

[54] **LNG SHIP TANK INERT GAS GENERATION SYSTEM**

[75] Inventor: **Stephen A. Locke**, Glen Ellyn, Ill.

[73] Assignee: **Chicago Bridge & Iron Company**, Oak Brook, Ill.

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[51] Int. Cl. **F17c 7/02**

[58] Field of Search 62/45, 50, 51, 54; 165/105; 220/88 B; 114/74 A

[56] **References Cited**

UNITED STATES PATENTS

2,870,936	1/1959	Clayton	220/88 B
2,983,405	5/1961	Taylor	220/88 B

FOREIGN PATENTS OR APPLICATIONS

605,490	9/1960	Canada	220/88 B
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Primary Examiner—Meyer Perlin

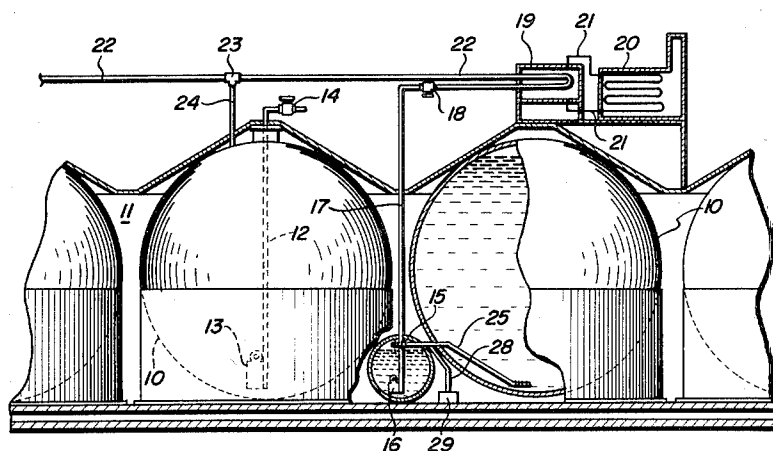
Assistant Examiner—Ronald C. Capossela

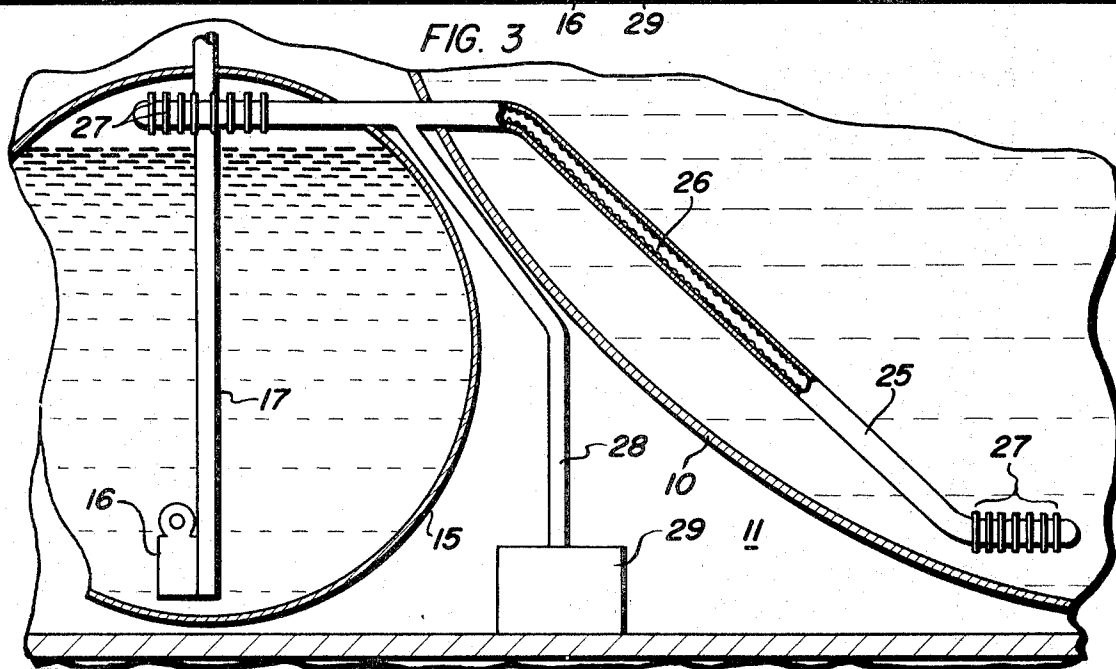
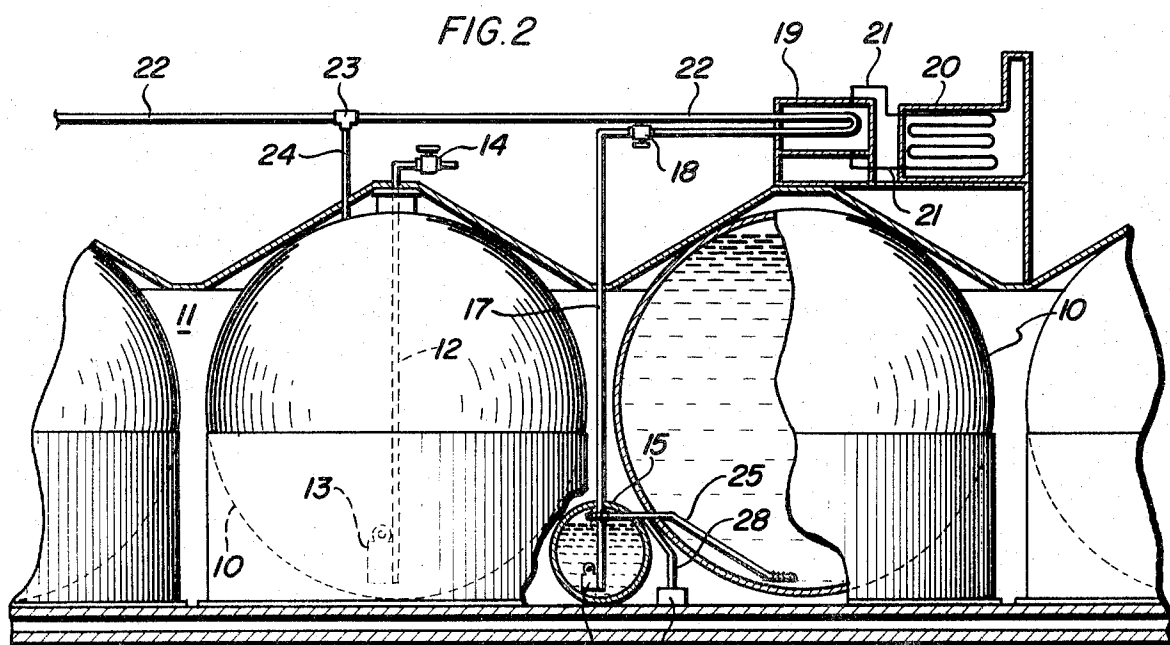
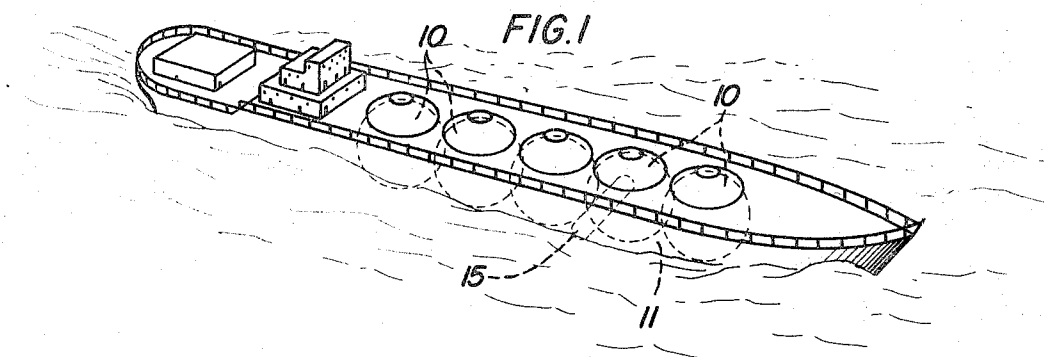
Attorney, Agent, or Firm—Merriam, Marshall, Shapiro & Klose

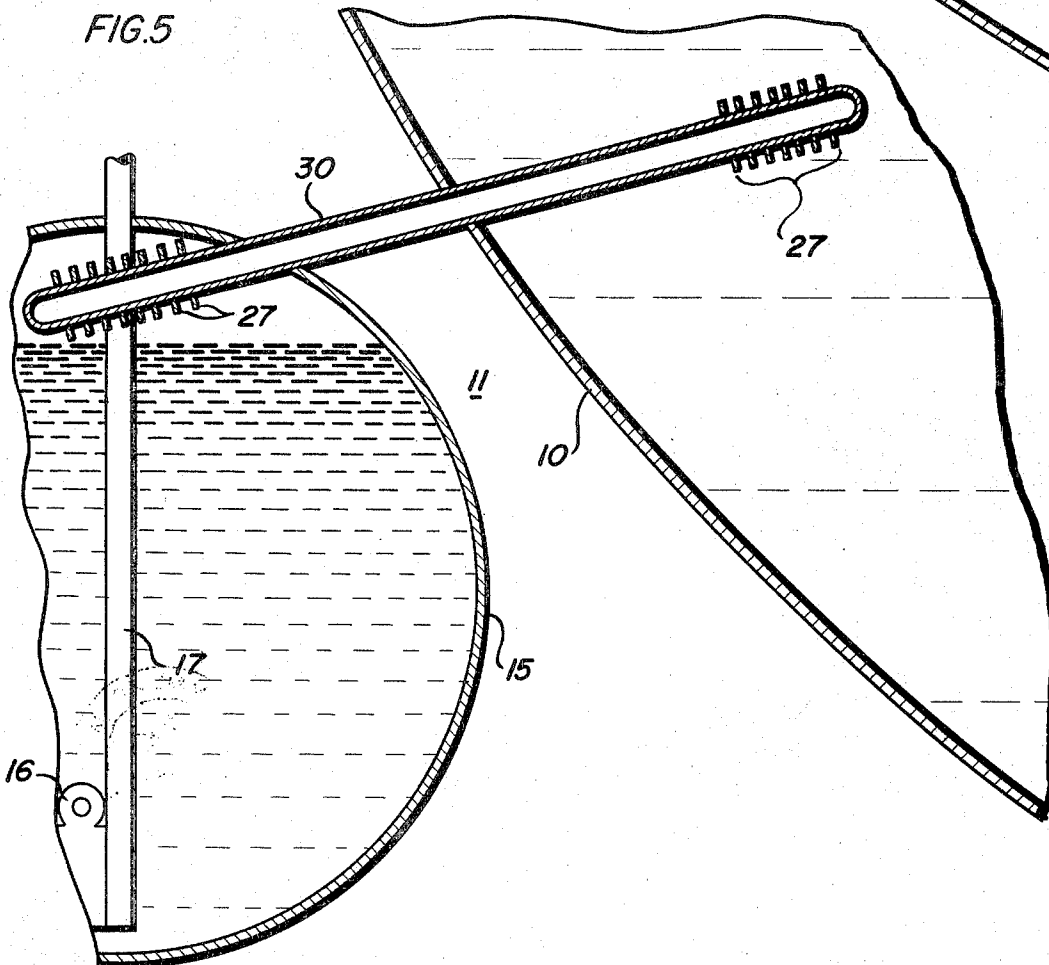
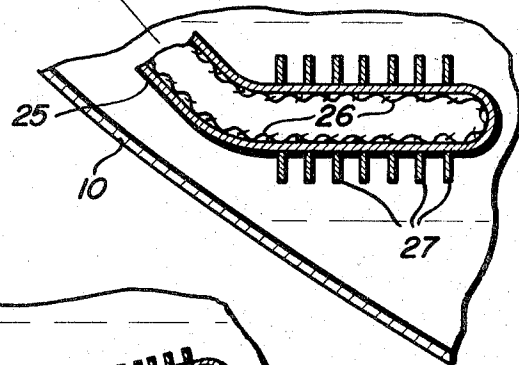
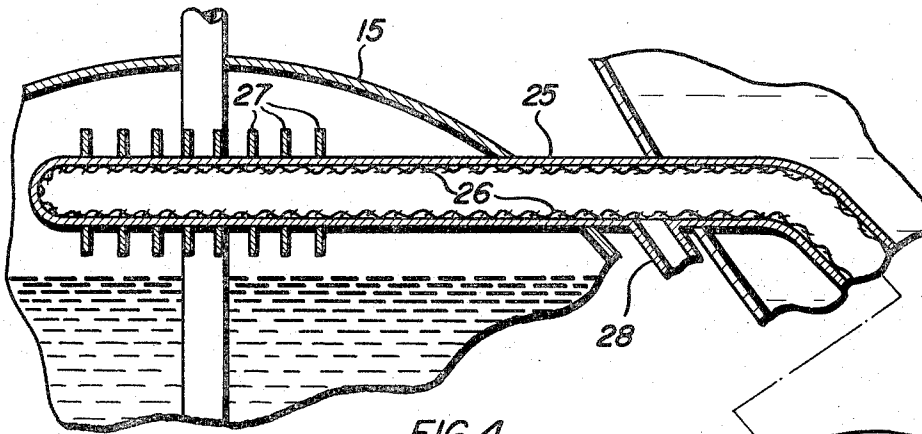
[57] **ABSTRACT**

An apparatus comprising an enclosed supply tank containing a liquefied gas, an enclosed storage tank containing a cryogenic liquefied gas having a lower temperature than the liquefied gas, and a heat pipe for transferring heat from the supply tank to the storage tank is disclosed. In a particular embodiment useful for selectively introducing an inert gas into an enclosure containing inflammable liquefied gas, the apparatus includes an enclosed supply tank containing liquefied inert gas, a vaporizer for vaporizing the liquefied inert gas, a conduit from the vaporizer to the storage tank for injecting the vaporized inert gas into the storage tank and a heat pipe for transferring heat from the supply tank to the storage tank to maintain the inert gas in a liquefied state as long as the storage tank is not being inerted.

6 Claims, 5 Drawing Figures







LNG SHIP TANK INERT GAS GENERATION SYSTEM

This invention relates to apparatus for safely emptying an inflammable liquefied gas, such as liquefied natural gas, from enclosed storage tanks. More particularly, the invention is concerned with apparatus for inerting enclosed storage tanks with an inert gas, such as nitrogen, to prevent the formation of an explosive air and gas mixture if a storage tank is ruptured during transportation.

Reference may be made to the following U.S. Pat. No. 2,961,841 and 2,889,955.

Natural gas is a widely used commodity throughout much of the world, but unfortunately, the gas fields from which it is obtained are very seldom close to major markets. As the supplies nearer the markets are depleted, an economical method of transporting natural gas from remote gas fields to market must be provided since there are many areas which cannot be practically or economically served by gas pipelines.

One such method is to liquefy the natural gas, place it in enclosed storage tanks and transport it by ship, barge, railroad or truck to a convenient distribution point where it can be stored and later vaporized for use when needed. In its liquefied form, natural gas occupies a much smaller space than it does in its gaseous form. Storage of liquefied natural gas in large volume storage tanks is not considered feasible, however, unless the gas is refrigerated to a temperature of -258°F. at which its vapor pressure is equal to or only slightly above atmospheric pressure. Under such conditions, the liquefied natural gas can be stored in relatively lightweight insulated tanks rather than storage tanks of heavy construction capable of withstanding the tremendous forces associated with storing the liquefied natural gas at a higher pressure.

If a catastrophic event should occur, however, such as the transport ship colliding with another ship causing the relatively lightweight storage tanks to rupture, the liquefied natural gas is rapidly vaporized. As a result, air is introduced into the storage tank, and some of the vaporized natural gas escapes into the ship's hold unavoidably creating a dangerous air and gas mixture which is not only flammable but also potentially explosive.

Accordingly, to reduce the hazard resulting from such an occurrence, it has been proposed that the liquefied natural gas be vented from the ruptured tank to the atmosphere by introducing an inert gas vapor such as nitrogen gas into the storage tank, forcing the liquefied natural gas from the tank and diluting the vaporized natural gas. Moreover, it is desirable to "flood" the entire hold with the vaporized nitrogen gas to further eliminate the danger of an explosion.

The quantity of nitrogen gas required to inert the storage tanks and the hold is so great, however, that it has heretofore been thought to be physically and economically impractical. That is, to maintain the inert gas in its liquefied form for the duration of the journey, a refrigeration system would have to be provided, entailing added expense and requiring a great deal of space which could be better used for transporting additional liquefied natural gas. If the liquefied nitrogen is not refrigerated, on the other hand, additional liquefied nitrogen gas must be initially stored aboard ship to insure that a sufficient amount remains to inert the ship as it

nears its destination. This is necessary because a large portion of the liquefied nitrogen is vaporized during the journey as a result of heat leak into the liquefied nitrogen supply tank.

Thus, it has been suggested that inert gas generators be placed aboard ship for producing the required inert gas. Typically, such generators have comprised an internal combustion engine fueled, for example, by gasoline, diesel fuel or even natural gas. The resultant exhaust or flue gases produced by the engine are dehydrated and other oxygen bearing components (e.g., carbon dioxide) removed so that the oxygen content of the exhaust gases is minimal. The gases are then compressed in a compressor powered by the internal combustion engine and introduced into the storage tanks to force the liquefied natural gas from the tanks so that it can be vented to the atmosphere.

Such a system, however, requires that additional machinery (i.e., an internal combustion engine and a compressor) be placed on the ship, further reducing the available space and requiring additional maintenance.

According to the present invention, there is provided an apparatus comprising an enclosed supply tank containing a liquefied inert gas, an enclosed storage tank containing a cryogenic liquefied gas having a lower temperature than the liquefied inert gas, and a heat pipe for transferring heat from the supply tank to the storage tank. One end of the heat pipe extends into the vapor space in the supply tank above the liquefied gas found therein, and the other end is submerged in the cryogenic liquefied gas in the storage tank. The heat pipe comprises a closed tube containing a partially liquefied inert gas for transferring heat from the supply tank to the storage tank thereby facilitating the condensation of vaporized gas in the enclosed supply tank. An extended surface heat exchanger is provided at each end of the heat pipe to increase the efficiency of the heat flow. Thus, as heat leaks into the supply tank, the liquefied gas is vaporized and confined to the space adjacent to the end of the heat pipe. The inert gas in the heat pipe is vaporized and flows to the end of the heat pipe located in the storage tank. There the vapor is condensed by the cooler cryogenic liquefied gas, transferring its heat thereto. A wick provided on the inner surface of the heat pipe transports the cooled liquefied inert gas in the closed heat pipe back to the end positioned in the supply tank. Heat is drawn from the vaporized gas in the supply tank to condense the vaporized gas therein, and the inert gas within the heat pipe is again vaporized.

In a particular embodiment useful for selectively introducing an inert gas into an enclosure containing inflammable liquefied gas, the apparatus comprises an enclosed supply tank containing liquefied inert gas, a vaporizer for vaporizing the liquefied inert gas, a conduit from the vaporizer to the storage tank for injecting the vaporized inert gas into the storage tank to force the inflammable liquefied gas therefrom, and means for transferring heat from the supply tank to the storage tank to maintain the inert gas in a liquefied state as long as the storage tank is not being inerted. More particularly, the heat transfer means comprises a heat pipe extending between the supply tank and the storage tank. Typically, the liquefied inert gas comprises liquefied nitrogen maintained at about -234°F. and about 477 psia while the inflammable liquefied gas is commonly

liquefied natural gas at a temperature of about -258° F.

The invention will be described further in conjunction with the attached drawings in which:

FIG. 1 is a perspective view of a transport ship having a storage tank inerting apparatus in accordance with the present invention;

FIG. 2 is a vertical sectional view of a portion of the transport ship of FIG. 1 showing the storage tank inerting apparatus and several of the storage tanks;

FIG. 3 is a partial vertical sectional view showing the storage tank inerting apparatus in greater detail;

FIG. 4 is longitudinal sectional view of the heat pipe shown in FIG. 3 taken along line 4—4; and

FIG. 5 is a partial vertical sectional view showing an alternative embodiment of the storage tank inerting apparatus.

So far as is practical, the same parts or elements which appear in the figures comprising the drawings will be identified by the same numbers.

With reference to FIGS. 1 and 2, there is shown a transport ship having five enclosed spherical storage tanks 10 for transporting cryogenic liquids such as liquefied natural gas. The storage tanks 10 are mounted in the enclosed hold, identified generally at 11, so that they are substantially below the ship's deck. When the transport ship reaches its destination, each storage tank 10 is emptied by pumping the liquefied natural gas through a conduit 12 to onshore storage or transportation facilities. More particularly, a submerged pump 13 is mounted on the end of conduit 12 at a point near the bottom of the storage tank 10 to pump the liquefied natural gas therefrom. The rate at which the tank is emptied is controlled by a valve 14 interposed in the conduit 12.

If, however, one or more of the storage tanks 10 are ruptured due to a mid-ocean collision or some other catastrophic event, the liquefied natural gas is unavoidably released into the hold 11 where the inflammable liquefied natural gas is vaporized to form a potentially explosive air and natural gas vapor mixture. Similarly, air is leaked into the storage tanks mixing with the natural gas vapor remaining therein.

To reduce the hazard of fire or explosion as a result of such conditions, an inventive inerting apparatus is included aboard ship to introduce an inert gas such as nitrogen into the storage tanks 10 as the liquefied natural gas is simultaneously vented to the atmosphere through conduit 12. Moreover, the inerting apparatus is effective to "flood" the entire hold 11 and the ruptured storage tank 10 with inert gas to dilute the air and vaporized natural gas mixture, thereby reducing the danger of an explosion.

The inerting apparatus includes an enclosed blimp-shaped supply tank 15 positioned in the hold 11 between a pair of storage tanks 10 for storing the inert gas in liquefied form. In the event that the hold 11 must be inerted, a pump 16 submerged in the liquefied inert gas near the bottom of the supply tank 15 is enabled to pump the inert gas from the tank 15 through a conduit 17 extending from the tank. A valve 18 controls the flow of inert gas from the supply tank 15 through conduit 17.

The liquefied inert gas from the supply tank 15 is transported through conduit 17 to a vaporizer 19 where the liquefied inert gas is heated until it is vaporized. The vaporizer 19 derives the heat required to vaporize

the liquefied inert gas from a steam generator 20 through heat coils 21 interconnecting them. Although a steam generator may be provided specifically for the inerting apparatus, the vaporizer 19 may instead obtain the requisite heat from the ship's power system.

The vaporized inert gas upon leaving the vaporizer 19 through conduit 22 is delivered to each of the storage tanks 10 through a distribution system comprising several headers 23 interposed at strategic points along the conduit 22. Each header 23 includes a one-way valve (not shown) for transferring a portion of the vaporized inert gas to a conduit 24 passing through the top of a corresponding storage tank 10. Accordingly, a portion of the vaporized inert gas is introduced into each storage tank 10 through its corresponding conduit 24. In the storage tank 10, the vaporized inert gas mixes with the vaporized natural gas to dilute the air and natural gas mixture therein. Moreover, the vaporized inert gas escapes through the rupture in the storage tank 10 to likewise dilute the air and gas mixture resulting from the leakage of liquefied natural gas into the hold 11. Simultaneously, the submerged pump 13 is enabled and valve 14 is opened to remove the liquefied natural gas from the storage tank 10 through the conduit 12, venting it to the atmosphere.

In order to minimize the amount of liquefied inert gas that must be stored aboard ship, a heat pipe 25 thermally connecting the storage tank 10 and the supply tank 15 is provided to maintain the inert gas in liquefied form as long as the inerting apparatus is not enabled. One end of the heat pipe 25 extends into the supply tank 15 and is advisably positioned in the vapor space above the surface of the liquefied inert gas while the other end of the heat pipe 25 is submerged in the cooler cryogenic liquefied natural gas contained in storage tank 10.

The heat pipe 25 is shown in greater detail in FIGS. 3 and 4. There it may be seen that the heat pipe 25 comprises an essentially hollow, closed tube having a layer of fibrous material or wick 26 adjacent to its inner wall and a hollow central core. Further, the tube is charged with a suitable inert gas, such as nitrogen.

Operationally, the nitrogen gas in the end of the heat pipe 25 submerged in the liquefied natural gas (i.e., storage tank 10) is cooled so that it is in liquid form. The wick 26, by capillary attraction, draws the liquefied nitrogen gas through the length of the heat pipe 25 until it is at the end of the heat pipe 25 positioned in the vapor space of supply tank 15. Since there is no refrigeration system provided for cooling the liquefied inert gas in supply tank 15, the heat leaking into the supply tank 15 vaporizes a portion of the liquefied inert gas. The vaporized inert gas consequently enters the vapor space adjacent to heat pipe 25 and transfers heat to the heat pipe 25, vaporizing the liquefied nitrogen gas therein. As the heat is removed from the vaporized inert gas in the vapor space surrounding heat pipe 25, the inert gas is condensed on the heat pipe 25, dripping into the mass of liquefied inert gas below. Simultaneously, the vaporized nitrogen gas in the heat pipe 25 passes through the hollow center of the tube to the other end of the heat pipe 25 where it is cooled through heat exchange with the liquefied natural gas.

Accordingly the heat pipe 25 is effective to continuously transfer heat from the liquefied inert gas in the supply tank 15 to the cooler cryogenic liquefied natural gas contained in the storage tanks 10. The heat trans-

ferred to the liquefied natural gas will cause some of it to vaporize, but this small amount of vaporized natural gas can be used to fuel the ship's power system.

Although the heat pipe 25 is effective to transfer heat between its two ends at very low temperature differentials, heat transfer between each end and its surrounding environment must be accomplished by convection. Since the surface of the heat pipe 25 extending into each of the tanks is relatively small, the convection heat transfer coefficient is very low, hindering heat flow. Consequently, in order to more effectively utilize the heat flux from the small heat pipe 25, a large extended surface heat exchanger 27 is provided at each end of the heat pipe 25 to facilitate heat transfer.

Also, the interior of heat pipe 25 is connected through a conduit 28 to a vacuum pump 29. Thus, if the liquefied natural gas storage tank 10 is to be taken out of service (e.g., emptied) or allowed to warm to a temperature exceeding that of the liquefied inert gas in the supply tank 15, the nitrogen gas in the heat pipe 25 can be removed by the vacuum pump 29 to thermally isolate the two tanks.

An alternative embodiment is shown in FIG. 5. There, a hollow tubular heat pipe 30 charged with an inert gas such as nitrogen is provided to transfer heat from the supply tank 15 to the storage tank 10. One end of the heat pipe 30 extends into the vapor space of the supply tank 15, and the other end is submerged in the cooler cryogenic liquefied natural gas contained in storage tank 10.

The inerting apparatus shown in FIG. 5 is nearly identical to that shown in FIG. 3 except that the end of heat pipe 30 submerged in the storage tank 10 must be elevated with respect to the end extending into the supply tank 15. That is, because heat pipe 30 does not include a wick, gravity must be utilized to return the condensed nitrogen gas charge in the heat pipe 30 to the end located in the vapor space of supply tank 15. Otherwise, the condensed gas would accumulate in the submerged end, and the heat pipe 30 would cease to function.

Operationally, the nitrogen gas in supply tank 15 is condensed by heat transfer to the liquefied natural gas contained therein. As it is liquefied, the nitrogen gas flows down the hollow heat pipe 30 to the end located in the vapor space of supply tank 15. The vaporized nitrogen gas in supply tank 15 is condensed by heat pipe 30, transferring its heat to the pipe 30 and vaporizing the liquefied nitrogen gas therein. The vaporized nitrogen gas then rises through the heat pipe 30 to the storage tank 10 where it is again liquefied to complete the heat transfer cycle.

In a specific application of the above-described system, liquefied natural gas at a temperature of about -258°F . and atmospheric pressure is stored in each of five enclosed spherical storage tanks 10 having an inside diameter of 120'. The wall, comprising the metal shell and insulating, of each tank 10 is approximately 12 inches thick so that the outside diameter of each spherical tank 10 is approximately 124 feet. To inert each of the five spherical tanks 10 and the hold 11, 950,000 pounds of liquefied nitrogen gas is required. For optimum storage, the liquefied nitrogen is stored in a blimp-shaped supply tank 15 having an inside diameter of about 25 feet and a length of 64 feet. The liquefied nitrogen is maintained at a temperature of about -234°F . and a pressure of about 477 psia. The wall of

supply tank 15 includes a 12 inch layer of urethane foam insulation which reduces the heat leak into the tank to about $5\frac{1}{2}$ million BTU per hour. Thus, a heat pipe having an inside diameter of about 11 inches is required to transfer a sufficient amount of heat from the supply tank 15 to the storage tank 10 in order to maintain the nitrogen gas in its liquefied form.

It should be recognized, however, that the particular construction of the storage tanks and the supply tanks employed in the subject invention is not critical. Rather the size and shapes of the tanks described in conjunction with the present embodiment have been selected to most efficiently utilize the available space within the transport ship. It will be obvious that other arrangements of storage tanks and supply tanks can be employed and therefore it is not intended that the invention be restricted to the specific embodiment disclosed in the drawings described herein. The particular shape and number of tanks is to be arrived at according to the most efficient utilization of space aboard ship.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations are to be understood therefrom, as modifications will be obvious to those skilled in the art.

I claim:

1. An apparatus for selectively inerting a storage tank containing inflammable liquefied gas, the apparatus comprising:

an enclosed supply tank containing liquefied inert gas;

an enclosed storage tank containing a liquefied gas having a lower temperature than the liquefied inert gas;

a vaporizer for vaporizing the liquefied inert gas;

a conduit from the vaporizer to the storage tank for injecting the vaporized inert gas into the storage tank; and

heat transfer means thermally connecting the supply tank to the storage tank for transferring heat from the supply tank to the storage tank to maintain the inert gas in a liquefied state as long as the enclosure is not being inerted.

2. In a ship having an enclosed storage tank containing inflammable liquefied gas, an apparatus for selectively inerting the enclosed storage tank, the inerting apparatus comprising:

an enclosed supply containing liquefied inert gas having a higher temperature than the inflammable liquefied gas;

a vaporizer for vaporizing the liquefied inert gas;

a conduit from the vaporizer to the storage tank for injecting the vaporized inert gas therein; and

a heat pipe for transferring heat from the supply tank to the storage tank to maintain the inert gas in a liquefied state as long as the storage tank is not being inerted.

3. An inerting apparatus according to claim 2 in which a conduit from the supply tank to the vaporizer is included for passing the liquefied inert gas to the vaporizer.

4. An inerting apparatus according to claim 2 in which the inflammable liquefied gas is liquefied natural gas, the heat transferred from the supply tank to the storage tank vaporizing the liquefied natural gas to fuel a ship power system.

5. An inerting apparatus according to claim 2 in which the inert gas is nitrogen.

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6. In a ship having an enclosed storage tank containing liquefied natural gas at about -258°F. , an apparatus for selectively inerting the enclosed storage tank, the inerting apparatus comprising:

- an enclosed supply tank containing liquefied nitrogen gas at about -234°F. and about 477 psia;
- a conduit from the supply tank to a vaporizer for vaporizing the liquefied nitrogen gas;
- a conduit from the vaporizer to the storage tank for

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injecting the vaporized nitrogen gas into the storage tank; and
 a heat pipe having one end extending into the vapor space in the supply tank and its other end submerged in the liquefied natural gas in the storage tank for transferring heat from the supply tank to the storage tank to condense the nitrogen vapor as long as the storage tank is not being inerted.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,850,001 Dated November 26, 1974

Inventor(s) Stephen A. Locke

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 58, change "insulating" to --insulation--;
column 6, line 47, after "supply" insert --tank--.

Signed and sealed this 21st day of January 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents