United States Patent [19]

Becker

[11] **3,882,685**

[45] **May 13, 1975**

[54] **METHOD OF AND APPARATUS FOR THE LOW-TEMPERATURE LIQUEFIED GAS**

[75] Inventor: **Rudolf Becker**, Munich, Germany

[73] Assignee: **Linde Aktiengesellschaft**, Wiesbaden, Germany

[22] Filed: **Dec. 17, 1973**

[21] Appl. No.: **425,131**

[30] **Foreign Application Priority Data**

Dec. 22, 1972 Germany 2263063
Nov. 12, 1973 Germany 2356395

[52] **U.S. Cl.** .... **62/55**; 62/240; 114/74 A; 220/9 LG

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

[58] **Field of Search** .... 62/45, 50, 55, 51, 240; 114/74 A; 220/9 LG

[56] **References Cited**

UNITED STATES PATENTS

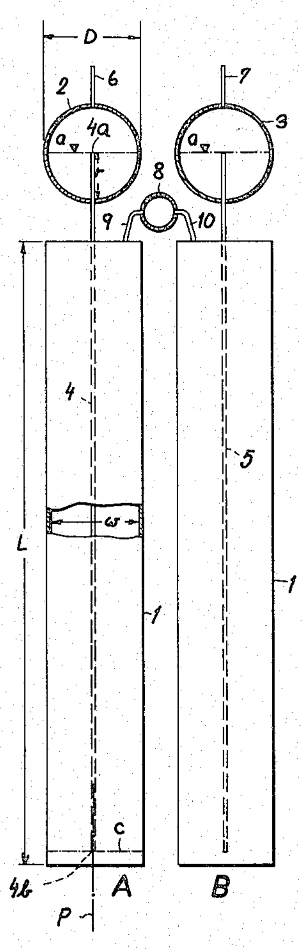
334,481	1/1886	Sone	114/74 A
2,687,618	8/1954	Bergstrom	62/50
2,897,658	8/1959	Beckwith	62/55
3,030,780	4/1962	Loveday	62/51 X
3,319,433	5/1967	Pauliukonis	62/45
3,392,537	7/1968	Woerner	62/50
3,698,200	10/1972	Johnson et al.	62/45

Primary Examiner—Meyer Perlin
Assistant Examiner—Ronald C. Capossela
Attorney, Agent, or Firm—Karl F. Ross; Herbert Dubno

[57] **ABSTRACT**

A system for the transportation of liquefied gas, e.g. in a methane-carrying tankship, in which the storage space is provided with a multiplicity of upright liquefied-gas vessels in which a quantity of the liquefied gas is retained during the return trip and the upper portions of the tanks are cooled by a cooling system in addition to the cooling afforded by the retained liquefied medium.

10 Claims, 6 Drawing Figures



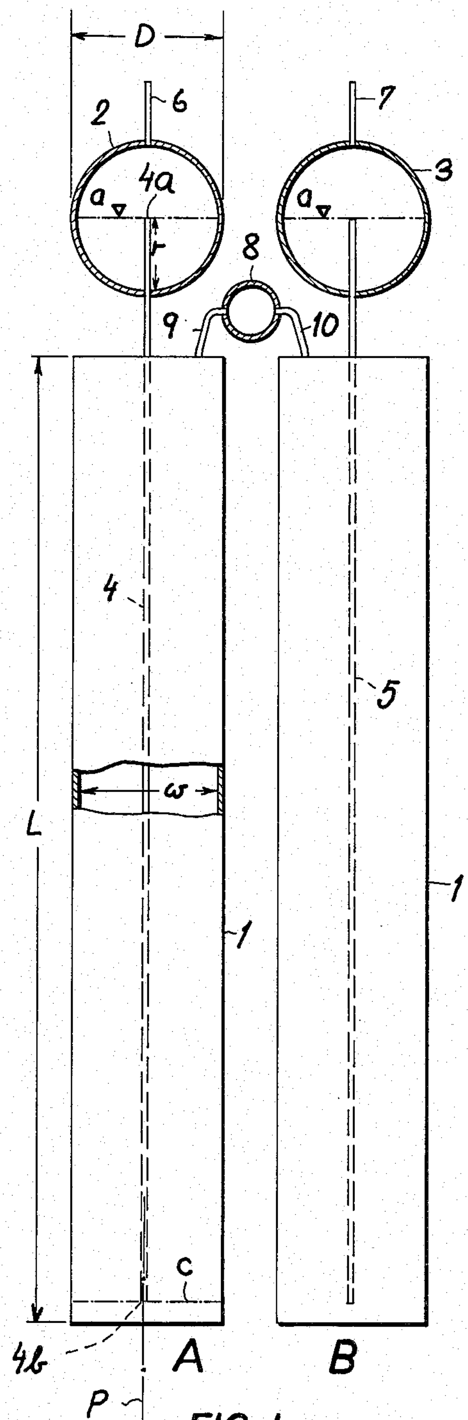

D
2
6
4a
a
r
7
3
a
8
9
10
4
5
w
L
1
1
c
4b
A
B
P

FIG. 1

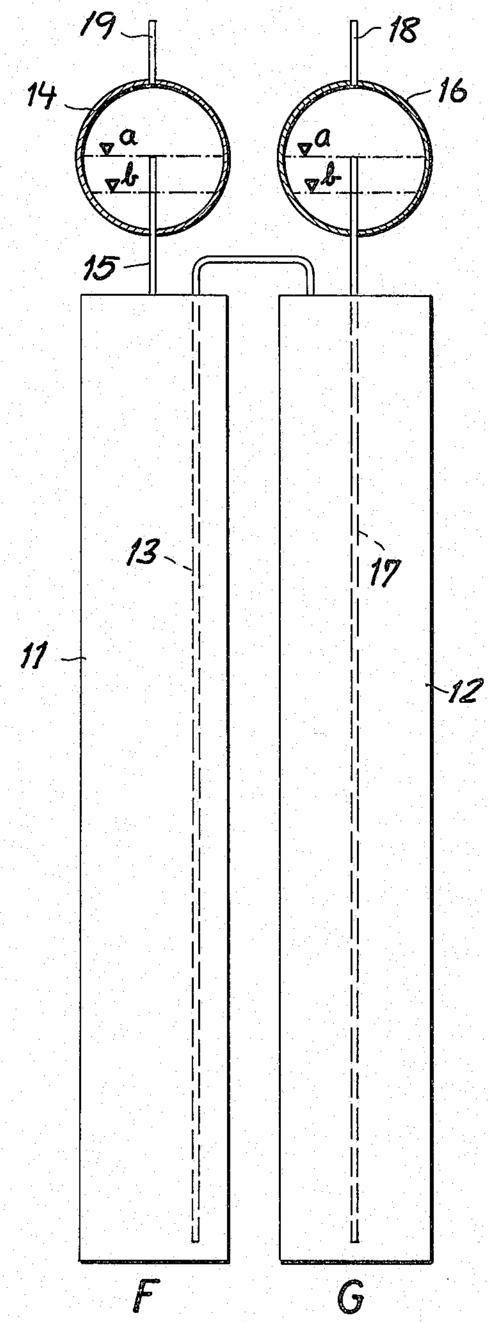

19
18
14
16
a
b
a
b
15
13
17
11
12
F
G

FIG. 2

PATENTED MAY 13 1975 3,882,685

SHEET 2 OF 3

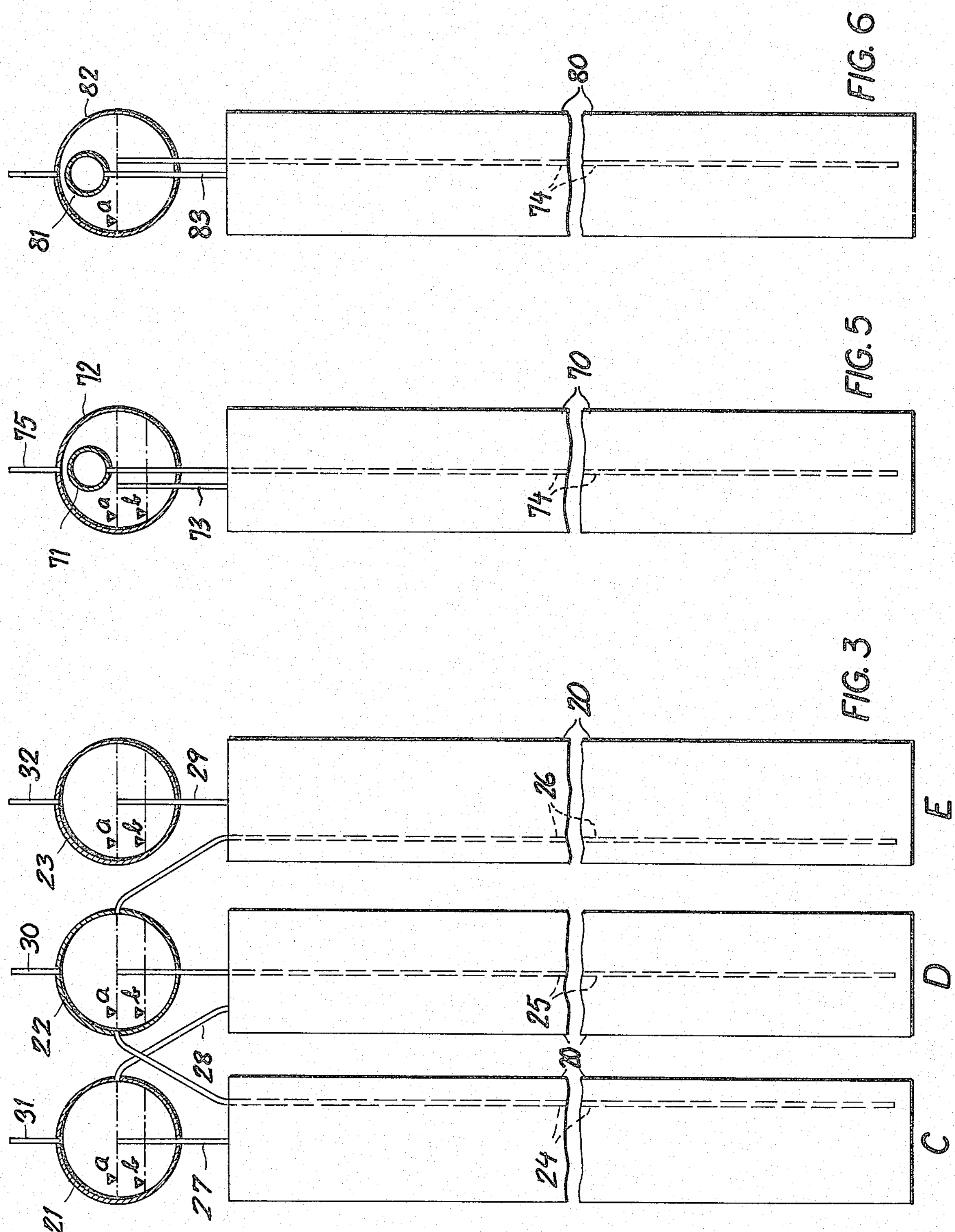


FIG. 6

FIG. 5

FIG. 3

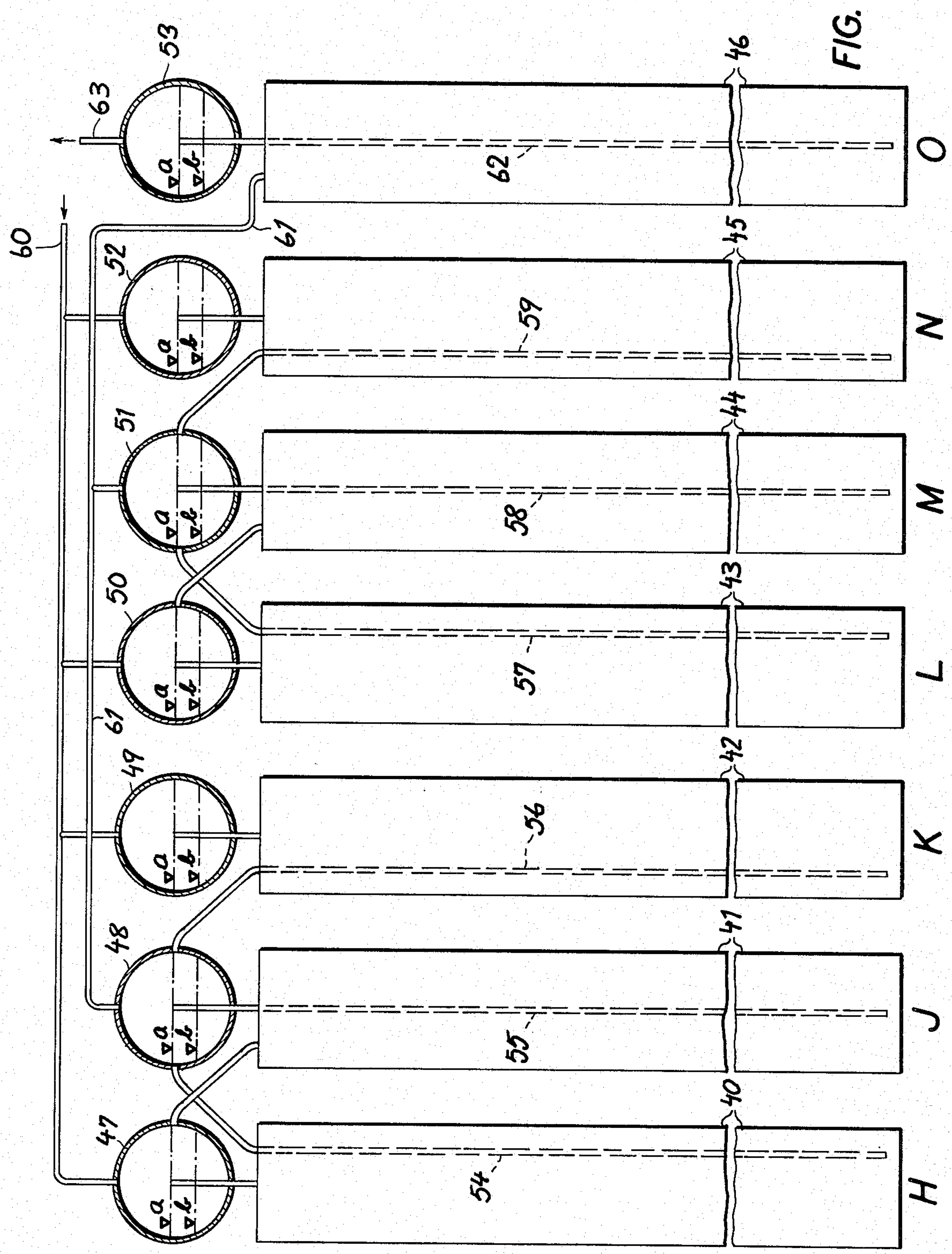

63
53
60
61
52
51
50
61
49
48
47
a
b
62
59
58
57
56
55
54
46
45
44
43
42
41
40
O
N
M
L
K
J
H

FIG. 4

METHOD OF AND APPARATUS FOR THE LOW-TEMPERATURE LIQUEFIED GAS

FIELD OF THE INVENTION

The present invention relates to a method of and an apparatus for the transport of liquefied gases at temperatures below their boiling point and especially such low-temperature liquefied gases as liquefied methane or natural gas; more particularly, the invention relates to the transport of such low-temperature liquids in an environment at a temperature above the boiling point of the liquid, with vertically elongated vessels or receptacles disposed in a storage space, generally the hold of a tanker or other ocean-going conveyance.

BACKGROUND OF THE INVENTION

As has been described in the aforementioned copending applications, it has been found to be advantageous to supply regions poor in fuel and petrochemical starting materials with liquefied methane or natural gas obtained from regions rich in such products by liquefaction of the gas at the extraction location, transport of the liquefied gas at temperatures below its boiling point via ocean-going vessels such as tank ships, and storage of the liquefied gas followed by regasification at a distribution or consumption site.

It has been proposed, more specifically, to transport liquefied natural gas in the thermally insulated hold of a tank ship or like ocean-going vessel by providing within this closed storage compartment a multiplicity of upright and generally vertically elongated vessels or receptacles which may be charged and discharged in succession, in groups or in parallel with one another. In general, the pressure in such vessels remains at ambience or only slightly thereabove during the transport and may be raised to a somewhat higher pressure when the liquefied gas is discharged, e.g. by applying pressure above the level of liquid in the receptacle to drive the liquefied gas upwardly and outwardly through a tube reaching towards the bottom of the vessel or receptacle.

Following discharge a limited quanity of the liquefied gas is frequently retained in the bottom of each vessel or receptacle to serve as a cooling medium for the vessel so that recooling of the system is not required when the receptacles are to be charged with the liquefied gas at the filling station.

While the retention of a small quantity of the liquefied gas required that a corresponding proportion of the receptacle be unavailable for delivery capacity, the loss in capacity is outweighed by the saving of energy and gas which would otherwise be necessary to bring the system down to a suitable temperature. Furthermore, fluctuations in the temperature of the vessel are not desirable because of the thermal stresses created thereby and the difficulties resulting from expansion and contraction of the parts of the chambers or the individual vessels and the duct systems provided therefore.

Thus, as a practical matter, it has been found to be advantageous to retain a small quantity of the liquefied gas at a temperature flow below its boiling point in the bottom of an upright vessel which has a width and even a girth in the horizontal plane which can be small relative to its height or length.

However, with such upright and vertically elongated vessels, it has been found that there is an unavoidable penetration of heat into the insulated compartment and a consequent heating of the regions of the receptacle which are remote from the retained quantities of liquefied gas. In other words, the presence of the small quantities of retained liquefied gas at the bottom of each receptacle does not prevent warming of the upper portions at the tops of these receptacles by, for example, a convection current rising between the receptacles. The problem becomes more pronounced as the height of the tank is increased, and, of course, it is desirable to have tanks which are as tall as can be accommodated in the storage compartment of the ship. In short, the thermal conduction of the walls of the individual compartments or receptacles and the heat-absorbing capacity of the retained volume of liquefied gas, does not insure maintenance of the upper portions of each receptacle and the space enclosed thereby at the desired low temperatures.

Consequently, upon filling of the vessels or receptacles at the source of the liquefied gas, a portion of the liquefied gas must be consumed in bringing the upper parts of the receptacles to the storage and transport temperatures. It has been found to be impractical to operate with receptacles of small height and in which the warming effect would be minimal, because this approach reduces the capacity of each vessel or receptacle, increases the number of receptacles which are required and consequently increases the proportion of the total load carrying capacity which must remain filled with the liquefied gas for the return trip as the cooling medium.

OBJECTS OF THE INVENTION

It is, therefore, the principal object of the present invention to provide an improved method of operating a multivessel storage compartment for the transport of low-temperature liquefied gases whereby the aforedescribed disadvantages may be obviated and vaporization losses on filling the vessels can be reduced.

It is another object of the invention to provide a system for the transport of liquefied gas, especially liquefied natural gas, whereby the aforedescribed disadvantages are obviated and improved efficiency can be attained with low loss.

It is still another object of the invention to provide a method of and an apparatus for the transport of a low-boiling liquefied gas in individual receptacles or vessels in an insulated compartment which is capable of holding the evaporation loss on filling to a minimum and yet is effective with relatively tall vessels.

SUMMARY OF THE INVENTION

The above and other objects of the invention are attained with a system in which at least the return transport of the storage system is carried out under conditions in which the primarily empty storage vessels are cooled with a cooling system effective at the upper portions of these vessels.

More particularly, the invention comprises a method of operating a system for the transportation of liquefied gases at temperatures below their boiling point which comprises filling a multiplicity of vertically extending storage vessels in a thermally insulated cargo compartment of a conveyor with liquefied gas at or below the transport temperature, transporting the liquefied gas by displacing the conveyance from the filling site to the discharge site, primarily emptying each of the vessels or compartments at the discharge site while retaining in each compartment a minor quantity of the liquefied gas to maintain a relatively low temperature during the return transport of the conveyance, returning the conveyance from the other discharge site to the charging site, and cooling the upper portions of the vessels during the return passage using a cooling arrangement or system specifically designed to prevent the development of large temperature gradients between the upper portion of each tan (cooled by the auxiliary system) and the lower portions of each tank cooled by the residual liquefied gas.

The heat which penetrates from the exterior to the upright vessels during the return transport of the conveyance generates in the region of each vessel an upwardly moving convection current which promotes heating of the container in its upper regions. According to the invention, this upwardly moving heat is dissipated or removed so that the upright vessels remain cold even during their return transport so that evaporation and concommitment energy loss, upon the next filling of the upright vessel, is held to a minimum.

The cooling system according to the invention may be a conventional cooling circuit having a coolant (refrigerant) in heat exchanging relationship with the upper portion of the upright vessel. The coolant can be a deep-cooled gas or a supercooled fluid which is heated in contact with or in heat-exchanging relationship with the upper portion of the upright vessel, but most advantageously is a cooled liquid which is evaporated in heat-exchanging relationship with these upper portions. In the latter case, the heat abstracted by the refrigerant or coolant is made up of part of the latent heat of evaporation abstracted upon transformation of the coolant liquid to gas.

It has been found to be especially economical for the coolant to be constituted at least in part by the low-boiling liquefied gas transported by the system and especially when all of the coolant is constituted thereby. Of course, another coolant or refrigerant can be provided in addition to this low-boiling liquefied gas.

According to a further feature of the invention, the cooling system is provided in the form of one or more vessels which are at least partly filled with the coolant or are traversed thereby, the auxiliary receptacles being disposed above the upright liquefied-gas storage vessels. These auxiliary receptacles provide heat-exchange surfaces above the storage compartment, abstract heat from the rising convection gas streams.

The geometric form of the auxiliary receptacles is also important. When the compartment is provided with a plurality of upright liquefied-gas storage vessels, it is preferred to provide the auxiliary vessels with a greater horizontal dimension than vertical dimension and to dispose these auxiliary receptacles in a prone position.

The filling of the prone vessel or vessels with a portion of the low-boiling liquefied gas can be carried out simply during the filling or emptying of the upright liquefied-gas storage vessels. In this case the system need not be provided with additional devices such as pumps or blowers to displace the liquid into the prone vessels since the apparatus provided for filling and emptying the storage vessels can be used directly for this purpose.

An apparatus for carrying out the method of the present invention can comprise a multiplicity of upright liquefied-gas storage vessels within a thermally insulated storage compartment and, also disposed in the latter, auxiliary receptacles with horizontal dimensions greater than their vertical dimension and a generally prone orientation, the auxiliary receptacles being connected via conduits with the lower portion of at least one upright storage vessel. In other words, at least one of the storage vessels is provided with a dip or siphon tube which reaches downwardly into the vessel, preferably to the surface of the residual liquefied gas therein and communicating at its upper end with one or more of the auxiliary cooling receptacles disposed above the bank of storage vessels.

The connection of the prone auxiliary-cooling receptacles with the upright storage vessels, according to the present invention, serves to cool the storage vessels with low-boiling liquefied gas at least partly displaced into the auxiliary receptacles during the emptying thereof.

As described in the aforementioned copending application, an increased pressure is applied to the storage vessels above the level of the stored liquefied gas therein to drive the liquid out of the vessel via a dip or riser tube, whereas in prior systems these tubes communicate with a main conduit and extend via other ducts to a land site. In the system of the present invention, at least one of these storage vessels is emptied through one or more of these auxiliary cooling receptacles, i.e. the liquefied gas passes first into the auxiliary receptacle and then is displaced toward the land storage or regasification site. Since the upright vessel is emptied, the dip tube connecting it with the auxiliary storage vessel is closed, e.g. by means of a valve, so that the liquid now contained in the prone auxiliary receptacle cannot return to the upright storage vessel from which it was displaced. This conduit preferably communicates with the central region of the prone auxiliary-cooling receptacle so that an automatic control, without additional valves, may be provided, to insure that sufficient coolant will be retained in the prone or auxiliary cooling receptacle. This quantity is the amount which fills a prone receptacle to its median level.

In this connection it should be noted that "middle region" of a prone vessel need not be the precise geometrical center but is a region, intermediate the upper and lower wall, in which the upstanding riser tube terminates and which corresponds to the quantity of liquefied gas determined to be advantageous for the auxiliary cooling process.

When a multiplicity of upright storage vessels is provided within the compartment, it has been found to be advantageous to provide a number of cold-storage members, i.e. a multiplicity of prone receptacles disposed above the respective upright vessels. The intermediate regions of at least several of the prone receptacles are connected with the lower regions of respective upright vessels. The intermediate regions of the remaining prone receptacle can then be connected with the upper regions of other upright vessels. In this manner all of the prone or auxiliary cooling receptacles receive the liquefying gas during filling and emptying and enable portions of low boiling liquefied gas to be returned to the storage vessel as the residue facilitating cooling during the return trip.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which FIGS. 1. through 6 are flow diagrams illustrating various embodiments of the present invention.

SPECIFIC DESCRIPTION

In FIG. 1 I have shown an embodiment of the invention, for a tankship of the type generally described in the aforementioned copending application and which thus comprises a thermally insulated cargo-carrying compartment having a multiplicity of upright liquefied-gas storage vessels or tanks close spaced apart and formed with means for filling and emptying the tanks. Neither the compartment nor such means has been shown in detail in the present case and it will be understood that the compartment and the charging and discharging means can be of the type described in the aforementioned copending applications. The upright liquefied-gas storage vessels are connected in rows A and B which extend horizontally (perpendicular to the plane of the pipe in FIG. 1), each row being associated with a prone receptacle **2** or **3**. In the illustrated embodiment, row A of the upright gas-storage vessels **1** is disposed immediately below the horizontal tank or receptacle **2** while row B of the storage vessels **1** is disposed immediately below the horizontal tank **3**. As also has been shown in FIG. **1**, the width w of each tank **1** perpendicular to the direction in which the row extends is a small fraction of the length L of the vessel **1** and preferably the length lies vertically. The diameter D of the horizontal tank **2** associated with each row is equal to the width w while the tanks **1** and **2** of each row have a common vertical plane P through their respective axes.

Riser tubes **4** and **5** extend from one or more storage vessels **1** of each row upwardly into the overlying horizontal receptacle **2** or **3** so that the end **4**a of each of these tubes lies at a distance r above the bottom of the horizontal tank to determine the level a of liquefied gas to be retained therein. Similarly, the bottom end **4**b of each of the riser tubes **4, 5**, terminates slightly above the bottom of the vessel **1** and defines the level c of liquefied gas to be retained therein upon emptying.

At the beginning of the return trip of the tankship, the liquefied gas in each upright vessel **1** lies at the level b while the liquefied gas within the tanks **2** or **3** lies at the level a, substantially at the ends **4**b and **4**a of the tube **4**. With continued evaporation during the return trip, the bodies of liquid at the base of the upright vessel **1** maintain the lower portion of each storage vessel cool, i.e. substantially at the storage temperature of the liquefied gas, while convection heating is precluded by the cooling of the ambient gas around the tanks **2** and **3** by heat exchange through the walls thereof with gradual evaporation of the liquefied gas retained therein. Thus the upper portions of the storage vessels **1** are likewise cooled. The vapors arising from such evaporation are vented via lines **6** and **7** communicating with the uppermost portions of the receptacles **2** and **3**.

During filling of the vessels **1** at the gas-liquefaction site, liquefied gas may be introduced through a tube reaching to the bottom of each vessel and the gases thereabove vented in the manner described in the aforementioned copending application. Upon emptying of the vessels **1** at the gasification site with gas at an atmospheric pressure, e.g. **2** atms. is supplied to each of the storage vessels **1** above the liquid level therein, e.g. through a central gas duct **8** and the branch lines **9** and **10**. The liquid is thereby displaced upwardly through the tubes **4** and **5** into the receptacles **2** and **3**, thereby filling the latter and thereafter driving the liquid out of the system through lines **6** and **7** to the gasification plant or some other storage facility. Upon termination of the operation, lines **8** through **10** are vented to restore ambient pressure to each of the storage vessels **1**, whereupon the level of liquid in tanks **2** and **3** sinks to the level a, the liquefied gas returning to the storage vessels **1** serving to cool the bottoms of each of the latter. The level a of liquid thus remains for the beginning of the return trip.

When a cooling in the lower portion of the upright vessel **1** is not required, the lines **6** and **7** can extend downwardly substantially to the level a and thus eliminate any residual liquid above the level a and precluding the return of liquid from the horizontal receptacles **2** and **3** to the upright receptacles **1**.

In FIG. **2**, we show a modification in which rows F and G of upstanding, vertically elongated vessels **11** and **12** are provided as storage and transport vessels. The bottom portion of each vessel **11** is connected via line **13** to the upper portion of a vessel **12** of the neighboring row. A pipe **15** here rises to the level a at the center of a horizontal receptacle **14** overlying the row F of upstanding vessels **11** and communicates with the top of at least one of these vessels. Another pipe **17** rises to the level a within the horizontal receptacle **16**, but reaches downwardly into a vessel **12** just short of the bottom thereof. Vent pipes **18** and **19** are provided from the tops of the horizontal receptacles **14** and **16**.

During the filling and emptying of the system, the horizontal receptacles **14** and **16** are completely filled with the liquefied gas. During the filling of the upright vessels **11, 12** the liquefied gas is first fed via line **18** into the horizontal receptacle **16**. Since this has been filled to the level a liquid passes through the tube **17** into upright vessel **12** or row G and then via lines **13** into upright vessel **11** of row F. Finally, the liquid reaches line **15** and fills the tank **14** to the level a thereof. When the level a is reached in both of the horizontal receptacles **14** and **16**, the filling process is terminated. During emptying of the system gas is forced under elevated pressure through line **19** and via line **15** into the top of receptacle **11**. The liquid is displaced through line **13** and vessel **12** until the liquid is fully driven out of the system except for residual liquid at the base of each storage vessel **11, 12** and in the tanks **14** and **16** to level a therein. During the return passage of the ship, evaporation losses cause a drop in the liquefied gas in the horizontal tank to the level b. During the payload passage, liquid in the tanks **14** and **16** also evaporates to maintain cooling and then a drop in the level is replenished at discharge in the manner stated.

In the system of FIG. **3**, three rows of upright vessels **20** are provided at C, D and E, linked together as will be apparent hereinafter. Each row is provided with a horizontal receptacle **21, 22** or **23**. In this embodiment, the horizontal receptacle **22** associated with the intermediate row D is connected at its horizontal median plane (level a) with tubes **24** and **26** dipping substantially to the bottom of the tanks or vessels **20** of the outer rows

C and E. The region at the horizontal median plane of horizontal receptacle **21** is connected by a line **28** to the top of upright vessel **20** of row D while another tube **27** connects this region to the top of a corresponding vessel of row C. Another line or tube **29** connects the top of a vessel **20** of row E with the intermediate region of the horizontal receptacle **23** associated with this row. During the return passage of the ship horizontal receptacle **21** and **23** contained liquefied gas to the level *b* and receptacle **22** contains liquefied gas to the level *a*. The wall of the uppermost portions of vessels **20** is effected by evaporation of liquid in the receptacles **21** through **23**.

The system is charged by supplying liquid via line **30** to the tank **22** from which the liquid, upon reaching the level *a* therein flows to the vessels **20** or rows C, D and E to drive gas from these vessels through lines **27**, **28** and **29** and lines **31** and **32**. When the vessels **20** are filled, the liquid rises to the level *a* in the horizontal receptacles **21** and **23**. The filling process is ended when the level *a* is attained in all of the horizontal receptacles.

During the payload passage, liquid evaporates from the receptacles **21** through **23** to bring the level of liquid therein to that represented at *b*.

During the emptying of the upright vessels **20**, gas at an elevated pressure is supplied via lines **31** and **32** into the horizontal receptacles **21** and **23** and, via lines **27** and **29**, to the upright vessels **20** of rows C and E. The liquid is driven through tubes **24** and **26** into the horizontal receptacle **22** and emerges at line **30**. Similarly gas pressure is applied via line **28** to the top of the horizontal vessel **20** of row D and the liquid therein is driven through line **25** and receptacle **22** from the system via line **30**. When the several upright vessels **20** are emptied to the extent that no further liquid is driven therefrom, the application of gas pressure is terminated at line **31** and **32** and the liquid in receptacle **22** above the level *a*, flows to each of the upright vessels **20** to form the sump liquid therein serving to cool the lower portions of each of these upright vessels. The liquid remains at the level *a* at the start of the return trip only in receptacle **22**.

Because of the relatively simple system for filling the horizontal receptacles the arrangement of FIG. **3** has the important advantage that within the upright vessels substantially no buffer volume is provided about the liquid surfaces therein. A buffer volume is provided for the entire system above the liquid level *a* in receptacle **21** and **23** during the payload passage of the ship and hence the overall transport capacity of the ship is increased.

The principles of FIGS. **1** through **3** are also applied, as shown diagrammatically in FIG. **4**, to five or more rows of upright vessels. In FIG. **4**, the upright vessels **41** through **46** are provided in rows H–O, each with a respective horizontal receptacle **47–53** overlying the row. The alternate horizontal receptacles **48** and **51**, each between a pair of other horizontal receptacles **47**, **49** and **50**, **52**, respectively, are connected by lines **54**, **55**, **56** and **57**, **58**, **59** to the vessels **41–42** and **43–45** as described for the three row assembly of FIG. **3**. Upon loading of the tankship, all of the upright vessels are filled and liquefied gas attains the level *a* in all of the overlying receptacles **47** through **53** as described for the system of FIG. **3**.

To empty the system, gas pressure is applied via central gas-supply line **60** to the horizontal receptacle **47**, **49** and **50**, **52**, thereby driving the liquid outwardly from all of the upright vessels **40–45** via the central receptacles **48** and **51**; and, via line **61** to the top of vessel **46**. The liquid is driven from this vessel **46** via a line **62** leading to the horizontal receptacle **53** and then through line **63** to the land station. Upon such emptying, the horizontal receptacles **47**, **49**, **50** and **52** contain liquid to the levels *b* while receptacles **48**, **51** and **53** retain liquid to the level *a*. During the return passage, evaporation of liquid in the receptacles maintains cooling of the upper portion of the upright vessel.

FIG. 4 shows how the principles of the invention can be extended practically to any number of rows of upright vessels with any desired retention of the coolant in the horizontal receptacle. Only the change in the liquid level in vessel **46** need be monitored to determine when emptying is complete.

FIGS. 5 and 6 illustrate another embodiment of the invention in which individual rows of upright vessels may each be provided with two horizontal receptacles of different diameters.

In FIG. **5**, the horizontal receptacle **72** of each row of upright vessels **70** receives an inner receptacle **71** of relatively small diameter. One of the outer receptacles **72** is of larger diameter. Both of the horizontal receptacles **71** and **72** are connected to the upright vessel **70**, the connections including a line **73** opening at the level *a* and at the top of the upright vessel **70** and a line **74** opening into the vessel **71** and close to the bottom of the upright vessel **70**. The liquid in receptacle **72** is supplied during the filling of the tankship. Thus liquefied gas is directed via the inner receptacle **71** which here acts as a central supply duct, and passes via line **74** to each of the upright vessels **70**. The liquid flows via line **73** into the outer receptacle **72** and, when liquid no longer is fed to the system, the level falls to that represented at *a*. During the payload passage, the liquid level may fall to that represented at *b*, the difference being represented by evaporation of liquid during the cooling of the upper portion of the vessel. During emptying of the system, a pressurizing gas is applied at fitting **75** to drive liquid from the system via line **74**. No additional coolant need be provided for the receptacle **72**. The advantage of this arrangement lies in the greater safety provided by enclosure of receptacle **71** in receptacle **72**.

The embodiment of FIG. **5** differs from that of FIG. **6** in that the immersion tube **74** here reaches to the level *a* of the outer horizontal receptacle **82** and substantially to the bottom of the upright vessels **80** while the tube **83** communicates between the inner receptacle **81** and the top of the upright vessels **80**. After emptying of the upright vessels **80**, the discharging gas blows through the system without disturbing the retained liquid at level *a* which is employed for cooling of the upper portion of the upright vessels **80** during the return passage.

I claim:

1. In the transport of a liquefied gas at a temperature below its boiling point in an insulated cargo compartment of a conveyance having a plurality of upright vertically elongated storage vessels disposed in said compartment with a horizontally extending receptacle overlying said vessels, connected thereto by a riser tube and in heat-exchanging relationship with ambient gases around upper portions of said vessels between a location in which the liquefied gas is loaded into said vessels and at a location at which the liquefied gas is discharged from the vessels, the improvement which comprises the following steps:

a. maintaining in said vessels a level of said liquefied gas above the base of said vertically elongated storage vessels to cool the vessels to preclude the necessity of recooling of the vessels when the vessels are to be charged with the liquefied gas at the filling station;
b. filling the vertically elongated storage vessels from said level to their tops and filling the horizontally extending receptacle overlying said vessels to a location at an intermediate distance between the bottom and the top of said horizontal receptacle with the liquefied gas to form a liquid-gas interface at said location; and
c. maintaining the level of the liquid-interface in the horizontal receptacle substantially at said location to insure an adequate amount of the liquefied gas is available in said horizontal receptacle to effect heat exchange with said vertically elongated storage vessels by vaporization of the liquid-gas interface.

2. In a liquefied-gas storage and transfer system comprising a thermally insulated compartment and a plurality of upright vertically elongated liquefied gas-storage vessels in said compartment, the improvement which comprises the following elements:

a. a horizontally extending receptacle overlying said vessels and in heat-exchanging relationship with ambient gases around upper portions of said vessels; and
b. a riser tube extending upwardly from a location near the bottom of one of said storage vessels into the horizontally extending receptacle and to a location in the interior thereof, said tube opening into the interior of said receptacle at a location above the bottom of the receptacle and as an intermediate distance between the bottom and the top of said horizontal receptacle to maintain a liquid-gas interface in said receptacle substantially at said intermediate distance between the bottom and top of said horizontal receptacle to cool said receptacle by vaporization at said interface.

3. The improvement defined in claim **2** wherein said riser includes a duct communication between said receptacle and a lower portion of at least one of said vessels.

4. The improvement defined in claim **3** wherein said duct opens substantially at a central portion of said receptacle between the top and bottom thereof.

5. The improvement defined in claim **3** wherein at least two such receptacles are provided and one of said receptacles is connected by said duct to a lower portion of said one of said vessels, said riser including a further duct connecting the other receptacle to an upper portion of one of said upright vessels.

6. The improvement defined in claim **3** wherein said vessels are arranged in at least one row, said receptacle overlying and extending along said row.

7. The improvement defined in claim **6** wherein a plurality of said rows are provided, each with a respective one of said receptacles, said riser including a respective duct connecting at least some of said receptacles with lower portions of the vessels of respective rows.

8. The improvement defined in claim **7** wherein said riser includes duct connecting to the receptacles to upper portions of the vessels of respective rows.

9. The improvement defined in claim **8** wherein said riser includes ducting connecting at least some of said receptacles to vessels of the respective row and other ducts connecting the same receptacles to the vessels of adjoining rows at bottom portions thereof.

10. The improvement defined in claim **8** wherein one of said receptacles is received in another of said receptacles.

* * * * *