

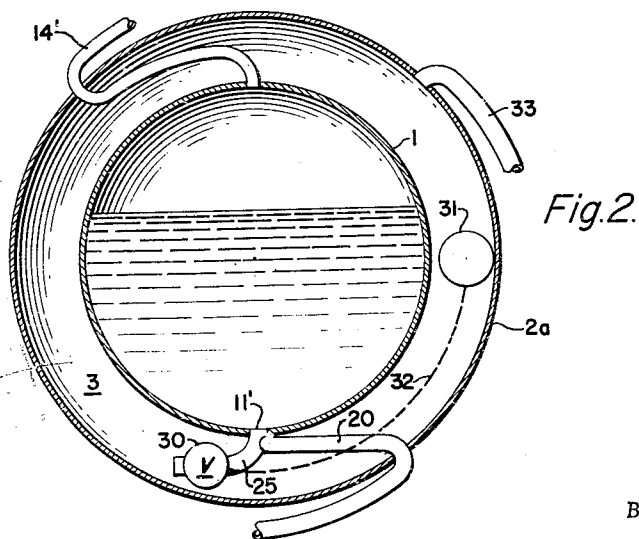
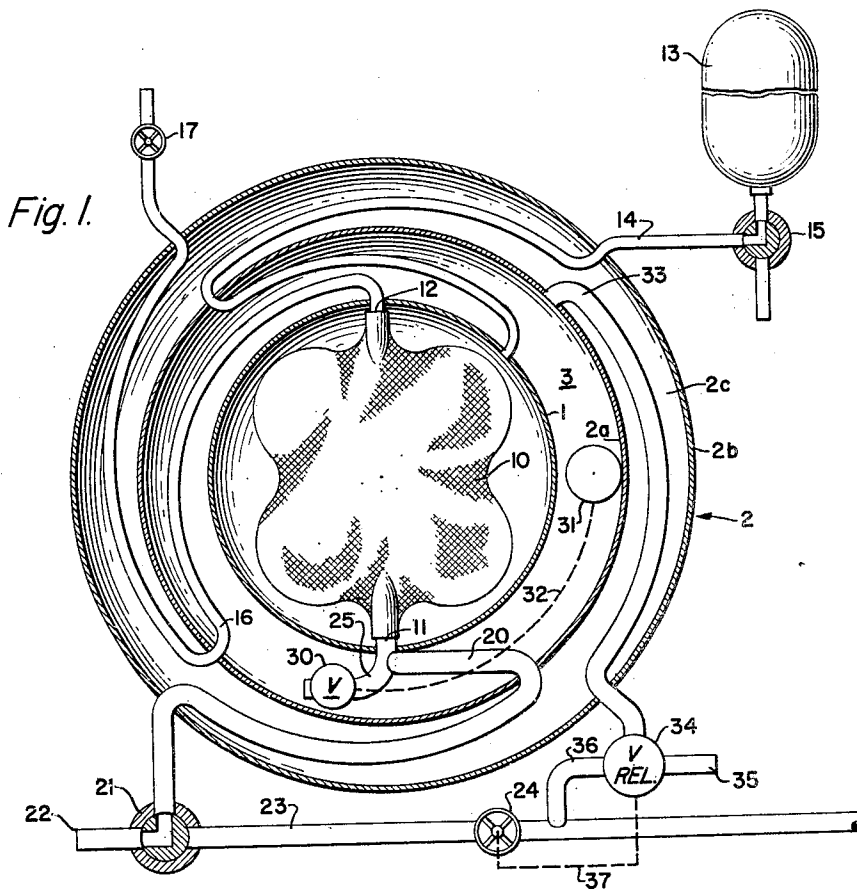
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CONTAINER FOR LIQUEFIED GAS

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CONTAINER FOR LIQUEFIED GAS

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My invention relates to an improvement in liquid storage vessels, and more particularly to a vessel which is specifically adapted for conservative storage of liquefied gases.

When it is required that a substance which normally exists in the gaseous phase at atmospheric pressure and temperature to be stored in the liquid phase for subsequent delivery and use, it is usually desirable that the storage vessel employed for such purpose incorporate conservative means, such as an athermanous envelope, whereby the loss due to evaporation of the stored liquid may be reduced to a minimum. It is well known, for example, to store liquefied atmospheric gases in double-walled containers, commonly referred to as Dewar vessels, wherein the opposing surfaces of the inner and outer walls are made highly reflective and the intermediate space therebetween is evacuated, thereby to oppose both radiant and conductive transfer of heat to the stored liquid. It is also known to conserve a liquefied gas in storage by surrounding the container therefore with an envelope of vapor evolved from the stored liquid, or with an envelope of appropriate insulative material, for example, polystyrene foam or expanded perlite. These and other methods which have been proposed, though effective to oppose transfer of heat to the stored liquid and hence to inhibit evaporation thereof, are at best limited to maintaining the interior of the storage vessel at the saturation temperature of the stored liquid under the prevailing pressure. Thus, when it is required to transfer the liquid from the storage vessel to a point of use, even a slight addition of heat thereto, such as might occur on contact with the interior surface of a pump or transfer line, will suffice to increase the enthalpy of the liquefied gas to the point where boiling will take place and a substantial loss due to vaporization, with consequent risk of vapor lock, hammer, or excessive turbulence in the transfer line, will be incurred. According to my invention, many of the difficulties customarily experienced in the storage of liquefied gases are overcome through the refrigeration thereof to a temperature lower than that at which boiling will occur at the pressure under which the liquefied gas is stored.

It is an object of my invention to provide a self-refrigerated storage vessel for liquefied gas wherein a temperature lower than the boiling point of said liquefied gas is maintained.

It is another object of my invention to provide a storage vessel for liquefied gas wherein a temperature lower than the boiling point thereof is maintained by low pressure evaporation of a portion of said liquefied gas.

It is another object of my invention to provide an apparatus for the delivery of liquefied gas under a variety of conditions of ambient pressure and temperature and under a variety of conditions of attitude and acceleration.

In accordance with these and other objects which will become apparent hereinafter, an exemplary practice of my invention will be described in connection with the accompanying drawings wherein like elements are designated by like reference characters. In the drawings:

FIGURE 1 is a partially diagrammatic cross section illustrating a storage vessel which embodies the invention; and

FIGURE 2 is a cross section illustrating an alternate

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construction for a portion of the storage vessel of FIGURE 1.

Referring to FIGURE 1, in which a storage vessel embodying my invention is shown in conjunction with associated piping and control means therefor, a first or inner vessel 1 adapted to contain a liquefied gas is housed within a second or outer vessel 2 outwardly spaced therefrom so as to define an intermediate chamber 3 wherein a portion of the stored liquid may be evaporated. As shown in the drawing, the outer vessel 2 is preferably provided with an athermanous barrier or heat shield which may take any of a number of well-known forms, but which is here illustrated for exemplary purposes as comprising an outer shell 2b separated from the inner shell 2a of the second vessel by an intermediate space 2c which may preferably be evacuated, thereby to provide, in effect, an athermanous barrier of the Dewar vessel type. The first and second vessels 1 and 2, respectively, may of course, be of any suitable shape, the spherical form which is commonly preferred for the construction of pressure vessels being here shown by way of example only, and may preferably be supported in spaced relation to each other in well-known and appropriate manner, for example, by means of intermediate members of low thermal conductivity (not shown).

The inner vessel 1 is provided internally with a flexible partition or bladder 10 having a liquid port 11 and a vent port 12, the latter preferably being located opposite to the former as shown and being connected by means of a passage 16 with a valve 17 whereby the interior of the bladder may be vented to ambient pressure. The liquid port 11 communicates via a line 20 and a two-way valve 21 with a supply line 22 and a delivery line 23, the latter preferably including a flow regulating valve 24 which may, for example, be provided with control means (not shown) responsive to the demand for liquefied gas. Adjacent to the outlet port 11, the line 20 communicates with a bleed passage 25 whereby a portion of the liquid stored in the bladder 10 may be transferred to the evaporation chamber 3, the bleed passage 25 being provided with regulator means in the form of a valve 30 responsive to a temperature sensitive control element 31 which may be of a well-known type and may preferably be arranged as shown so as to sense the temperature of the evaporation chamber 3 in a region thereof removed from the proximity of the bleed passage 25. It is to be understood that the arrangement shown in the drawing is largely diagrammatic and that the connection between the valve 30 and the control element 31 may include power, amplification or supplementary control means located externally of the outer shell 2, the dashed line 32 serving merely to indicate a functional relation between the respective members.

A regulated source of pressurizing gas 13 communicates with the vessel 1 via a line 14, the latter preferably being provided with valve means, such as the two-way valve 15, whereby the interior of the vessel 1 may be vented to ambient pressure. The internal pressure of the evaporation chamber 3 is regulated at a level lower than that in the vessel 1 by means of a vent line 33 which communicates with a relief valve 34. In the embodiment shown in the drawing, the relief valve 34 is provided with a first outlet path 35 by which the vapor evolved in the chamber 3 may be vented directly to the surrounding atmosphere, and a second outlet path 36 communicating with the liquefied gas delivery line 23. Through the operation of suitable control means which may, for example, comprise a mechanical connection between the delivery valve 24 and the relief valve 34, as indicated by the dashed line 37, vapor evolved in the chamber 3 may be exhausted therefrom via the vent line 33, the relief valve 34 and the outlet path 36, thereby to cool the

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delivery line 23 during such time as no delivery of liquefied gas is required; alternately, when the delivery valve 24 is opened in response to a demand for liquid delivery, the outlet from the relief valve 34 may be transferred from the path 36 to the alternate path 35, thereby to permit the evolved vapor to escape to the surrounding atmosphere.

It is to be understood, of course, that in order to establish the desired pressure difference between the inner vessel 1 and the evaporation chamber 3, it is not essential that the latter be vented to ambient pressure. Where it is desirable, for example, to refrigerate the liquefied gas to a temperature several degrees below the boiling point thereof, the chamber 3 may be placed in communication with any suitable source of low pressure corresponding to the vapor pressure of the liquefied gas at the desired temperature.

Referring to the foregoing discussion of the embodiment of my invention shown in FIGURE 1, a complete cycle in the operation thereof will now be described. In order to charge the container with liquefied gas, the bladder vent valve 17 is opened, the interior of the first vessel 1 is vented to ambient pressure by means of the two-way valve 15, and the interior of the bladder 10 is placed in communication with the liquefied gas supply line 22 by means of the two-way valve 21. When a desired quantity of liquefied gas has been transferred to the bladder, the vent valve 17 is closed, the interior of the inner vessel 1 is connected with the regulated source of pressurizing gas 13 by means of the two-way valve 15, and the bladder is placed in communication with the delivery line 23 by means of the two-way valve 21. As previously noted, the delivery of liquefied gas via the delivery line 23 is controllable by means of the valve 24, the influence of the pressurizing gas in the vessel 1 being effective to express the liquefied gas from the bladder 10 under various conditions of attitude and acceleration.

In the absence of any transfer of ambient heat thereto, the liquefied gas stored in the bladder 10 would assume an equilibrium temperature at which its own vapor pressure coincided with the surrounding pressure established by the pressurizing gas supply 13; such a temperature is commonly known as the saturated liquid temperature or boiling point of the liquefied gas at the prevailing pressure. Since a perfect thermal insulation of the bladder 10 cannot be achieved, however, some transfer of ambient heat thereto must be tolerated, and in the absence of the refrigerative means afforded by the evaporation chamber 3 of the present invention, such heat transfer would result in a continuous boiling accompanied by an increase in the pressure and temperature of the liquefied gas confined in the bladder 10. In the prior art, it has been proposed to relieve this difficulty by venting the vapor evolved through boiling of the liquefied gas to a surrounding chamber, thereby to preserve a uniform pressure and temperature in the vessel containing the stored liquid and to provide an insulative envelope therefor. In the present invention, actual refrigeration of the stored liquid to a temperature lower than the boiling point thereof is achieved by transferring a quantity of liquefied gas, via the bleed passage 25, from the relatively high pressure prevailing in the inner vessel 1 to the relatively low pressure prevailing in the evaporation chamber 3, the boiling point of the liquid being lowered in proportion to the pressure acting thereon. As will be apparent to those skilled in the art, a portion of the heat necessary to vaporize the liquefied gas transferred to the evaporation chamber 3 will be supplied by the transfer of ambient heat via imperfections in the insulation of the outer vessel 2 as hereinbefore noted, the remainder being drawn from the inner vessel 1 and the liquid stored therein, thereby tending to cool the latter to the equilibrium temperature of the liquid and its vapor at the reduced pressure maintained by the relief valve 34. In order to maintain a uniform temperature in the vessel

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1 the transfer of liquefied gas from the bladder 10 to the evaporation chamber 3 is controlled by the valve 30, which is responsive to the temperature sensitive control element or thermostat 31, the latter being calibrated so as to meter the flow of liquid through the bleed passage 25 in accordance with any desired degree of cooling consonant with the differential pressure existing between the vessel 1 and the chamber 3.

As will be apparent from the foregoing discussion, the embodiment of the invention illustrated in FIGURE 1 is particularly adapted to use in a movable installation where it is desired to maintain delivery of liquefied gas throughout variations in the static pressure due to the mass thereof, the influence of the pressurizing gas on the bladder 10 being effective to urge the contained liquid, independently of the attitude or acceleration of the container therefor, in the direction of the pressure difference occurring across the delivery valve 24. It will be further apparent to those skilled in the art that alteration of specific features of the construction shown in FIGURE 1 may be made without departing from the spirit and scope of the invention. For example, it is anticipated that for some applications certain mechanical and thermodynamic advantages may be secured through a construction wherein the liquefied gas is stored in the space surrounding the bladder 10 and the pressurizing gas is admitted to the interior thereof, appropriate modification, such as will be apparent to those skilled in the art, being made in the connections of the various pressurizing, venting and liquid withdrawal lines. It is to be still further understood, moreover, that where a stationary rather than a mobile installation is required, the flexible bladder 10 may be eliminated without prejudice to the refrigerative performance of the container, a partial cross section illustrative of such a modification being shown in FIGURE 2. In the drawing, wherein members external to the inner shell 2a of the vessel 2 have been omitted for the sake of clarity, it being understood that such members may be identical to those described and illustrated in connection with the embodiment of FIGURE 1, the numeral 1 denotes an inner vessel adapted to contain a liquefied gas, the vessel being provided with a liquid port 11' communicating with a bleed passage 25 and a line 20 whereby the vessel 1 may be connected to liquefied gas supply and delivery means (not shown). By virtue of the elimination of the bladder 10, the venting and pressurizing functions associated with the lines 14 and 16 of the embodiment shown in FIGURE 1 may be performed by a single line 14', it being understood that where delivery of liquefied gas at greater than ambient pressure is required the line 14' may be connected with an appropriate source of pressurizing gas as previously described. It will, of course, also be understood that simple withdrawal of liquid from the inner vessel 1 by gravity instead of by the use of pressurization may be employed in a stationary installation.

It will be apparent from the foregoing specification that my invention relates to a method and apparatus whereby a liquefied gas may be evaporated under a pressure lower than that at which it is stored, thereby to produce a refrigerative vapor effective to cool the stored liquid below the boiling point thereof. It is to be understood that the embodiments of the invention herein shown and described are presented for exemplary purposes only and are not to be construed by way of limitation.

I claim:

1. A container for liquefied gas which comprises: a vessel adapted to contain said liquefied gas; means for placing said liquefied gas in communication with a source of pressure including flexible partition means whereby said liquefied gas may be segregated in a portion of said vessel; means defining an insulated chamber surrounding said

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vessel, said chamber being maintained at a lower pressure than said liquefied gas;

a bleed passage whereby a portion of said liquefied gas may be transferred from said vessel to said chamber including valve means operable in response to variation in the temperature of said chamber; and

a delivery passage whereby liquefied gas may be withdrawn from said vessel to a point of use.

2. A container for liquefied gas which comprises:

a first vessel for containing said liquefied gas including a flexible partition internally thereof for confining said liquefied gas in one region of said vessel;

a second vessel enclosing said first vessel and spaced therefrom to define a chamber surrounding said first vessel, said second vessel comprising inner and outer wall members defining an insulative space therebetween;

pressurizing means communicating with said first vessel and cooperative with said partition to maintain said liquefied gas at a higher pressure than said chamber;

a bleed passage providing a flow path for said liquefied gas from said first vessel to said chamber whereby a portion of said liquefied gas may be evaporated at the lower pressure prevailing in said chamber for refrigeration of said vessel;

temperature responsive valve means in said passage for regulating the flow therethrough in accordance with the temperature in said chamber; and

a delivery passage providing a flow path for said liquefied gas from said first vessel to a point of use external to said second vessel.

3. A container for liquefied gas which comprises:

a vessel adapted to contain said liquefied gas;

means defining an evaporation chamber surrounding said vessel;

means for maintaining a pressure differential between the interior of said vessel and said chamber such that the chamber pressure is less than the interior pressure of said vessel;

there being a passage communicating said vessel interior to said chamber through which liquefied gas may be transferred from said vessel to said chamber for evaporation in the latter to refrigerate said vessel; and

temperature responsive valve means for said passage operable to control flow of liquefied gas through said passage in response to the temperature within said chamber, thereby to maintain said chamber temperature below a predetermined maximum temperature.

4. A container for liquefied gas which comprises:

a vessel adapted to contain said liquefied gas;

means defining an evaporation chamber surrounding said vessel;

means for maintaining a pressure differential between the interior of said vessel and said chamber such that the chamber pressure is less than the interior pressure of said vessel;

there being a passage communicating said vessel interior to said chamber through which liquefied gas may be transferred from said vessel to said chamber for evaporation in the latter to refrigerate said vessel; and

temperature responsive means for controlling flow of liquefied gas through said passage including a valve for said passage and means for operating said valve in response to the temperature within said chamber at a position remote from said passage, thereby to maintain said chamber temperature below a predetermined maximum temperature.

5. A container for liquefied gas which comprises:

a vessel adapted to contain said liquefied gas;

means defining an evaporation chamber surrounding said vessel;

means for maintaining a pressure differential between the interior of said vessel and said chamber such

that the chamber pressure is less than the interior pressure of said vessel;

there being a passage communicating said vessel interior to said chamber through which liquefied gas may be transferred from said vessel to said chamber for evaporation in the latter to refrigerate said vessel; and

temperature responsive means for controlling flow of liquefied gas through said passage including a valve for said passage, a temperature sensing element located within said chamber remote from said passage means, and means controlled by said sensing element for operating said valve in response to the chamber temperature in the immediate vicinity of said element, thereby to maintain said chamber temperature below a predetermined maximum temperature.

6. A container for liquefied gas which comprises:

an inner vessel adapted to contain said liquefied gas;

an outer vessel surrounding and spaced from said inner vessel to define an evaporation chamber between said vessels;

there being a first passage leading from said chamber to the outside of said container through which said chamber is adapted to be vented to a pressure lower than the internal pressure of said inner vessel;

there being a second passage communicating the interior of said inner vessel to said chamber at a position remote from said first passage through which liquefied gas may flow from said inner vessel to said chamber; and

temperature responsive valve means for controlling flow of liquefied gas through said second passage in response to the temperature within said chamber at a position intermediate said passages.

7. A container for liquefied gas which comprises:

an inner vessel adapted to contain said liquefied gas;

an outer vessel surrounding and spaced from said inner vessel to define an evaporation chamber between said vessels;

there being a first passage leading from said chamber to the outside of said container through which said chamber is adapted to be vented to a pressure lower than the internal pressure of said inner vessel;

there being a second passage communicating the interior of said inner vessel to said chamber at a position remote from said first passage through which liquefied gas may flow from said inner vessel to said chamber; and

temperature responsive means for controlling flow of liquefied gas through said second passage including a valve for said second passage, a temperature sensing element located in said chamber between said passages, and means controlled by said sensing element for operating said valve in response to the chamber temperature in the immediate vicinity of said element.

8. A container for liquefied gas which comprises:

an inner vessel adapted to contain the liquefied gas;

an outer vessel defining an evaporation chamber surrounding said vessel;

means for maintaining a pressure differential between the interior of said inner vessel and said chamber such that the chamber pressure is less than the interior pressure of said inner vessel;

a first fluid conduit communicating the interior of said inner vessel to said chamber through which liquefied gas may flow to said chamber;

a valve in said conduit, said conduit and valve being completely enclosed by said outer vessel;

a second conduit branching off from said first conduit between said valve and the interior of said inner vessel and extending to the outside of said outer vessel for delivering liquefied gas from said inner

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vessel to a point of use external to said outer vessel;
and
a valve in said second conduit.
9. A container for liquefied gas which comprises:
a vessel adapted to contain the liquefied gas; 5
means defining an evaporation chamber surrounding
said vessel;
a liquefied gas delivery line external to said container;
means for transferring liquefied gas from said vessel to
said chamber; 10
means for transferring liquefied gas from said vessel to
said delivery line;
a vent line extending from said chamber to the outside
of said container;
means including a two-way valve for selectively com- 15
municating said vent line to a passage leading to said
delivery line or to a reduced pressure less than the
internal pressure of said vessel;
a flow regulating valve in said delivery line between said
vessel and said passage; and 20
a connection between said valves whereby said two-way
valve is operated to communicate said vent line to
said reduced pressure when said regulating valve is
opened and to communicate said vent line to said
delivery line when said regulating valve is closed. 25
10. A container for liquefied gas which comprises:
a vessel adapted to contain said liquefied gas;
means defining an evaporation chamber surrounding
said vessel;
means for maintaining a pressure differential between 30
the interior of said vessel and said chamber such

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that the chamber pressure is less than the interior
pressure of said vessel;
there being a passage communicating said vessel in-
terior to said chamber through which liquefied gas
may be transferred from said vessel to said chamber
for evaporation in the latter to refrigerate said ves-
sel; and
valve means responsive to the temperature in a region
external to said vessel for controlling flow of liquefied
gas through said passage to said vessel, thereby to
maintain said chamber temperature below a prede-
termined maximum temperature.

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