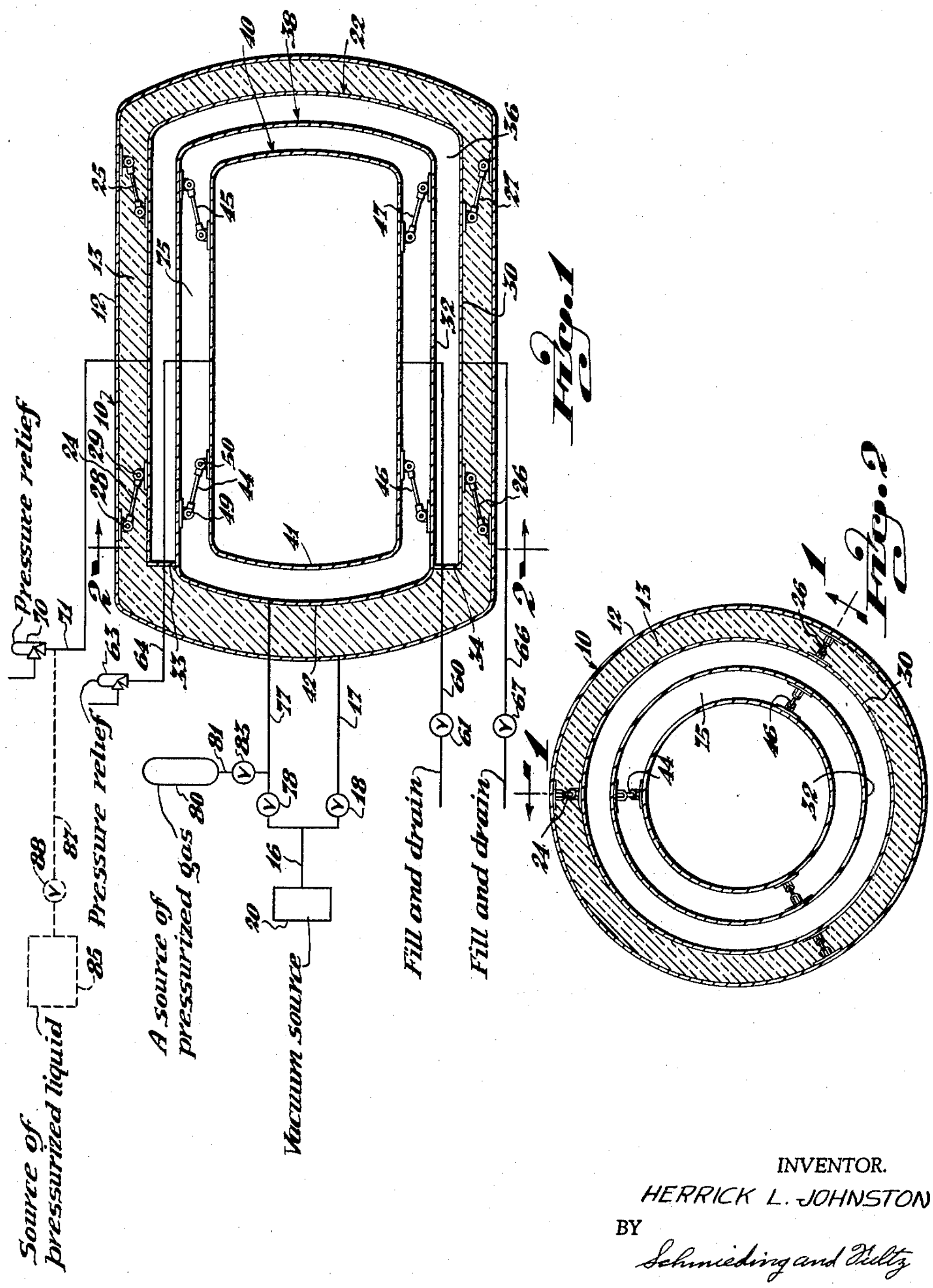
Dec. 9, 1958 H. L. JOHNSTON 2,863,297

METHOD AND APPARATUS FOR STORING LIQUIFIED GASES

Filed March 29, 1955



INVENTOR.
HERRICK L. JOHNSTON
BY
Schmieding and Fultz
ATTORNEYS.

United States Patent Office

2,863,297

Patented Dec. 9, 1958

1

2,863,297

METHOD AND APPARATUS FOR STORING LIQUIFIED GASES

Herrick L. Johnston, Columbus, Ohio, assignor to Herrick L. Johnston, Inc., Columbus, Ohio, a corporation of Ohio

Application March 29, 1955, Serial No. 497,778

9 Claims. (Cl. 62—45)

This invention relates to storing volatile liquids having boiling point temperatures materially below 273° Kelvin at atmospheric pressure and particularly to novel method and apparatus whereby the liquid may be contained for indefinite storage on a no-loss basis.

In general, the present invention provides method and apparatus for the safe and efficient storage of expensive, toxic, corrosive, flammable or otherwise hazardous liquified gas having a boiling point below 273° Kelvin utilizing a colder radiation shield containing a liquid having a boiling point below the boiling point of the liquid being stored. The liquid utilized in the colder radiation shield may be less expensive or less toxic, or less corrosive, or less flammable than the liquid being stored. Moreover, it can be inert or unreactive with the stored liquid, thus providing an efficient and safe means of storing a liquified gas on an indefinite no-loss storage basis. In practicing the present invention, not only can the stored liquid be contained for indefinite storage, but it can be safely contained for shipment via the various conventional modes of transportation.

As an example of one aspect of the present invention, liquid fluorine can be safely and efficiently stored and transported utilizing liquid nitrogen as a colder radiation shield according to the teachings of the present invention.

It is therefore an object of the present invention to provide method and apparatus for storing a volatile liquid of the type described wherein a novel colder radiation shield is utilized to shield the stored liquid from radiation from the environment.

It is another object of the present invention to provide method and apparatus for storing a volatile liquid of the type described by means of a novel radiation shield comprising a contained liquid having a boiling point below the boiling point of the liquid being stored. With such arrangement, said second liquid not only isolates the stored liquid from radiation from the environment, but also permits heat transfer only from the stored liquid to the second liquid whereby the stored liquid is contained on a no-loss basis.

It is another object of the present invention to provide method and apparatus for storing a volatile liquid of the type described utilizing a novel radiation shield interposed between the stored liquid and the environment, said radiation shield being adapted to control the temperatures of the stored liquid by effecting controlled heat transfer from the stored liquid to said radiation shield whereby said stored liquid can be maintained at a predetermined storage temperature.

It is another object of the present invention to provide method and apparatus for storing a volatile liquid of the type described which utilizes a novel radiation shield interposed between the stored liquid and the environment, and which includes means for varying the rate of heat transfer from the stored liquid to said radiation shield whereby the temperature of the stored liquid can be efficiently and safely varied.

It is another object of the present invention to provide

2

method and apparatus for storing a volatile liquid of the type described utilizing a novel radiation shield interposed between the stored liquid and the environment and which provides means for effecting heat transfer from the stored liquid to said radiation shield whereby the stored liquid can be maintained at a predetermined subcooled temperature notwithstanding the occurrence of a certain amount of heat transfer from the environment to the liquid being stored.

It is another object of the present invention to provide method and apparatus for storing a liquified gas of the type described whereby the liquid being stored can be delivered to the storage means at boiling point temperature, yet due to the novel radiation shield utilized in the present invention, the stored liquid can be efficiently and safely subcooled subsequent to delivery thereof to the storage means.

It is another object of the present invention to provide method and apparatus for storing a liquified gas of the type described which eliminates boil-off, and hence loss of the liquid being stored, without the need for a recondensor apparatus or an external refrigeration cycle.

It is another object of the present invention to provide method and apparatus for storing a volatile liquid of the type described whereby the liquid is maintained in a subcooled condition which permits the pumping of same without the need of pressurizing the liquid or elevating the containing vessel above pump suction to effect subcooling.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawing wherein a preferred form of embodiment is shown.

In the drawings:

Figure 1 is a schematic view of a storage means and associated control apparatus arranged according to one aspect of the present invention and adapted for practicing the method thereof. Figs. 1 and 2 are sectional views, taken on lines 1—1 of Fig. 2 and 2—2 of Fig. 1, respectively, and looking in the direction of the arrows.

Referring next to the drawing, an apparatus for practicing the present invention is schematically illustrated in Figure 1 with such apparatus including a storage means indicated generally at 10. Storage means 10 includes an outer jacket 12 which surrounds an insulating space 13. Insulating space 13 may be in the form of a vacuum chamber or it may be formed as a vacuum chamber containing insulating material such as fine particles of low conductivity and high reflectivity. A vacuum can be maintained in the insulating space 13 by connecting such space with a source of vacuum 20 by means of the lines 16 and 17. A valve 18 is located along line 17 to control and maintain the vacuum in insulating space 13.

Reference is next made to a radiation shield structure indicated generally at 22. Radiation shield 22 is supported within the outer jacket 12 by a plurality of structural members 24, 25, 26 and 27, which extend between the inner wall of the outer jacket 12 and an outer wall 30 of the radiation shield. For example, structural member 24 has one end thereof secured to the outer jacket 12 at 28, and the other end thereof secured to the radiation shield 22 at 29.

Radiation shield 22 further includes an inner wall 32 and end walls 33 and 34 which form a sealed chamber 36. At this point it should be noted that the chamber 36 of the radiation shield substantially surrounds a second insulating means indicated generally at 38 and provided with an outer shell 42. Insulating means 38 in turn surrounds a container 40 which directly contains the liquid being stored.

Referring further to the inner container 40, such container is supported in spaced relationship with the radiation shield 22 and wall means 42 by means of a plurality of structural members such as are exemplified by the members indicated at 44, 45, 4 6 and 47. For example, structural member 44 has one end thereof secured to the inner side of wall 32 at 49, and the other end thereof secured to the outer side of wall 41 at 50.

Since the inner container 40 is supported by the radiation shield structure 22, and since the radiation shield structure is suspended within the outer shell 12 it will be understood that the inner container 40 is maintained in substantially rigid suspension relative to the surrounding structure of the storage means.

The inner container can be filled and drained of the liquid to be stored by means of a line 60 and valve 61. The inner container is further provided with a safety pressure release valve 63 which is connected to the inner container by means of a line 64.

Reference is again made to the radiation shield 22 and particularly to chamber 36 thereof which is adapted to receive and store a fluid in the liquid state. A fluid having a boiling point lower than the boiling point of the stored liquid is utilized to provide a radiation shield which is maintained colder than the liquid being stored. A line 66 and valve 67 serve to fill and drain the colder liquid carried in chamber 36, and a safety pressure relief control valve 70 is connected with the chamber 36 by means of a line 71.

Reference is next made to the inner insulating means 38 which includes a chamber 75 in surrounding relationship with the inner container 40. Chamber 75 is connected to the source of vacuum 20 by means of a line 77 which extends from chamber 75 to the vacuum line 16. A valve 78 is interposed along the line so that the chamber 75 can be selectively isolated from the vacuum source 20. A pressurization source 80 is connected to chamber 75 by lines 81 and 77, and a valve 83 is provided for controlling the rate of gas flow from the pressurization source 80, or for isolating such source from the chamber 75. Hence it is seen that the pressure in the chamber 75 can be readily varied by means of the valve 78, which is interposed between chamber 75 and the vacuum source 20, and by means of the valve 83 which is interposed between chamber 75 and the pressurization source 80.

In addition to the above described vacuum and pressurization arrangement for chamber 75, it will be understood that chamber 75 can also be arranged to contain insulating materials such as fine particles of low thermal conductivity and high reflectivity.

In operation, radiation shield liquid is introduced into the chamber 36 of the radiation shield through the fill line 66. The liquid to be stored is transferred to the inner container 40 by means of the fill line 60. With this arrangement, the radiation shield liquid in the chamber 36 substantially surrounds the stored liquid in the inner container 40 and hence the radiation shield liquid is interposed between the stored liquid and the ambient temperature of the environment surrounding the outer shell of the storing means. At this point, it will be understood that the colder radiation shield 22 accepts radiation heat from the surrounding environment and thereby prevents the radiation heat from passing to the stored liquid in the inner container 40. This must occur since the radiation shield liquid in the chamber 36 is colder, according to the present invention, than the temperature of the stored liquid in the inner container 40. Since heat can be transferred only from the warmer substance to the colder substance, it will be understood that heat can only move outwardly from the inner container to the radiation shield 22 and hence the stored liquid can only become colder.

At this point it should be noted that the structural members 44, 45, 46 and 47 extend between the inner container 40 and the radiation shield 22 and form heat conducting paths whereby a certain amount of heat is continuously conducted outwardly from the warmer stored liquid to the colder radiation shield. Since the rate of heat conduction is a function of the physical characteristics of the support members 44, 45, 46 and 47, a continuous outward conduction of heat from the stored liquid can be effected at a predetermined rate by the appropriate structural design and selection of material for such structural members.

It will be understood that it is advantageous to control the temperature of the stored liquid in the inner container 40 in order to efficiently supply the liquid with necessary refrigeration, or in other instances, to subcool the liquid after it has been placed in the inner container 40, or, in still other instances, to maintain the stored liquid in a subcooled condition. According to the present invention, the temperature of the stored liquid can be controlled by controlling the rate at which the stored liquid gives up heat to the colder radiation shield **22.** To effect such controlled heat transfer, the present apparatus may be adapted to readily and precisely vary the rate at which heat is transferred outwardly through the insulating space **75** by varying the pressure therein by means of the control valves **83** and **78** in the manner previously described. Since all heat passing from the stored liquid to the radiation shield must pass through the gas contained in insulating space **75,** it will be understood that the rate of heat transfer will be a function of the molecular concentration of the gas and hence a function of pressure of the gas in insulating space **75.**

When it is desired to lower the temperature of the stored liquid, valve **83** to the pressurization source **80** can be opened and valve **78** to the vacuum source can be closed to produce an increase in the gas pressure in chamber **75.** The rate of heat transfer from the stored liquid to the colder radiation shield **22** will then increase and valve **83** can be maintained open until the temperature of the stored liquid has dropped to the desired valve.

If an increase in temperature of the stored liquid is desired, valve **78** to the vacuum source **20** can be opened and valve **83** to the pressurization source **80** can be closed to effect a rapid reduction in pressure in insulating space **75** with a resulting decrease in the rate of heat transfer from the stored liquid to the colder radiation shield **22.** In this case the design of the vessel would incorporate a heat leak to the stored fluid, through piping **60** and **64** and other means, greater than the heat loss through the suspension members to the radiation shield. Thus the present method and apparatus are readily adaptable to meet various conditions encountered in service.

As an illustrative example of one aspect of the present invention, liquid fluorine can be safely and efficiently stored on a no-loss basis by using nitrogen as a radiation shield liquid according to the present teachings. Liquid fluorine has a boiling point of −180° C. and a freezing point of −223° C., while nitrogen has a boiling point of −195.8° C. and a freezing point of −209.8° C. In this particular example, both the boiling point and freezing point of the radiation shield liquid are between the boiling point and freezing point of the stored liquid and hence the two liquids could be maintained in controlled heat transfer relationship and without freezing the stored liquid. Due to the presence of the colder radiation shield of the present invention, however, heat can transfer only from the fluorine to the nitrogen and the fluorine can only get colder. Hence, with the particular example of fluorine and nitrogen, the aspect of controlling the rate of heat transfer through the intermediate insulating space **75,** by controlling the pressure therein, need be utilized only when it is desired to provide control for the temperature of the stored fluorine as would be the case when it is desired to subcool the fluorine to a certain predetermined temperature after it has been introduced into the storage means.

As another aspect of the present invention, it will be understood that a radiation shield liquid can be utilized having a boiling point temperature below the freezing point temperature of the liquid being stored. In such instance, when the heat loss through the structural members 44, 45, 46, 47 of the suspension system is less than the heat leak inwardly along the pressure relief, fill and drain piping 64 and 60, and other means, then the control system for varying the rate of heat transfer through the intermediate insulating space 75 is required to control the temperature or amount of subcooling of the stored liquid. Such temperature control can be effected by raising and lowering the pressure of the gas in insulating space 75 to raise and lower the rate of heat transfer from the stored liquid to the radiation shield 22.

As still another aspect of the present invention, the temperature of the stored liquid can be controlled by varying the pressure, and hence the corresponding temperature, of the liquid contained in the radiation shield 22. To effect such control of the pressure of the radiation shield liquid, a variable pressurization means, schematically illustrated at 85, can be connected to the line 71 by means of a line 87 and a valve 88. In effecting control of the temperature of the stored liquid in container 40, by means of the variable pressurization means 85, the valve 88 is opened to connect the radiation shield liquid with the variable pressurization means. When it is desired to vary the temperature of the stored liquid, the variable pressurization means is adjusted to produce a desired corresponding variation in the temperature of radiation shield liquid. Such variation in the temperature of the radiation shield liquid will produce a corresponding change in the rate of heat transfer from the stored liquid to the radiation shield liquid. Hence the temperature of the stored liquid is made warmer or colder by varying the effect of the variable pressurization means on the radiation shield liquid.

In summary, it is seen that the present invention provides a safe and efficient way for storing dangerous or expensive liquified gases on a no-loss basis by use of a novel radiation shield which substantially completely isolates the stored liquid from heat radiation from the environment, and which permits heat transfer, between the stored liquid and the radiation shield, only in the direction of the radiation shield and away from the liquid being stored. Moreover, the method and apparatus of the present invention is readily adaptable to provide convenient and precise control of the temperature of the liquid being stored. Hence the system becomes versatile in its adaptation to the various applications to which it may be employed.

While the form of embodiment of the present invention as disclosed herein constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

I claim:

1. An apparatus for no-loss storage of volatile liquid fluorine having a boiling point materially below 273° K. at atmospheric pressure comprising, in combination: a storage container for the liquid being stored, an insulating jacket in spaced surrounding relationship with said storage container, a cold radiation shield interposed between said storage container and said insulating jacket, and means for supplying a different volatile liquid which contacts said shield continuously to maintain it cold, said radiation shield being immediately separated from said storage container by an insulating space evacuated below atmospheric pressure.

2. An apparatus for no-loss storage of volatile liquid fluorine having a boiling point material below 273° K. at atmospheric pressure comprising, in combination: a first container for the liquid being stored, an insulating jacket in spaced surrounding relationship with said first container, a cold radiation shield interposed between said first container and said insulating jacket, said radiation shield comprising a second container containing a different volatile liquid and immediately separated from said first container by an insulating space evacuated below atmospheric pressure, said different volatile liquid having a boiling point lower than the boiling point of the stored liquid.

3. An apparatus for no-loss storage of volatile liquid fluorine having a boiling point temperature materially below 273° K. comprising, in combination: a storage container for the liquid being stored; an insulating jacket in spaced surrounding relationship with said first container; a cold radiation shield formed to contain a different volatile liquid, said radiation shield being interposed between said storage container and said insulating jacket and spaced from said jacket; a gas-containing insulation chamber evacuated below atmospheric pressure and immediately disposed between said shield and said storage container; and pressure-control means including a conduit in communication with said chamber for varying the effectiveness of said insulation by varying the gas pressure in said chamber.

4. An apparatus for no-loss storage of volatile liquid fluorine having a boiling point temperature materially below 273° K. comprising, in combination: a storage container for the liquid being stored; an insulating jacket in spaced surrounding relationship with said first container; a cold radiation shield formed to contain a different volatile liquid, said radiation shield being interposed between said storage container and said insulating jacket and spaced from said jacket, a chamber immediately disposed between said shield and said storage container, and vacuum-producing means including a conduit in communication with said chambers, for varying the degree of vacuum in said chamber.

5. An apparatus for no-loss storage of volatile liquid fluorine having a boiling point temperature materially below 273° K. at atmospheric pressure, comprising, in combination: a storage container for the liquid being stored; an insulating jacket in spaced surrounding relationship with said container; a cold-radiation shield formed to contain a different volatile liquid and interposed between said storage container and said insulating jacket; insulation evacuated below atmospheric pressure and immediately disposed between said storage container and shield; and means for varying the pressure and corresponding temperature of said different liquid whereby the rate of heat transfer from said stored liquid to said radiation shield can be predetermined.

6. In no-loss storage of liquid fluorine in apparatus having an exterior jacket and an interior storage container, the method of controlling the temperature of the stored liquid in the container, which method comprises interposing between said stored fluorine and the jacket a quantity of a different liquid having a boiling point below the boiling point of the stored fluorine; maintaining said different liquid in a liquefied state to provide a radiation shield; vacuum-insulating the stored fluorine from said second liquid; and varying the magnitude of the insulating effect whereby control of the temperature of said stored fluorine is effected.

7. In no-loss storage of liquid fluorine in apparatus having an exterior jacket and an interior storage container, the method of controlling the temperature of the stored fluorine in a container which method comprises interposing between said stored fluorine and the jacket a quantity of liquid having a boiling point below the boiling point of the stored fluorine; maintaining the last-mentioned liquid in a liquefied state to provide a colder radiation shield; interposing a vacuum between said stored fluorine and the shielding liquid; and varying the amount of the vacuum to effect control of the temperature of the liquid fluorine.

8. In no-loss storage of volatile liquid fluorine having a boiling point temperature materially below 273° K. at atmospheric pressure in apparatus having an exterior jacket and an interior storage container, the method comprising: interposing between the stored liquid and the jacket a quantity of radiation-shielding liquid; vacuum

insulating the stored and shielding liquids from each other; and determining the pressure and corresponding temperature conditions of the radiation shield liquid whereby the rate of heat transfer from said stored liquid to said radiation shield can be controlled within predetermined limits.

9. An apparatus for no-loss storage of liquid fluorine, having a boiling point temperature materially below 273° K. at atmospheric pressure, comprising, in combination, container means for the liquid fluorine; a jacket surrounding the container means; and means forming a nitrogen-cooled radiation shield colder than the boiling point and warmer than the melting point of said liquid being stored, said radiation shield being interposed between said container and the jacket, and spaced from

the container means by a chamber, which is evacuated below atmospheric pressure.

References Cited in the file of this patent

UNITED STATES PATENTS

646,459	Place	Apr. 3, 1900
797,577	Heylandt	Aug. 22, 1905
1,515,165	Oswald	Nov. 11, 1924
1,680,873	Lucas-Girardville	Aug. 14, 1928
2,148,109	Dana et al.	Feb. 21, 1939
2,195,077	Brown	Mar. 26, 1940
2,229,437	Birdsall	Jan. 21, 1941
2,269,172	Birdsall	Jan. 6, 1942
2,396,459	Dana	Mar. 12, 1946
2,550,040	Clar	Apr. 24, 1951

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,863,297 December 9, 1958

Herrick L. Johnston

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 37, for "desired valve" read -- desired value --; column 5, line 67, for "material" read -- materially --; column 6, line 30, for "said chambers" read -- said chamber --.

Signed and sealed this 19th day of May 1959.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents