June 7, 1966 R. BECKER 3,254,498

METHOD OF AND APPARATUS FOR THE TRANSPORTATION AND STORAGE OF LIQUEFIABLE GASES

Filed Aug. 7, 1964

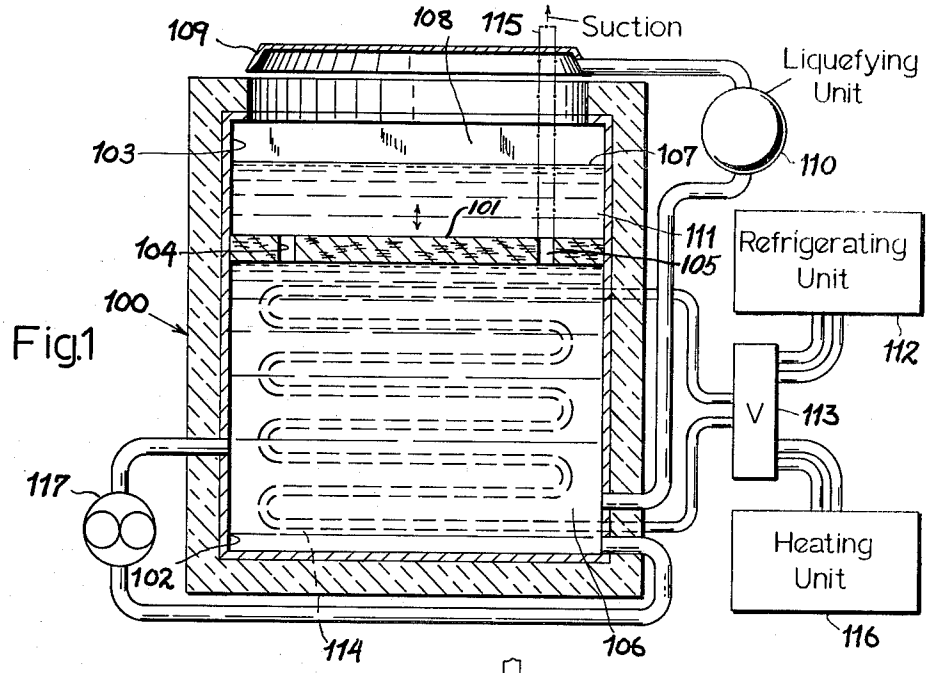


Fig.1

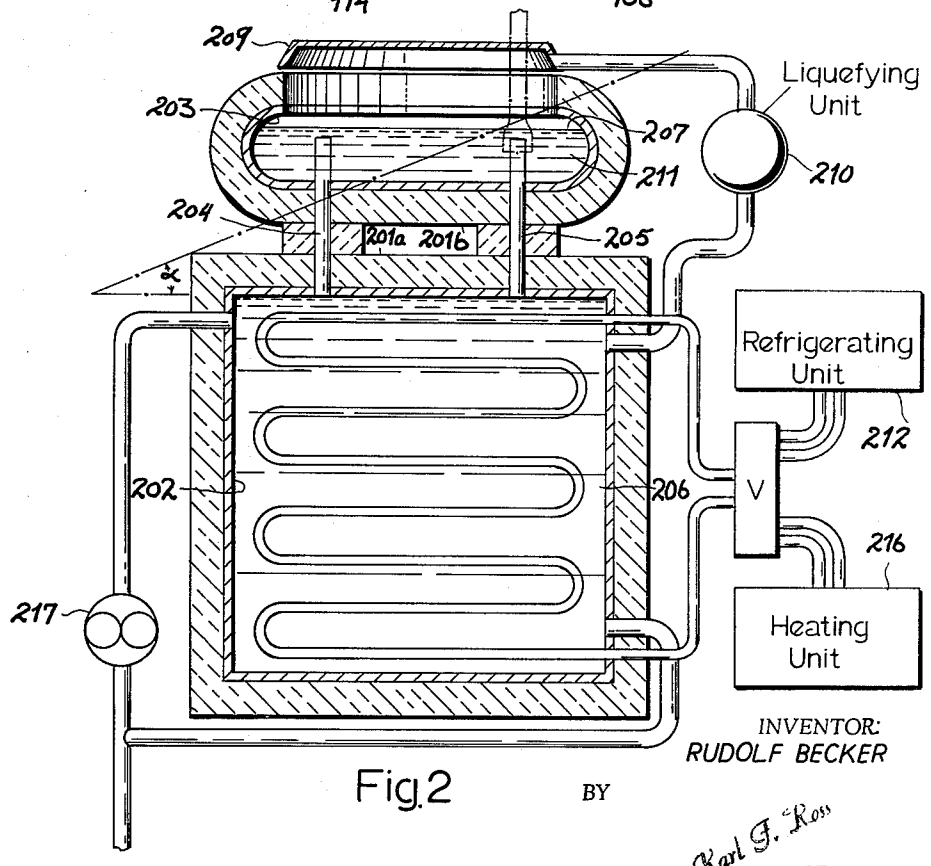


Fig.2

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United States Patent Office

3,254,498

Patented June 7, 1966

3,254,498

METHOD OF AND APPARATUS FOR THE TRANSPORTATION AND STORAGE OF LIQUEFIABLE GASES

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Filed Aug. 7, 1964, Ser. No. 388,216
Claims priority, application Germany, Aug. 9, 1963, G 38,436
10 Claims. (Cl. 62—45)

The present invention relates to a method of and an apparatus for the storage and transportation of industrial gases which are liquefiable and, more particularly, those gases which can be maintained in a condensed state at ambient pressures in insulated vessels.

With time, it has become an increasingly widespread practice to transport and store gases, which can be maintained in a liquid state at ambient or atmospheric pressure, in thermally insulated vessels; storage tanks and other receptacles for the liquefied gases are carried in ships, on railroads and in motor vehicles, while liquefied-gas storage tanks are common at manufacturing plants and distribution centers. Typical gases stored and transported in this manner are those substances whose boiling point at atmospheric pressure is less than the ambient temperature but not so low that, in practice, the gas must be maintained at elevated pressures to keep it in a liquid state. Gases which are liquefiable at ambient pressure and can be stored in thermally insulated receptacles include ammonia (boiling point at standard pressure=—33.4° C.), hydrocarbons such as methane (boiling point S.P.=—161° C.), ethane (boiling point S.P.=—88.6° C.) and propane (boiling point S.P.=—42.5° C.) as well as fluoro-carbons of the type widely known under the trade name Freon (e.g. chlorodifluoromethane). These compounds are typical of the gases to which the present invention is applicable.

In general, the storage vessels for the liquefied gas are open to the atmosphere, although highly insulated, so that a vapor/liquid interface is present within the chamber in which the liquid mass is stored. The existence of this free surface frequently results in a considerable loss of the stored gases because of the relatively continuous evaporation of gases from the liquid phase at the free surface. It has been proposed heretofore to reduce the losses by providing the apparatus with a refrigerating or compressing system whereby vapors are removed from above the surface and condensed for return to the liquid mass. Additionally or alternatively, circulating means were provided to equalize the temperature within the liquid mass so that there was no tendency for certain portions of the mass to be at a higher temperature than others and thus more prone to volatilization. Both the cooling and the circulating devices were relatively expensive and complex.

It is the principal object of the present invention to provide an improved method of and apparatus for the storage and transportation of gases, which can be stored in the liquid state at ambient pressure, whereby the aforementioned disadvantages can be eliminated and complex cooling and circulating means can be dispensed with.

Another important object of this invention is to provide a method and apparatus of this character adapted to reduce losses during the storage and transportation of liquid gases.

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, by a method of storing and transporting liquefied gases whereby the liquid is introduced into a thermally insulated first chamber and confined therein at atmospheric pressure in a mass free from the formation of any vapor/liquid interface within this chamber; the first, relatively large chamber is connected with a second, relatively small chamber in which a liquid/vapor interface can be maintained. The passage connects the first and second chambers to maintain them both at ambient or atmospheric pressure, the second chamber being preferably open to the atmosphere; the passage is relatively narrow, according to an important feature of this invention, to restrict heat exchange between the contents of the two chambers. The narrow passage can be a bore or a tube extending through a thermally insulated partition separating the chambers from one another.

A more particular feature of this invention resides in the step of cooling the mass within the first chamber below the boiling point of the gas so that the mass is undercooled and at least partially solidified, so that the heat of fusion given up by the mass is sufficient to compensate, over the duration of storage thereof, for the potential heat absorption during temperature rise from its initial storage temperature to the boiling point of the gas at ambient pressure. The temperature of the mass within the large chamber can be equalized by means of a circulating device while, if desired, a cooling or compressing system can be provided for liquefying vapor from the small chamber and returning it to the first chamber. The passage or passages communicating between the chambers should be insulated sufficiently to reduce absorption of heat by the mass whether in the interior of the first chamber or in the passages. It is especially important, for the present purposes, that the mass within the first chamber completely fill the latter and extend to or into the passages so that no free surface can develop above the mass. The second chamber normally serves only to take up liquid driven out of the first chamber by expansion, hold vapors volatilizing from the interface in the passages should such an interface exist, and retain temporarily the liquid or vapor discharged from the first chamber when the apparatus is to be emptied. From the small second chamber the liquid or vapor can be dispensed as required.

According to a further feature of this invention, a free surface is prevented from forming above the stored mass by surmounting it with a partition member subdividing a receptacle into the first and second chamber mentioned above and provided with the passages (e.g. in the form of bores). This partition means is composed of a cellular material, preferably sheet or particulate cork, and has a specific gravity less than that of the mass so that it floats thereon and automatically compensates for variations in the volume of this nonvaporous mass. Thus the partition moves upwardly and downwardly in accordance with the volume of the mass within the larger chamber. The specific gravity of the partition should be such that the liquid of the mass partially climbs into the passage.

According to another aspect of this invention, the two chambers can be separated by a fixed wall or partition means or can even be spaced considerably free from one another. In this case, the passages are formed by upright tubes projecting from the partition into the second chamber and having a length above the first chamber sufficient to prevent discharge of the mass through the maximum rolling of the apparatus (with respect to the vertical) during transportation of the gas (e.g. in a ship or other vehicle).

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:

FIG. 1 is a vertical cross-sectional view through an apparatus according to the present invention wherein a movable partition separates the two chambers; and

FIG. 2 is a vertical cross-sectional view through a modified storage and transportation apparatus.

In FIG. 1, I show an upwardly open, thermally insulated receptacle **100**, which is subdivided by a thermally insulating and vertically movable partition **101** composed of cork or the like, into a relatively large first chamber **102** and a relatively small second chamber **103**. The first chamber **102** communicates with the second chamber **103** via a plurality of narrow apertures or passages **104, 105** which do not permit convection currents to flow between the chambers but maintain the liquid or solid mass **106** within the chamber **102** at atmospheric pressure. The liquefied gas has a vapor/liquid interface designated **107**. This interface can be above the partition **101** as indicated in FIG. 1 or within the passages **104, 105**.

The space **108** above the free surface **107** is a gas chamber which is open to the atmosphere or partially closed by a liquefying arrangement whose hood **109** overlies chamber **108** and draws gas evaporating from the surface **107** into a liquefying unit **110** for return to the first chamber **102**. In the small chamber **103**, the liquid **111** is not cooled below its boiling point so that, by heat exchange with the gas chamber **108** or with the walls of the second chamber **103**, the liquid **111** slowly evaporates. The mass **106** in chamber **102** is, however, strongly cooled via a refrigerating unit **112** connected by a distributing valve **113** to a network of cooling tubes **114** embedded in a wall of the chamber **102**, i.e. the far wall in FIG. 1, to permit the partition **101** to move freely in the vertical direction as it rests upon the mass **106**. The cross-section of the passages **104, 105** is so selected that heat exchange between the first and second chambers is practically nonexistent. Indirect heat exchange through the partition **101** is also sharply reduced.

To fill the first chamber **102**, a conduit **115** can be inserted in one of the passages **105** and can extend therefrom through chamber **103** to the exterior, thereby enabling air within the compartment **102** to be driven out with introduction of the liquefied gas or to permit a source of reduced pressure to be connected to the chamber **102** to facilitate the filling. A heating unit **116** can also be connected to the valve **113** to pass a heating fluid through the pipe **114** and permit the melting of the mass when, as is preferred for the purposes of the present invention, this mass has been cooled to partial solidification. Until solidification, a circulating unit **117** can displace the liquid of mass **106** to equalize the temperature within the first chamber **102**.

The embodiment of FIG. 2 comprises a thermally insulated vessel **202** forming the first chamber which is connected via narrow channels **204, 205** in the form of tubes of thermally insulating material (e.g. glass) with the relatively small second chamber **203** spaced from the first chamber by the walls **201***a*, **201***b*. Chamber **203** is oriented above the first chamber **202** and contains the liquid gas **211** which is not undercooled and has a free surface **207** from which vapors are evolved and are drawn into the hood **209** of a condensing unit **210** for return to the second chamber. Chamber **203** is open to the atmosphere, however, and is at ambient pressure. To prevent liquid from running from the first chamber **202** to the second chamber **203** when the ship or other transportation vessel tilts through its maximum angle α of roll, the length of the tubes **204, 205** is so selected that it is equal to the product of the tangent of angle α and the horizontal distance of the base of the tube from the distal wall of the receptacle in a plane perpendicular to the roll axis of the vehicle. When it is desired to empty the apparatus, a suction pump can be used since the liquid in the first chamber is undercooled. When the fluidity is low, additional gas pressure may be necessary to avoid boiling of the liquid in the ducts. To generate this gas pressure, the heating unit **216** may be used. A circulating pump **217** is provided for equalizing the temperature within the second chamber while a refrigerating unit **212** serves to cool the mass **206** to at least partial solidification.

The invention as described and illustrated is believed to admit of many modifications within the ability of persons skilled in the art, all such modifications being considered within the spirit and scope of the appended claims.

What is claimed is:

1. A method of storing and transporting gas liquefiable at ambient pressure, comprising the steps of

(a) liquefying said gas;

(b) introducing said liquefied gas into a thermally insulated first chamber and confining it therein at atmospheric pressure in a mass free from the formation of a vapor interface with said mass within said first chambers;

(c) cooling the mass within said first chamber to a temperature below the boiling point of said gas at said atmospheric pressure; and

(d) connecting said first chamber with a second chamber containing vapor of said gas at atmospheric pressure via at least one narrow passage in a thermally insulating chamber preventing substantial heat transfer between the mass in said first chamber and the vapor in said second chamber while maintaining said first chamber at atmospheric pressure.

2. A method of storing and transporting gas liquefiable at ambient pressure, comprising the steps of

(a) liquefying said gas;

(b) introducing said liquefied gas into a thermally insulated relatively large-volume first chamber and confining it therein at atmospheric pressure in a mass free from the formation of a vapor interface with said mass within said first chamber;

(c) cooling the mass within said first chamber to a temperature below the boiling point of said gas at said atmospheric pressure and sufficiently low to effect at least partial solidification of said mass; and

(d) connecting said first chamber with a relatively small-volume second chamber open to the atmosphere and containing vapor of said gas at atmospheric pressure above a layer of liquefied gas via at least one narrow passage preventing substantial heat transfer between the mass in said first chamber and the vapor in said second chamber while maintaining said first chamber at atmospheric pressure.

3. The method defined in claim **2** wherein said mass is confined in said first chamber free from a vapor interface by summounting on said mass a freely movable layer of thermally insulating material separating said chambers and resting on said mass, said partition being provided with said passage.

4. The method defined in claim **2**, further comprising the step of equalizing the temperature of said mass by circulating it in said first chamber.

5. The method defined in claim **2** wherein the heat of fusion of the solidified portion of said mass is at least sufficient to compensate, over the duration of storage of said mass, for the potential heat absorption of said mass tending to raise its temperature to the boiling point of said gas.

6. Apparatus for the storage and transporting of gas liquefiable at ambient pressure, comprising a thermally insulated relatively large first chamber confining liquefied gas at atmospheric pressure in a mass free from a vapor interface with said mass within said first chamber; a relatively small second chamber freely communicating with the atmosphere above said first chamber and containing vapor of said gas at atmospheric pressure; and a generally horizontal thermally insulating partition separating said chambers from one another and provided with at least one narrow passage communicating between said chambers but of a cross-section suffiicently small to prevent substantial heat exchange between said chambers said partition resting freely upon said mass and movable

relatively to the walls of said chambers, said mass being at least partly liquid and said partition having a specific gravity less than that of the liquid, and said passage being a bore provided in said partition.

7. Apparatus as defined in claim 6 wherein said partition is at least partly composed of cork.

8. Apparatus as defined in claim 6, further comprising refrigerating means in said first chamber for cooling said mass to solidify at least a portion thereof, and means for circulating said mass to equalize the temperature thereof within said first chamber.

9. Apparatus for the storage and transporting of gas liquefiable at ambient pressure, comprising an upright, upwardly open thermally insulated vessel for receiving liquefied gas; a thermally insulating substantially horizontal partition substantially freely movable within said vessel and floating on a mass of liquefied gas therewithin while subdividing the interior of said vessel into a thermally insulated relatively large first chamber confining said liquefied gas in said mass at atmospheric pressure and free from a vapor interface, and a relatively small second chamber above said first chamber and communicating with the atmosphere while containing vapor of the gas at atmospheric pressure, said partition being provided with at least one bore communicating between said chambers and of a cross-section sufficiently small to prevent substantial heat exchange between said chambers; liquefying means for condensing vapor of said gas emerging from said second chamber and returning the condensate to said first chamber; refrigeration means for cooling the mass within said first chamber to solidify at least a portion thereof; and means for circulating said mass in said first chamber for equalizing the temperature thereof.

10. Apparatus for the storage and transporting of gas liquefiable at ambient pressure, comprising a substantially closed thermally insulated vessel forming a relatively large first chamber for receiving liquefied gas and confining it in a mass at atmospheric pressure and free from a vapor interface; a further upwardly open thermally insulated vessel surmounted on the first-mentioned vessel and forming a relatively small second chamber above said first chamber and in communication with the atmosphere while containing vapor of the gas at atmospheric pressure, the walls of said vessels intermediate said chambers constituting a generally horizontal thermally insulating partition separating said chambers from one another, said partition being provided with at least one narrow passage communicating between said chambers but of a cross-section suffiicently small to prevent substantial heat exchange between said chambers; liquefying means for condensing vapor of said gas emerging from said second chamber and returning the condensate to said first chamber; refrigeration means for cooling the mass within said first chamber to solidify at least a portion thereof; and means for circulating said mass in said first chamber for equalizing the temperature thereof.

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