank **36**. For this purpose, it is desirable to construct the inner tank of a metal, such as aluminum, or the like material capable of retaining its strength characteristics under the extremely low temperatures to which it will be exposed when the liquefied natural gas is housed therein. The inner tanks are mounted in place in the insulated cells but in a manner to permit expansions and contractions in a lateral and in a vertical direction such as occurs in response to the change of temperature from ambient temperature to —258° F. It is desirable to locate the tanks within the cells so as to maintain their relative positions one with the other and without contact to permit such expansions and contractions without relative movement. To maintain the tanks in a predetermined relative position out of contact with each other means are provided, such as interconnecting keys **38** and keyways **40** in the bottom side of the tank and the supporting insulation to center the tank while permitting lateral expansions. Additional means, such as halters **42** are provided to interconnect the top of the tank with the ship structure to center the top while permitting changes in vertical dimension responsive to expansions and contractions. Such stabilizing means as might be employed for retaining the tank in the desired relation within the insulating cells are more fully described in the copending application Ser. No. 634,571, filed January 16, 1957.

It will be apparent from the foregoing that the inner tanks **36** are supported directly on the insulation lining the bottom wall of the inner hull **14**. Suitable structurally strong insulating material can be fabricated of balsa wood, foamed glass and the like structurally strong, porous thermal insulating material of low heat conductivity. For a more detailed description of the construction of the insulation and its installation, reference may be made to the copending application Ser. No. 646,001, filed March 14, 1957.

The inner tanks **36** are normally spaced a short distance one from the other and from the inner faces of the insulation lining the inner hull and cofferdams defining the separated cells. When the tanks are properly located within the insulated cells, the top walls are covered with a relatively thick layer **43** of insulation material, such as glass wool, mineral wool, or built-up layers of balsa wood, foamed glass and the like materials of low heat conductivity. The insulation material employed should be capable of withstanding low temperatures since their inner faces adjacent the tanks **36** will ordinarily be at a temperature of about —258° F. while their outer faces attached to the ship's hulls and cofferdam will ordinarily be at about ambient temperature. The temperature gradient from ambient to —258° F. will exist throughout the described insulating layer lining the cells.

Thus the insulation layer is employed to minimize the amount of heat that is capable of transmission from the ship's hulls to the liquefied natural gas housed within the tanks. That which does penetrate through the insulation into the liquid will cause small amounts of the liquefied natural gas to vaporize. Such vapors as are normally released can be bled from the tanks through suitable connections for use as a fuel in powering the ship. Instead of utilizing the released vapors as a fuel, the vapors can be reliquefied for return to the tanks or else otherwise disposed of by release to the atmosphere.

Under normal circumstances little if any difficulties will be encountered in the operation of the tanks for water transportation of the cold boiling gas from one station to another. It is advisable, however, to anticipate any difficulties which might arise that could have destructive effect on the ship or elements associated with the housing and transportation of the cold boiling liquefied natural gas.

For this purpose, means are provided in the wing tanks between the hulls and in the cofferdams between the cells to control the temperature at the outer walls of the cells to stabilize the conditions existing in the tanks and to conduct heat or cold, as the case may be, away from the cell walls to protect the inner hull and the outer hull of the ship from excessive cold and to prevent the build-up of barriers within the confined space between the hulls which might otherwise block the flow of fluids used to carry away heat or cold from the cell walls.

As illustrated in Figs. 3 and 4, a main header **44** extends lengthwise of the ship above the upper deck **20** and in vertical alignment with the space between the inner and outer hulls. The main header is connected at one end with a water pump for introducing water under pressure from a supply source. Branch headers **46** extend downwardly from the main headers into the wing tanks. Connected to the vertically disposed branch headers **46** are a plurality of horizontally disposed vertically spaced apart pipes **48** fitted with openings or spray nozzles **50** positioned to direct a spray of water angularly outwardly onto the outer faces of the inner hull **14**.

While only one branch header will suffice for each wing tank between the cofferdams, it is preferred to subdivide the wing tanks into two or more sections each of which will be provided with separate branch headers **46**. The number of spray pipes **48** per branch header can be varied from as little as one to a multiplicity spaced from the top portion of the wing tank to the lower end portion of the wing tank in substantial alignment with the bottom of the tanks. It is desirable to space the spray pipes one from the other and laterally to space the spray heads in the pipes by a distance corresponding to the fanning out of the spray so as substantially completely to cover the outer faces of the inner hull uniformly to wet the walls with water. In the illustrated modification, the spray pipes are about equidistantly spaced between the hulls as by a distance from 2–3 feet from the inner hull and the spray heads are spaced about 6–10 feet apart.

Above the deck, branch headers **52** also extend inwardly on the main header **44** to about the central portion of the ship and in vertical alignment with the cofferdams. The branch headers **52** turn downwardly to extend vertically between the spaced walls of each cofferdam. These branch headers **52** are also fitted with a multiplicity of vertically spaced apart spray pipes **54** having spray openings **56** facing in both directions towards the spaced walls of the cofferdam to wet the walls with water. The spaced relationship and arrangement corresponds somewhat to the same elements as employed in the wing tanks thereby to provide means for wetting the outer walls of the cells throughout their entire vertical surfaces. In the illustrated modification, the main header is provided with a main valve **58** for controlling the flow of water from the pump to the branch headers. Instead of making use of a single control valve, use can be made of separate valves (not shown) for each of the branch headers individually to control the flow of water therethrough.

Also extending lengthwise of the ship in vertical align-

ment with the wing tanks are steam headers 60 connected to a source of steam under pressure, as from the engine room. Steam pipes 62 joined to the main steam header through gate valves 64 extend downwardly through the top deck into the wing tanks and into the cofferdams between the spaced walls. The steam pipes extend downwardly in a serpentine fashion between the walls of the wing tanks and the cofferdams to provide suitable coverage uniformly to heat the walls of the inner and outer hulls of the cofferdams and to heat the space in between. While the steam pipes can extend downwardly to the bottom of the wing tanks, it is preferred to limit the steam pipes to the upper wing tank section whereas it is more desirable to cover the entire area of the cofferdams, as illustrated in Figs. 4 and 5.

This is because the water level in the wing tanks can be raised to the level of the upper wing tank to provide ballast while at the same time providing means for carrying away cold whereas the cofferdams will usually be kept free of water. When water is allowed to collect in the wing tanks, it is desirable to provide means for keeping the water in movement for removal of heat or cold from the walls of the tanks thereby to avoid solidification of water by freezing when cold spots develop in the cell walls. For this purpose, it is desirable to provide one or more drain openings 64 at a level below the steam pipes to maintain the water at a predetermined level in the wing tanks, independently of the spray of water from the pipes onto the cell walls.

In addition to the use of spray heads for the introduction of water into the wing tanks or onto the walls of the cells, separate water pumps may be provided in the wing tanks or elsewhere in a convenient location in the ship for the rapid introduction and circulation of water through the wing tanks to carry away heat and cold from the walls. Such pumps, usually of larger capacity than the spray head, can introduce water in large volumes to cause rapid circulation from the pump to the drain for return to the sea.

By spraying to wet the outer faces of the inner hull and the cofferdams, the walls to which the insulation 26 is attached can be maintained at a desired safe level and at a constant level to minimize variations in temperature thereby to maintain a relatively constant rate of heat transfer through the walls independently of the ambient temperature. This is desirable not only for the purpose of decreasing the amount of heat transferred but it also enables more accurate control in the amount of vapors generated so that fuller utilization can be made of the vapors that are released during the voyage.

In the event of deterioration of portions of insulation, such deterioration can be detected either by the increase in the amount of vapors generated from an adjacent tank or by a differential in the temperature of the outer cell walls. If the deterioration is minor in character, it can be compensated by cooling the walls with water to minimize the temperature differential through the insulation.

In the event of a more substantial failure of the insulation, the metal walls can be protected against being cooled down to excessively low temperatures by causing the water rapidly to flow over the walls to carry away larger amounts of cold from the cell walls thereby to protect the walls against break-down until the liquefied natural gas can be removed or the damage repaired. The rapid flow of water thus operates as an emergency measure to hold back the forces which might otherwise lead to the development of dangerous conditions.

Steam will be circulated through the steam pipes to heat the space between the hulls and the cofferdams for the purpose of heating the metal to an elevated temperature in the event of local failure of insulation or to raise the temperature within the tanks or cofferdams in the event that ambient temperature is below freezing. Thus the heat introduced will prevent the freezing of water on the walls of the wing tanks and cofferdam so as to have full access to the walls for the desired temperature control. In the event that ice is allowed to accumulate on the insulated walls, the metal will become vulnerable to temperatures far below that capable of being tolerated by the metal without having means available immediately to dissipate or remove the cold. Heat can also be introduced to heat the water in contact with the tanks for more effective dissipation of cold.

Thus the need for being able to heat the water and the wing tanks and cofferdams about the cells to maintain uniform temperature differentials independently of ambient temperature or differences in the characteristics of the insulation.

Instead of steam pipes arranged in serpentine fashion as described, the steam pipes may be otherwise arranged in a network through the wing tanks and cofferdams or other heating means may be employed.

It will be apparent from the foregoing that elements have been embodied in the ship structure to safeguard the ship in its voyage for the transportation of a cold boiling liquefied natural gas from a source of plentiful supply to an area which is deficient in low cost fuels. It will be apparent that the concepts described for use in a ship structure will be applicable also for on-land storage of the cold liquefied natural gas to protect the metal walls of the tank against destructive forces which might otherwise develop and to minimize the loss of vapors from the tanks by control of temperature at the outer walls.

It will be understood that the concepts described may be adapted for other ship structures housing insulated tanks for the transportation of such cold boiling liquefied gases and it will be understood further 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. Means for the storage, at about atmospheric pressure, of a liquefied gas having a boiling point below —40° F. at atmospheric pressure, comprising:

(*a*) a housing of a fluid and vapor impervious material,

(*b*) a thick layer of insulating material lining the inner face of the housing wall,

(*c*) a tank within the insulated housing for housing the liquefied gas therein,

(*d*) means mounting the tank within the insulated housing in a manner to maintain the tank in a predetermined relative position while permitting relative expansion and contraction movements,

(*e*) water applying means for wetting the outer face of the insulated wall of the housing for temperature control, and

(*f*) heating means for increasing the temperature adjacent portions of the outer face of the insulated wall of the housing to heat the wall and to prevent the accumulation of ice thereon.

2. Storage means as claimed in claim 1 in which the tank (*c*) is spaced a short distance from the insulated layer lining the wall of the housing for enabling expansion and contraction movements independently of the insulated wall.

3. Storage means as claimed in claim 1 in which a plurality of tanks are mounted within the insulated housing in spaced apart relation one with the other and with the insulated wall of the housing to permit expansion and contraction movements without disturbing the relative positions of the tanks within the housing.

4. Means for the storage and over-water transportation at atmospheric pressure of a liquefied gas having a boiling point below —40° F. at atmospheric pressure comprising a ship having:

(*a*) an outer hull,

(*b*) an inner hull spaced a short distance from the outer hull but interconnected therewith to define wing tanks between the spaced inner and outer hulls and to define a hold within the inner hull,

(c) a thick layer of insulating material lining the inner surfaces of the inner hull to define a thermally insulated hold,

(d) a tank within the insulated hold for housing the liquefied gas therein at atmospheric pressure,

(e) means mounting the tank within the insulated hold in a manner to maintain the tank in a predetermined relative position while permitting relative expansion and contraction movements,

(f) water applying means within the wing tanks for wetting the outer surfaces of the inner hull having the insulating layer on the opposite side thereof, and

(g) heating means within the wing tanks for raising the temperature within the wing tanks to prevent overcooling of the ship's hulls and to prevent the accumulation of ice on the outer surface of the inner hull.

5. A ship structure as claimed in claim 4 which includes cofferdams comprising spaced walls extending crosswise between the ship's hulls to subdivide the hold into a plurality of cells and which includes a layer of thermal insulating material lining the inner surfaces of the cofferdam walls to provide with the insulated walls of the inner hull an insulated cell in which the liquid containing tank is mounted.

6. A ship structure as claimed in claim 5 in which a plurality of liquid containing tanks are mounted within the insulated cell in closely spaced apart relation one with the other and with the insulated walls of the cell.

7. A ship structure as claimed in claim 6 which includes heating means between the spaced walls of the cofferdams and which includes water applying means between the spaced walls of the cofferdams for wetting the adjacent surfaces of the cofferdam opposite the insulated surfaces.

8. A ship structure as claimed in claim 5 in which the water applying means comprises a water header extending lengthwise of the ship in vertical alignment with the wing tanks, a plurality of branch headers extending downwardly from the main header into longitudinally spaced apart sections of the wing tanks and the cofferdams, spray pipes vertically spaced apart in the cofferdams and wing tanks and in communication with the branch headers, and spray heads longitudinally spaced apart in the spray pipes.

9. A ship structure as claimed in claim 8 which includes valve members in the branch headers between the spray pipes and the main header for controlling the flow of water therethrough.

10. Means for the storage and over-water transportation at atmospheric pressure of a liquefied gas having a boiling point below —40° F. at atmospheric pressure comprising a ship having:

(a) an outer hull,

(b) an inner hull spaced a short distance from the outer hull but interconnected therewith to define wing tanks between the spaced inner and outer hulls and to define a hold within the inner hull,

(c) a thick layer of insulating material lining the inner surfaces of the inner hull to define a thermally insulated hold,

(d) a tank within the insulated hold for housing the liquefied gas therein at atmospheric pressure,

(e) means mounting the tank within the insulated hold in a manner to maintain the tank in a predetermined relative position while permitting relative expansion and contraction movements,

(f) water applying means within the wing tanks for wetting the outer surfaces of the inner hull having the insulating layer on the opposite side thereof, and

(g) cofferdams comprising spaced walls extending crosswise between the ship's hulls to subdivide the hold into a plurality of cells and which includes a layer of thermal insulating material lining the inner surfaces of the cofferdam walls to provide, with the insulated walls of the inner hull, an insulated cell in which the liquid containing tank is mounted.

11. Means for the storage and over-water transportation at atmospheric pressure of a liquefied gas having a boiling point below —40° F. at atmospheric pressure comprising a ship having:

(a) an outer hull,

(b) an inner hull spaced a short distance from the outer hull but interconnected therewith to define wing tanks between the spaced inner and outer hulls and to define a hold within the inner hull,

(c) a thick layer of insulating material lining the inner surfaces of the inner hull to define a thermally insulated hold,

(d) a plurality of liquid containing tanks mounted within the insulated inner hull in closely spaced apart relation one with the other and with the insulated walls of the hull,

(e) means mounting the tank within the insulated hold in a manner to maintain the tank in a predetermined relative position while permitting relative expansion and contraction movements, and

(f) water applying means within the wing tanks for wetting the outer surfaces of the inner hull having the insulating layer on the opposite side thereof.

12. Means for the storage and over-water transportation at atmospheric pressure of a liquefied gas having a boiling point below —40° F. at atmospheric pressure comprising a ship having:

(a) an outer wall,

(b) an inner hull spaced a short distance from the outer hull but interconnected therewith to define wing tanks between the spaced inner and outer hulls and to define a hold within the inner hull,

(c) a thick layer of insulating material lining the inner surfaces of the inner hull to define a thermally insulated hold,

(d) a tank within the insulated hold for housing the liquefied gas therein at atmospheric pressure,

(e) means mounting the tank within the insulated hold in a manner to maintain the tank in a predetermined relative position while permitting relative expansion and contraction movements, and

(f) water applying means within the wing tanks for wetting the outer surfaces of the inner hull having the insulating layer on the opposite side thereof, in which the water applying means comprises a water header extending lengthwise of the ship in vertical alignment with the wing tanks, a plurality of branch headers extending downwardly from the main header into longitudinally spaced apart sections of the wing tanks, spray pipes vertically spaced apart in the wing tanks and in communication with the branch headers, and spray heads longitudinally spaced apart in the spray pipes.

References Cited in the file of this patent

UNITED STATES PATENTS

2,242,635	Whittelsey	May 20, 1941
2,465,779	Ahblom	Mar. 29, 1949
2,600,015	McLaughlin	June 10, 1952
2,689,461	Brandon	Sept. 21, 1954
2,798,364	Morrison	July 9, 1957