Dec. 17, 1963 L. P. MEADE 3,114,344

SHIP FOR TRANSPORTING VOLATILE LIQUID AND PROCESS

Filed Sept. 4, 1962 3 Sheets-Sheet 1

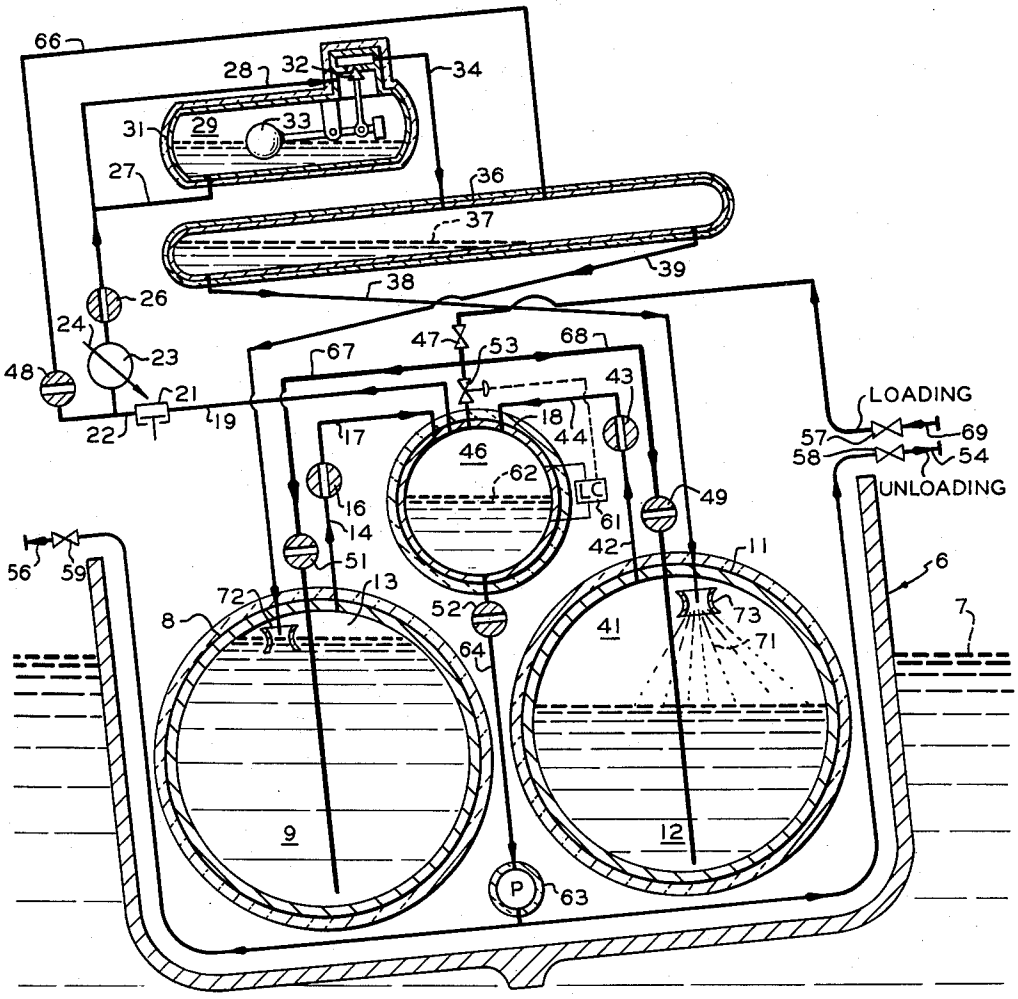

FIG. 1

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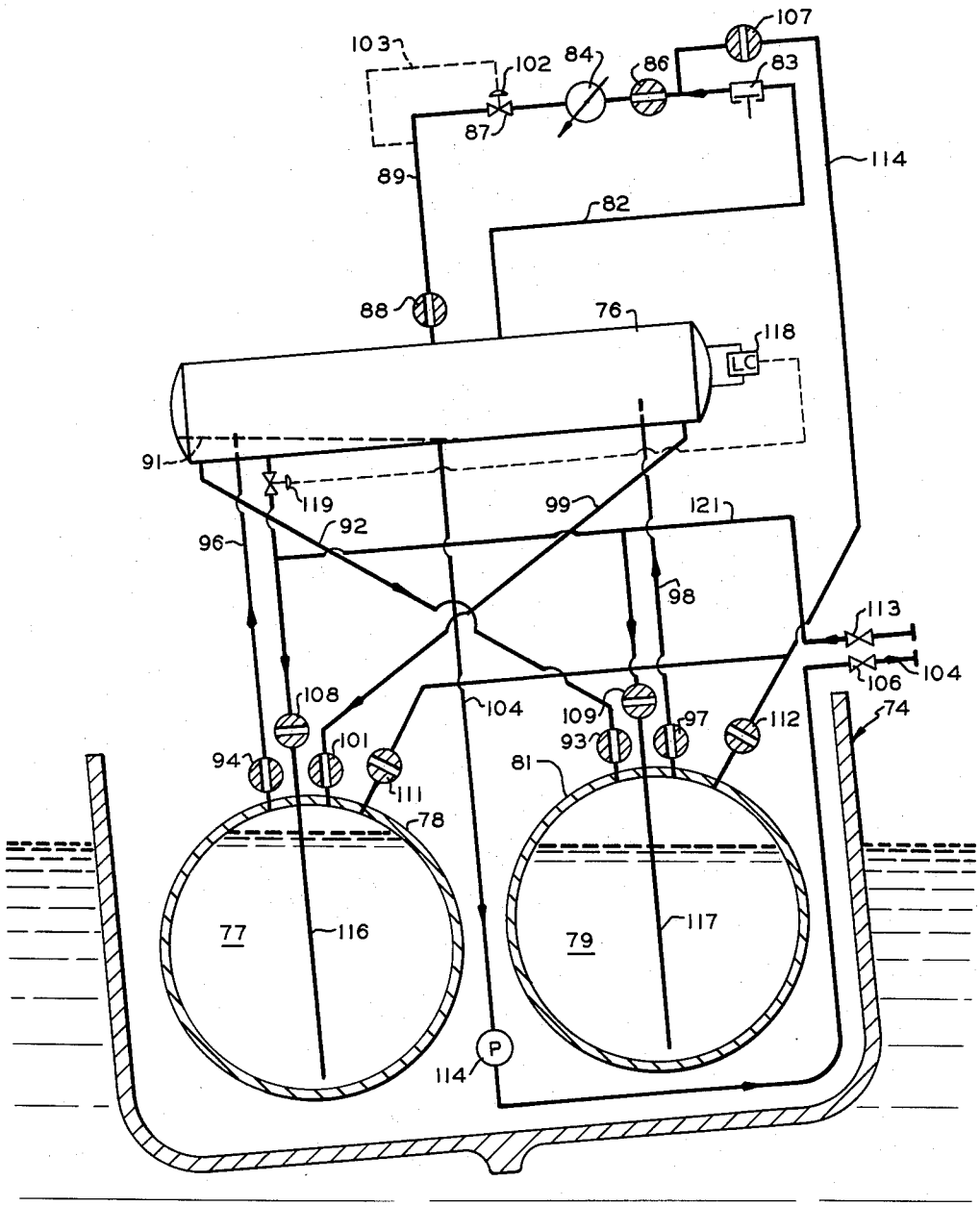

FIG. 2

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SHIP FOR TRANSPORTING VOLATILE LIQUID AND PROCESS

Filed Sept. 4, 1962 3 Sheets-Sheet 3

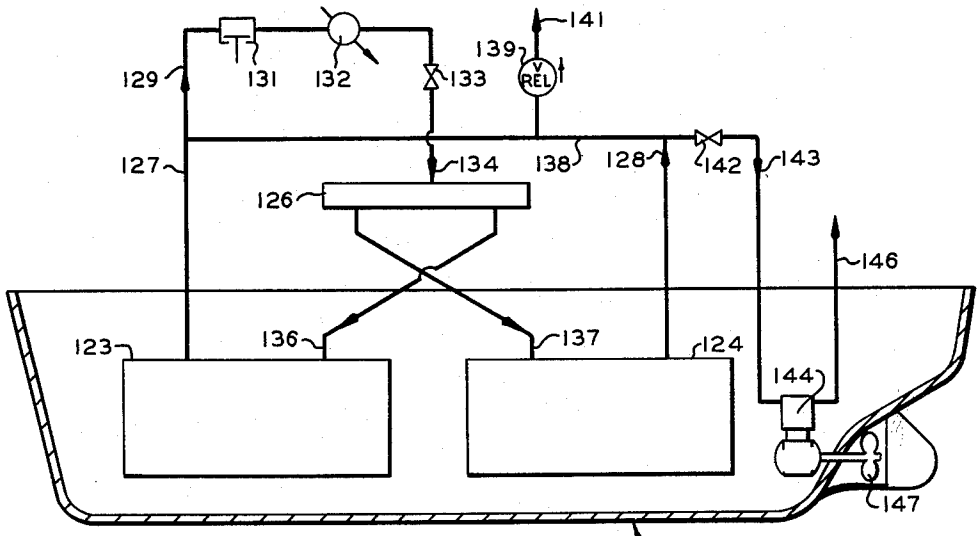

FIG. 3

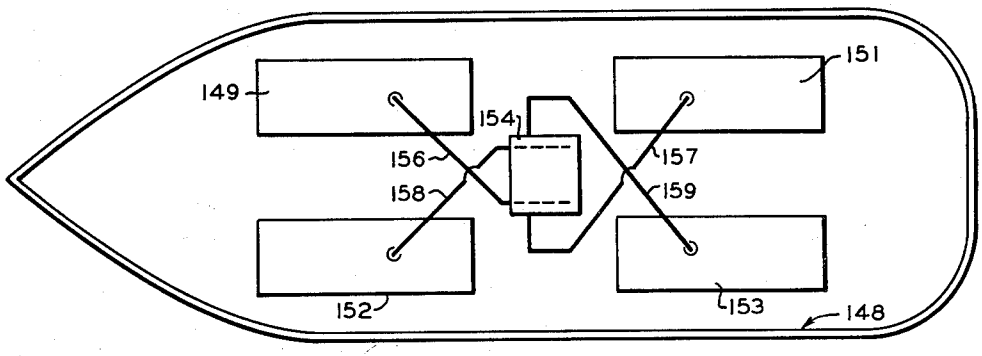

FIG. 4

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3,114,344

SHIP FOR TRANSPORTING VOLATILE LIQUID AND PROCESS

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12 Claims. (Cl. 114—74)

This invention relates to tank ships for transporting volatile liquids, systems for controlling said liquids, and processes involving the same. In one aspect it relates to an automatic tank trimming system and a process of operating the same for volatile liquid transporting ships. In another aspect it relates to refrigerated liquefied gas transporting ships, and processes and systems for controlling the liquefied gas.

In the prior art in the transportation of volatile liquids, particularly liquefied gases that would be gases at atmospheric temperature and pressure, and more particularly those liquefied gases which must be transported in refrigerated condition in order to reduce their vapor pressure to that which can be contained in tanks of relatively light construction, numerous tank ships have been designed with a plurality of cargo tanks. One difficulty with these ships of the prior art is that when sailing on a given course, especially in the morning or afternoon, one or more of these tanks are heated more by the sun than the others. This results in increased evaporation in the tanks more exposed to the rays of the sun, with the result that these tanks become lighter than the remaining less-exposed tanks, resulting in the ship listing toward the portion of the ship containing the less-exposed and, therefore, heavier tanks. In a ship having a single line of tanks running axially from bow to stern, the listing to be corrected would be a listing to fore or aft. However, in most ships the plurality of cargo tanks are divided so that one or more are on the port or starboard side of the ship, respectively, in which case the listing is to port or starboard, which generally is more serious than any listing fore or aft, principally because the length of the ship is generally several times that of the width of its beams.

One of the advantages of the present invention is that it provides an apparatus and the process of righting a listing ship having a plurality of horizontally-spaced cargo tanks containing a volatile liquid by collecting the vapors from the tanks, compressing, cooling and condensing at least a portion of said vapors into liquid, and selectively returning at least the major portion of this liquid to one of said tanks that is located on said ship in a direction opposite to the direction in which it lists, whereby said ship is at least partially righted. At the same time, especially if the volatile liquide is a liquefied gas, the same equipment and process described above for righting the listing ship is at the same time reducing the vapor pressure in all the cargo tanks and may even be refrigerating the liquefied gas, or even maintaining its temperature below the critical point at which it could not exist as a liquid regardless of its pressure. At the same time, the system disclosed as embodying the invention includes in combination other features, such as spraying the returning liquid into the vapor space of the cargo tank, thereby absorbing vapor and reducing the pressure in the cargo tank, especially when sprayed into a venturi vapor-entraining device or similar constricted zone and/or in combination with means to provide at all times a high enough hydrostatic head of liquid above the liquid cargo unloading pump to prevent vaporization in the pump as the last portion of the volatile liquid cargo is being discharged from the liquid cargo tanks.

One object of this invention is to provide a novel and useful ship for transporting volatile liquids, including liquefied gases.

Another object is to provide a suitable system for the control of such volatile liquids during the transportation thereof.

Another object is to provide suitable processes for the operation of such ships and systems.

Another object is to provide a system and process for righting ships that list due to unequal vaporization of volatile liquids in a plurality of cargo tanks therein.

Further objects are to provide in such systems and processes the reduction of vapor pressure in the tanks, the provision of refrigeration for the volatile liquids and the elimination of vapor formation in the cargo unloading pump.

Numerous other objects and advantages will be apparent to those skilled in the art upon reading the accompanying specification, claims and drawings.

In the drawings:

FIGURE 1 is a schematic cross-sectional view taken along the beam of a ship embodying the present invention in which the ship is listing toward the left side of the drawing and the invention has started operating to correct this list and right the ship. This embodiment includes separate cargo discharge and liquid distributing tanks.

FIGURE 2 is a view of the same type as FIGURE 1 of a ship embodying a second species of the invention in which there is a single combined cargo discharge and liquid distributing tank instead of the two separate tanks shown in FIGURE 1.

FIGURE 3 is a schematic cross-sectional view of a third species of the invention taken along the central plane of a ship having only one fore and one aft liquid cargo tank. It should be noted that the liquid distributing tank has been oriented along the axis of the ship in order to compensate for fore and aft listing.

FIGURE 4 is a schematic plan view of a fourth species of the invention in which there are two sets of cargo tanks, one set being forward and the other set being aft, one tank of each set being a starboard tank and the other a port tank. By making the liquid distributing tank square and feeding the liquid from the opposite corner to the respective cargo tank, both fore and aft and starboard and port listing can be compensated for.

In FIGURE 1 a tank ship, generally designated as 6, floating on a body of water 7 is shown listing toward the left side of the drawing. Assuming the view is taken in the direction of the bow of the ship, the ship is listing to port due to the fact that the port cargo tank 8 contains more volatile liquid cargo 9 than the starboard tank 11 contains volatile liquid cargo 12. This condition of having more volatile liquid 9 in tank 8 than volatile liquid 12 in tank 11 may have been due to the heating rays of the sun (not shown) having been directed more on tank 11 than on tank 8 while the ship was on a certain course during the morning or afternoon, but the reason why there is more liquid in tank 8 than in tank 11 is immaterial to the operation of the invention, and the invention will work to equalize this level regardless of its cause.

This equalization of level is accomplished by withdrawing vapor 13 from tank 8 through line 14, valve 16, line 17, tank 18 and line 19 and vapor 41 from tank 11 through line 42, valve 43, line 44, tank 18 and line 19 to compressor 21 by the suction of compressor 21, which compresses the vapor and forces the same through line 22 into indirect heat exchanger-condenser 23. Condenser 23 may be indirectly cooled by any available cooling fluid 24, such as the atmosphere, or some of water 7 forced through condenser 23 by a conventional pump (not shown). When condenser 23 is suitably cooled, some of the compressed vapor from line 22 is condensed to a liquid and this liquid and/or vapor passes through valve

26, most of the liquid passing through line 27 and most of the vapor passing through line 28 into chamber 29 of tank 31. As the pressure goes up and the temperature goes down, the vapor in space 29 condenses into the liquid therein. Tank 31 has an outlet controlled by valve 32 moved by float 33, which moves said valve to open said outlet when the liquid in said tank rises above a set point and close said outlet when said liquid falls below said set point. Obviously, when condenser 23 is cooling properly, tank 31 soon floods with liquid, valve 32 opens, and liquid and/or vapor passes through both lines 27 and 28 through valve 32 and line 34 into an elevated liquid distributing tank 36 extending athwart ship disposed horizontally to the beam of the ship and elevated above said cargo tanks 8 and 11. The inclination of the liquid level 37 in tank 36 depends upon the degree of listing of the ship and, as shown, liquid 37 is concentrated mostly in the port side of tank 36. The port side of tank 36 is connected by a liquid drain conduit 38 to the starboard cargo tank 11, while the starboard end of tank 36 is similarly connected to the port cargo tank 8 by a liquid drain line 39. As shown, the major portion of liquid 37 will drain through line 38 into tank 11 and only a minor portion, or merely some vapor, will pass through line 39 into cargo tank 8. As a result liquid accumulates in tank 11, raising the level of liquid 12 so that it will approach the level of liquid 9 in tank 8, and liquid in tank 8 will vaporize into vapor space 13 and be carried off to compressor 21 as explained above.

At the same time as vapor 13 is being moved from tank 8, some vapor 41 is being removed from tank 11 through line 42, valve 43 and line 44, into vapor space 46 in tank 18, from which it is drawn through line 19 to compressor 21, as lines 17 and 44 communicate through the vapor space 46, and this equalizes the pressure in vapor spaces 13 and 41. As valves 47, 48, 49, 51 and 52 are all closed during this process of redistributing the volatile liquid cargo to reduce the listing of this ship, in effect conduits 17 and 44 are connected to conduit 19, and tank 18 becomes merely a portion of conduit 19 and could be eliminated except for the function of tank 18 as a cargo discharge tank, which will be explained below. The position of valve 53 is immaterial during this process of redistribution, as valves 47, 49 and 51 are closed.

The volatile liquid cargo 9, 12 and 62 may be any volatile liquid known to commerce, such as liquid methane, ethane, ethylene, propane, butane, pentane, anhydrous ammonia, or the like, or mixtures of the same, which liquid has a relatively high vapor pressure, the vapors of which may be compressed, cooled, condensed to liquid, and returned to the tanks. For some of these liquids, such as liquid butane or pentane, no heat insulation is absolutely necessary on the tanks and pipes, but for others, such as liquid methane, it would be highly uneconomical to not provide suitable heat insulation on the exterior surfaces of all the equipment in all the figures of the drawings. As any engineer can design such heat insulation, it has not been shown in the drawings except in FIGURE 1, as it would only complicate the drawings. It should be understood that while not absolutely necessary, it is preferred to design and build each ship with a layer of heat-insulating material of suitable thickness for the most volatile liquid said ship is being built to carry, and to place this insulation around every tank, pipe, valve and pump that will contain said liquid at below atmospheric temperature. A ship can be economically designed for carrying a plurality of liquids, each liquid at a different time, such as a ship designed to carry ammonia, propane, butane or mixtures of propane and butane, which ship would not be economical for methane transportation because the thickness of insulation desirable for liquid methane would not be provided.

In FIGURE 1, for example, for such a propane or ammonia ship all the fluid containing apparatus is heat insulated, except compressor 21 and condenser 23, by a blanket of heat-insulating material, such as glass wool, cork, or other insulation at least an inch thick. The same insulation would be employed in the species shown in all the other figures, although not shown therein to simplify them.

When the ship 6 and its cargo reach its destination and dispensing line 54 or 56 (or both) is connected to means (not shown) to receive the liquid cargo, valves 16, 43, 26, 47 and 57 are closed, valves 48, 49, 51, 52, 58 and 59 are opened and valve 53 is opened by liquid level control 61 whenever the liquid level 62 in tank 18 falls below a predetermined point and closed whenever said level rises above said point. Of course, if only one of unloading lines 54 or 56 is being used, the valve 58 or 59 in the other line remains closed. A pump 63 is provided for unloading cargo and is driven by any suitable source of power (not shown). Pump 63 may be any type of pump, but preferably is a centrifugal pump. Because of the head of liquid provided in line 64 and tank 18 between liquid level 62 and pump 63, the pump will run liquid full and will not cause vaporization of the liquid, no matter where the level of liquid 9 in tank 8 and liquid 12 in tank 11 may be, and pump 63 may be located above the bottoms of tanks 8 and 11 (or even above the tops of tanks 8 and 11) and still operate liquid full. Obviously, it is advantageous to be able to locate pump 63 above the bottom of tanks 8 and 11 because this enables these tanks to be placed as low as possible in the ship, which results in greater stability and resistance to listing of the ship.

During the unloading, not only is pump 63 pumping liquid out the bottom of tank 18, but compressor 21 is removing vapor from tank 18 through line 19. As it is not desirable to condense this vapor in line 22, valve 26 is closed and valve 48 is open, by-passing condenser 23 and valve 32 through line 66 into tank 36. As only vapor is entering tank 36, liquid 37 rapidly drains down line 38 into tank 11 and the vapor from compressor 21 then flows down both lines 38 and 39 into both tanks 8 and 11. The resulting superior pressure in spaces 13 and 41 over the pressure in space 46 then forces liquid 9 and 12 up liquid discharge pipes 67 and 68 and into tank 18 through valve 53 whenever said valve is open, thus maintaining liquid level 62 the desired distance above pump 63 to prevent vaporization of liquid in the pump 63 or unloading lines 54 and 56.

When the ship is being loaded, of course valves 58 and 59 should be closed, and after loading line 69 is connected to a suitable source of liquid (not shown), valves 57, 47, 49 and 51 are open and the liquid flows by gravity or pressure from said source into tanks 8 and 9 through loading line 69 and lines 67 and 68 as indicated. During this loading it is preferred to have valves 16, 43 and 26 open and valve 48 closed, and to run compressor 21 so that the vapor in spaces 13 and 41 of tanks 8 and 11 is removed through lines 14, 17, 42, 44 and 19, compressed in compressor 21, condensed to liquid in condenser 23 and returned as a liquid through lines 27, 28 and 34, tank 36, and lines 38 and 39, as described above in describing the process of redistributing the volatile cargo, which process starts during this loading period. When the loading is completed, valve 57 is closed and line 69 disconnected from the source of supply.

While not essential to the invention, it is preferred in returning the liquid through line 38 to tank 11 and line 39 to tank 8 to have the liquid spray out as a cone of liquid droplets 71. This naturally occurs as shown in space 41 of tank 11 when the liquid emerges from the lower end of an ordinary pipe 38, but may be augmented by supplying the lower end of pipes 38 and 39 with any conventional spray nozzle or spray head (not shown). In addition, it is preferred to surround the lower ends of pipes 38 and 39 with means aiding the entrainment of vapor by the spray 71, such as venturis 72 and 73. The liquid spray 71, especially when vapor from space 41

is being entrained therein by the reduced pressure in the throat of the venturi **73** created by said spray, absorbs some of the vapor in the vapor space and thereby lowers the vapor pressure in the tank in which the spray is located, both during loading and during redistribution of the liquid cargo.

In FIGURE 2 a second species of the invention is shown installed in a ship **74**. Ship **74** is essentially the same as ship **6**, except it contains a single, combined cargo discharge and liquid distributing tank **76** instead of the two separate tanks **18** and **36** of FIGURE 1. Ship **74** is shown listing to the left side of the drawing because there is temporarily more liquid **77** in tank **78** than there is liquid **79** in tank **81**.

This liquid is redistributed in FIGURE 2 by pumping vapor out of the top of tank **76** through line **82** by suction from compressor **83**, which compresses the vapors, which are then cooled and condensed into liquid by indirect heat exchange with cooling fluid in condenser **84** and returned as liquid through valves **87**, and **88** and line **89** to tank **76**. The liquid entering tank **76** accumulates in the bottom of the left end of the tank as indicated by dotted line **91** and then drains down through line **92** and valve **93** into tank **81**, thereby increasing the level of liquid **79**. At the same time vapor is evaporating from the surface of liquid **77** and is passing through valve **94**, line **96**, tank **76** and line **82** into compressor **83**, so the liquid level in tank **78** is falling. In time this redistribution of liquid balances the tanks **78** and **81**, which rights the ship. While vapor can pass through valve **97** and line **98** into tank **76**, there is still a net gain in the tank **81** of liquid coming down line **92**, because as long as the ship is listing as shown, there will be no liquid coming down the opposite drain line **99** through valve **101** into tank **78**. Liquid cannot come down either line **96** or **98**, because their upper ends extend into tank **76** well above the drain lines **92** and **99**.

While a float valve like **31** of FIGURE 1 could be used in place of valve **87**, in FIGURE 2, and vice versa, it is preferred sometimes to use motor valve **87** designed to open whenever the pressure in line **34** or **89** transmitted to the motor **102** through control line **103** falls below a predetermined value. The temperature of liquid **91** in tank **36** or **76** depends on the pressure in line **34** or **89**, respectively, and by opening and closing valve **87** in response to this pressure the temperature is controlled at a constant level.

When it is desired to unload the ship of FIGURE 2, unloading line **104** is connected to a receiving tank (not shown) and then valves **106**, **107**, **108**, **109**, **111** and **112** are opened and valves **113**, **86**, **88**, **94**, **101**, **93** and **97** are closed. Compressor **83** draws vapor from tank **76** through line **82**, compresses said vapor and pumps it through valve **107** and line **114** and valves **111** and **112** into tanks **78** and **81**. The superior vapor pressure in tanks **78** and **81** over that in tank **76** drives liquid **77** and **79** up liquid withdrawal pipes **116** and **117** into tank **76** until the liquid level rises to a predetermined level at which level control **118** closes valve **119**. When this level falls, then control **118** will reopen valve **119**. In this manner, a head of liquid above pump **114** sufficient to prevent the liquid vaporizing in pump **114** and discharge line **104** is maintained at all times, and yet the bottoms of tanks **78** and **81** can be in the bottom of the ship and lower than pump **114**.

The tanks **78** and **81** can be loaded by connecting loading line **121** to a source of supply of the volatile liquid (not shown) under superior pressure and opening valves **113**, **108** and **109**.

FIGURE 3 shows a ship **122** having only one fore cargo tank **123** and one aft cargo tank **124**. It should be noted that the liquid distributing tank **126** has been oriented along the axis of the ship in order to compensate for fore and aft listing. As described with relation to the previous figures, the vapor from tanks **123** and **124** flows into lines **127** and **128** through line **129** to compressor **131**, which compresses the same so that it may be condensed to liquid in condenser **132** and returned through valve **133** (which may be like valve **32** or valve **87**) and line **134** to tank **126**. The liquid in the lower end of tank **126** returns to whichever of tanks **123** or **124** is the highest through line **136** or **137**. While not shown in the other figures, it should be understood that in any figure it is common to have a transfer line **138** containing a pressure relief valve **139** leading to the atmosphere at a safe point, such as stack **141**, while the vapor can also be drawn off through throttle valve **142** and intake line **143** as fuel for internal combustion engine **144** having exhaust stack **146**. Engine **144** turns propeller **147** to drive the ship through the water.

In FIGURE 4, ship **148** has four cargo tanks **149**, **151**, **152** and **153** located to fore and aft and port and starboard as shown. The liquid distributing tank **154** is square and the liquid drains from the lowest corner of the distributing tank **154** to the highest cargo tank through the respective drain line **156**, **157**, **158** or **159**.

In order to simplify FIGURE 4, the means for removing vapor from tanks **149**, **151**, **152** and **153**, compressing this vapor, condensing the same to liquid, and supplying this liquid to liquid distributing tank **154** has not been shown, as they are obviously the same as lines **127**, **128** and **129**, compressor **131**, condenser **132**, valve **133** (which may be like valve **32** or like valve **87**) and line **134** in FIGURE 3.

Obviously, any engineer would supplement the essential systems shown in each of the figures with the usual relief valves, check valves, manual shut-off valves, pressures gauges, liquid level gauges, and such other fittings that seem desirable to him, without departing from the invention disclosed and claimed herein.

Various materials of construction known to the refrigeration art may be substituted without departing from the present invention. One new heat insulation material that is especially good for nautical use is foamed glass, in which gas in solution in the molten glass under pressure is allowed to expand upon reduction of the pressure to form a great number of unconnected bubbles as a discontinuous phase in the continuous solid glass phase. This is sold as "Foamglas" and "Foamsil" by Pittsburgh Corning in slabs, pipes, half pipes and other shapes, and a four-inch blanket made of this material is very effective insulation and will not absorb moisture or induce corrosion of tanks or pipes under it.

While the invention has been described with reference to preferred illustrative embodiments, it is believed obvious that the invention is not limited thereto.

Having described my invention, I claim:

1. A ship having a plurality of horizontally-spaced cargo tanks for containing a volatile liquid, means for collecting vapor from said tanks and compressing, cooling and condensing at least a portion of said vapors into return liquid, and means to return said return liquid to said tanks, said last means being selective when said ship lists in one direction to return at least a major portion of said return liquid to one of said tanks that is located in the opposite direction on said ship, whereby said ship is at least partially righted.

2. The combination of claim 1 in which there is means in each tank disposed to spray the returning return liquid into the vapor space in said tank, whereby some of the vapor therein will be condensed, and the vapor pressure in said tank will thereby be reduced.

3. The combination of claim 2 in which a venturi is disposed in said vapor space and said means to return said return liquid is disposed to spray said liquid axially through said venturi, whereby vapors will be entrained by the resulting suction in said venturi and will be more intimately mixed with said sprayed liquid, and thereby will be more readily at least partially condensed.

4. A ship having a port tank and a starboard tank adapted to contain volatile liquid and an athwart ship tank disposed horizontally relative to the beam of said ship at an elevation above said port and starboard tanks, means to draw vapors from said port and starboard tanks and compress said vapors, means to cool and condense at least a portion of said compressed vapors into a return liquid, conduit means to return said return liquid to said athwart ship tank, conduit means for said return liquid connecting a port portion of said athwart ship tank to said starboard tank, and conduit means for said return liquid connecting a starboard portion of said athwart ship tank to said port tank, whereby at least a major portion of said return liquid will return to the one of said port and starboard tanks that is on the high side of said ship whenever said ship is listing.

5. The combination of claim 4 in which the conduit means to return said return liquid to said athwart ship tank comprises a valve in said conduit, and a motor opening said valve responsible to the pressure downstream of said valve dropping below a set value and closing said valve when said pressure rises above said set value.

6. The combination of claim 4 in which the conduit means to return said return liquid to said athwart ship tank comprises a tank in said conduit, a valve in said conduit downstream of said tank, and a float in said tank responsive to a rise in liquid level therein to open said valve and upon a fall in said level to close said valve.

7. A ship having a port and a starboard cargo tank for volatile liquids, an elevated cargo discharge tank, and an elevated liquid distributing tank extending athwart ship disposed horizontally to the beam of the ship and elevated above said cargo tanks, a liquid cargo unloading first conduit connected to a lower portion of said elevated cargo discharge tank and containing a pump positioned a substantial distance below said elevated cargo discharge tank, a valve in said first conduit, second and third vapor conduits connecting the upper portion of said elevated cargo discharge tank with the upper parts of said cargo tanks, a valve in each of said second and third conduits, fourth and fifth liquid withdrawal conduits connecting a lower portion of said cargo tanks with an upper portion of said elevated cargo discharge tank through a valve controlled to open at a set liquid level in said elevated cargo discharge tank and close when the liquid therein is above said level, said fourth and fifth conduits each having a valve therein, liquid drain conduits each connected to one side of said elevated liquid distributing tank and connected to the cargo tank on the other side of the ship, a sixth conduit connected to the upper portion of said elevated cargo discharge tank, a compressor, condenser, and liquid flow control valve in series in said sixth conduit, said sixth conduit being disposed to discharge liquid into said elevated liquid distributing tank.

8. The combination of claim 7 in which the condenser and liquid flow control valve are connected in said sixth conduit in parallel with a by-pass, and valves are disposed to control the flow through the condenser and through the by-pass.

9. The combination of claim 7 in which the liquid flow control valve in the sixth conduit comprises a tank having a liquid inlet and a vapor inlet connected to the upstream portion of said sixth conduit and an outlet connected to the downstream portion, a valve controlling said outlet, and a float moving said valve to open said outlet when the liquid in said tank rises above a set point and close said outlet when said liquid falls below said set point.

10. A ship having a port and a starboard cargo tank for volatile liquids, an elevated cargo discharge and liquid distributing tank extending athwart ship disposed horizontally to the beam of the ship and elevated above said cargo tanks, a liquid cargo unloading first conduit connected to a lower portion of said elevated tank and containing a pump positioned a substantial distance below said elevated tank, a valve in said first conduit, second and third vapor conduits connecting said elevated tank with the upper parts of said cargo tanks, a valve in each of said second and third conduits, fourth and fifth liquid withdrawal conduits connecting a lower portion of said cargo tanks with said elevated tank through a valve controlled to open at a set liquid level in said elevated tank and close when the liquid therein is above said level, said fourth and fifth conduits each having a valve therein, liquid drain conduits each connected to one side of said elevated tank and connected to the cargo tank on the other side of the ship, a sixth conduit connected to the upper portion of said elevated tank, a compressor, condenser, and liquid flow control valve in series in said sixth conduit, said sixth conduit being disposed to discharge liquid into said elevated tank.

11. The combination of claim 10 in which a by-pass seventh conduit is connected to the sixth conduit between the compressor and the condenser and connected to the cargo tanks, with valves in said seventh conduit and in said sixth conduit between said condenser and said seventh conduit disposed to control the flow through said condenser and through said by-pass.

12. The combination of claim 10 in which the liquid flow control valve in the sixth conduit comprises a downstream constant pressure control valve.

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