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W. WILKINSON
STORAGE OF LIQUEFIED GASES

2,682,154

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3 Sheets-Sheet 1

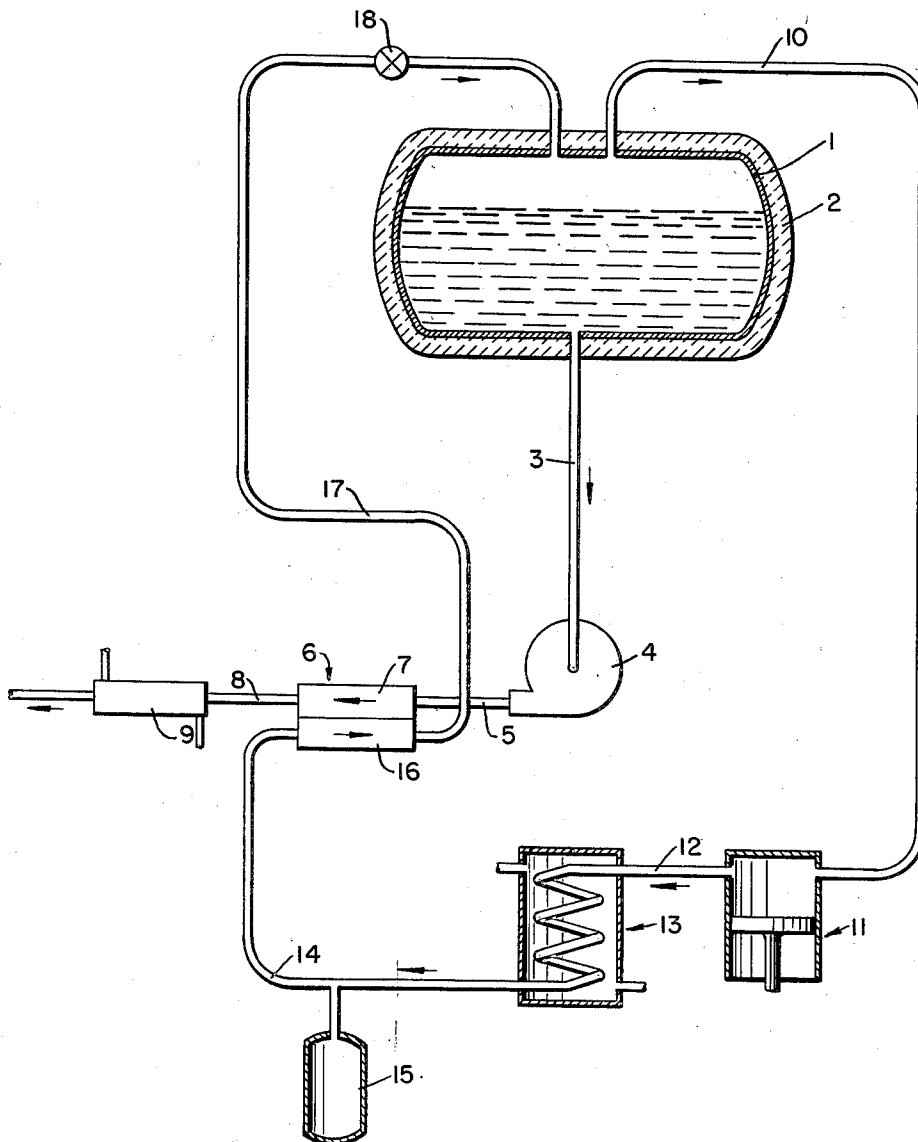


FIG. 1

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3 Sheets-Sheet 2

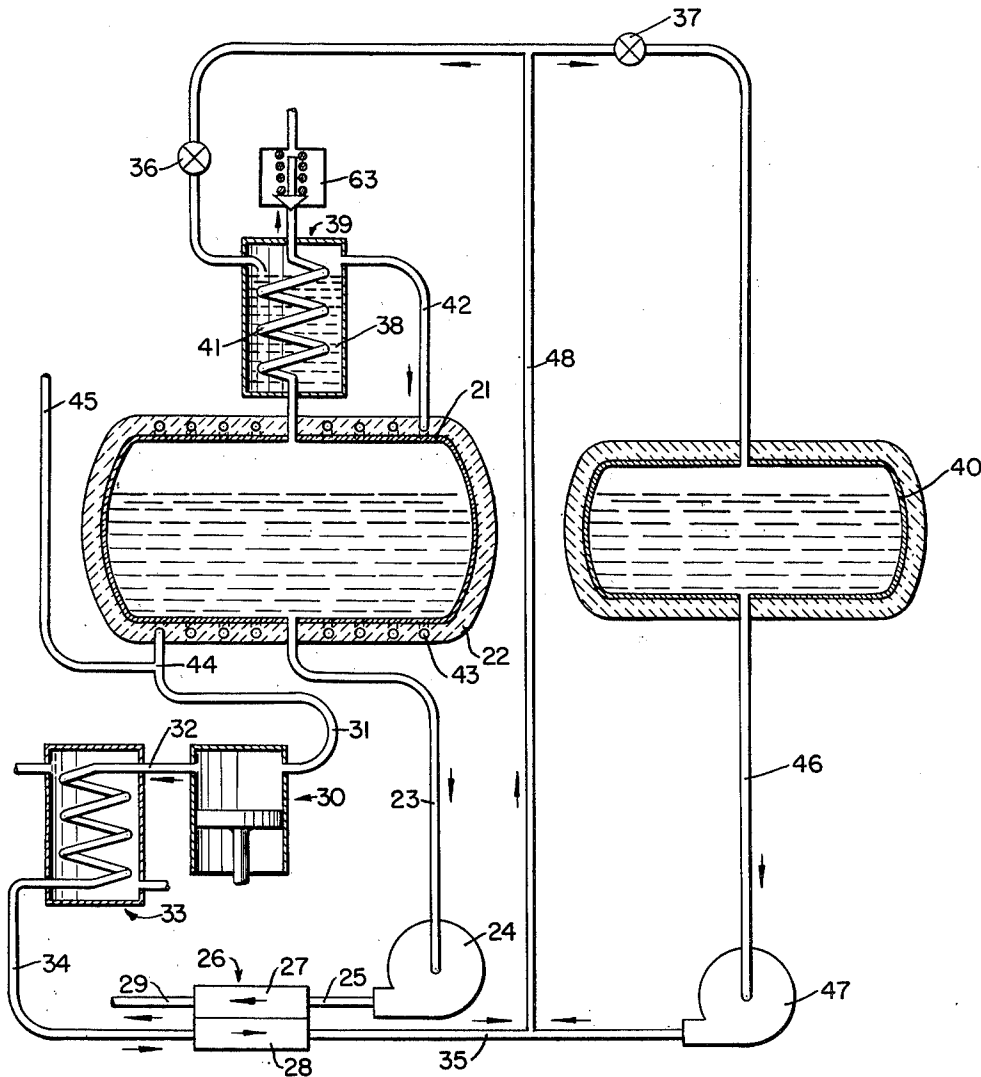


FIG. 2

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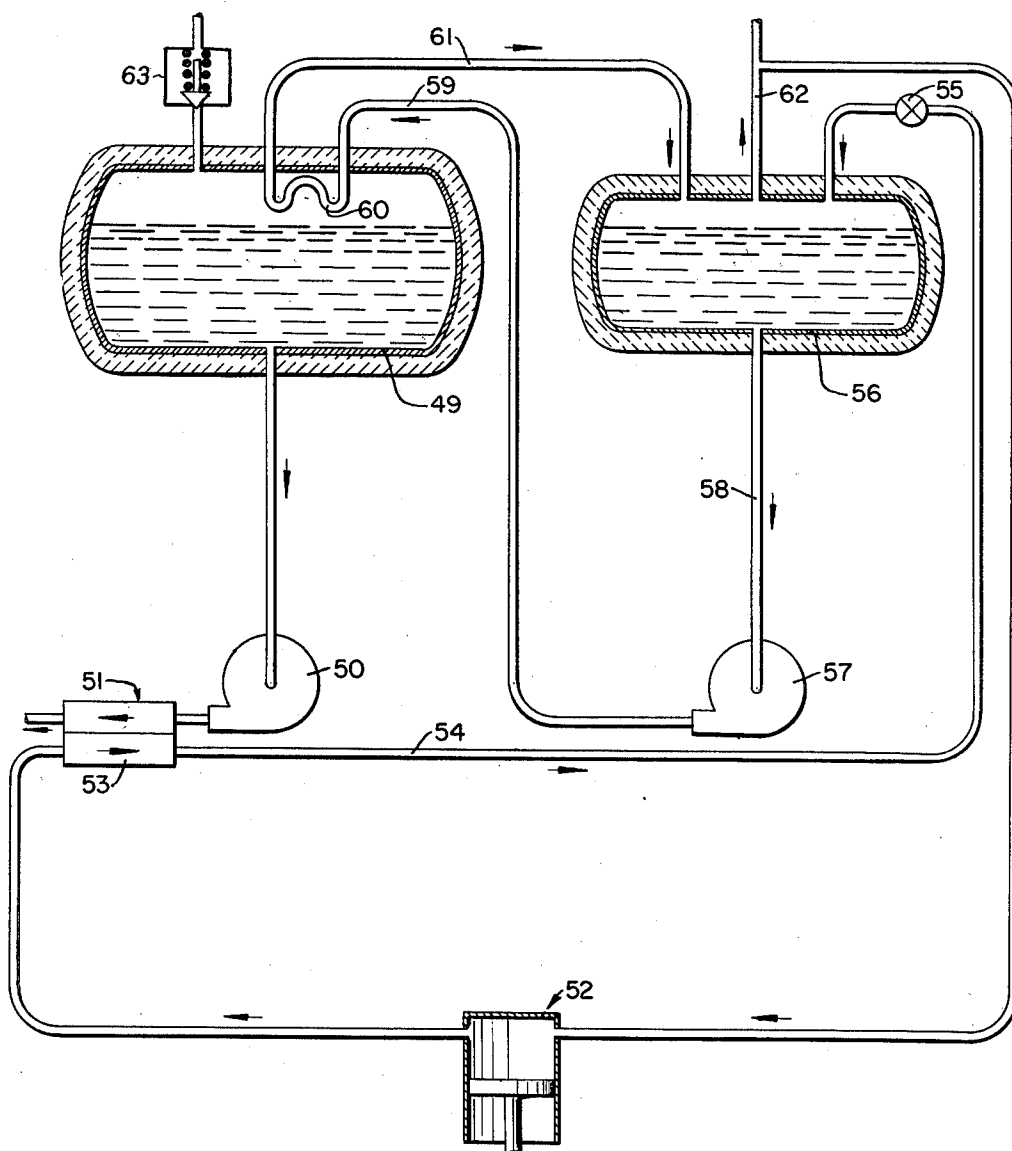


FIG. 3

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UNITED STATES PATENT OFFICE

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STORAGE OF LIQUEFIED GASES

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18 Claims. (Cl. 62—1)

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This invention relates to the storage of liquified gases and particularly to methods and apparatus adapted to minimize or prevent excessive evaporation due to heat leak from the environment.

The practice of storing liquefied gases of low boiling point, such as oxygen and nitrogen among others, involves the use of thermally insulated containers which substantially, but not completely, prevent the flow of heat from the surroundings to the liquefied gas. The small, but unavoidable, heat flow into the liquefied gas causes vaporization of the liquid. One way to avoid building up high gas pressures in the containers is to vent the vapor to the atmosphere. This practice results in a continuous loss of the valuable stored substance and consequently increases the final cost of that portion of the liquefied gas which is available for useful purposes.

It might seem, perhaps, that the losses by evaporation from storage containers are relatively inconsequential. However, the containers must be large compared to the daily consumption of the stored gas if the transportation of liquefied gases and the refilling of the containers are to be conducted in the most economical and reliable manner. If we assume a storage capacity of ten times the normal daily consumption, a daily loss by evaporation of 1% of the capacity of the container becomes 10% of the daily consumption. This, of course, adds materially to the cost of the liquefied gas which is actually put to use.

It is the object of the present invention to provide an economical means for preventing excessive vaporization of liquefied gases while in storage and particularly to employ for that end the refrigerating capacity which is available when liquefied gas is withdrawn from a storage container for use or storage in the gaseous state. For most uses liquefied gases must be re-gasified. The latter operation involves a heat exchange process in which the available refrigeration generally has not been usefully employed.

The scope and advantages of the invention will become apparent by reference to the following illustrative descriptions of several of the particular methods by which the invention may be put into practice.

Figure 1 is a diagrammatic representation of apparatus adapted to accomplish the purposes of the invention;

Fig. 2 is a similar representation of a modified form of the invention; and

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Fig. 3 represents another modification.

In carrying out the invention according to Fig. 1, liquid desired for utilization in the gaseified state is withdrawn from the bottom of the container and pumped through a vaporizer and one or more heaters. The warmed, gaseous product is piped to the point of use. The vapor produced within the liquid storage container by the volatilizing effect of that heat which leaks from the atmosphere through the insulation of the container is withdrawn from the top part of the container, compressed to a suitable pressure and re-liquefied by heat exchange with the liquid withdrawn from the bottom of the container. The liquid produced by condensation of the vapor is returned to the storage container. This system eliminates the need for discharging vapor from the top of the storage container to the atmosphere with its irretrievable loss thereby.

Referring to Figure 1, 1 indicates a container for liquefied gas consisting of a metal tank of any suitable form and construction surrounded by media, 2, and supported by devices, which afford a high degree of thermal insulation of the liquefied gas from the atmosphere and adjacent bodies. For withdrawal of liquid from the container for useful employment, there is a pipe, 3, leading to pump 4. The latter compresses the fluid to such pressures as may be desired for use or storage of the ultimate gaseous product. The effluent of the pump passes through pipe 5 to a vaporizer 6 where it is wholly or partly vaporized in compartment 7. The vaporizer is supplied with heat by a stream of gas which is pumped through compartment 16 as hereinafter described. The effluent from compartment 7 is delivered through pipe 8 to a second vaporizer or heater 9, which raises the temperature of the fluid to the desired level.

In order to accomplish the particular purpose of the present invention, the vapor generated within the storage container 1, as a consequence of heat leak through the insulation 2, and such supporting devices as may be provided, is withdrawn through pipe 10 and conveyed to compressor 11 where the vapor is compressed to a pressure suitable for a re-condensation process. The compressed vapor leaves the compressor through pipe 12 and may be passed through an after-cooler 13 for removal of the heat of compression. The cooling medium in 13 may be either water or product gas which has passed through heater 9. Pipe 14 conveys the compressed gas to compartment 16 of vaporizer 6.

A surge tank 15 is connected to pipe 14, or alternately it may be inserted in pipe 14. In compartment 16 of vaporizer 6, the compressed vapor is cooled and liquefied by heat exchange with the cold fluid passing in counter current flow through compartment 7. The liquid condensed in compartment 16 is delivered through pipe 17 and pressure regulating valve 18 to the liquefied gas container 1.

Thus the invention effectuates a recovery, recondensation and return to storage of the valuable liquid which is vaporized by heat leaking through the insulation and supports of the container. The refrigeration required for the recondensation is obtained from the liquid which is withdrawn for use and which for most applications must be gasified by absorption of heat whether the invention here described is practiced or not.

Actual operation of the system described requires various accessory and regulating devices of an obvious sort which, in order to simplify the description, have not been mentioned.

Figure 2 represents schematically a modification of the invention herein disclosed. In this apparatus provision is made for a situation in which liquefied gas may be withdrawn for use from the container only intermittently with relatively long periods between withdrawals.

For purposes of illustrative description, the liquefied gas in storage is assumed to be liquid oxygen. Liquid oxygen vaporized within the storage container as a result of heat leakage is recondensed by allowing the vapor to enter a reflux condenser which is refrigerated by liquid air. The pressure in the container is maintained at a level which insures effective condensation of oxygen vapor by thermal contact with liquid air. The liquid oxygen condensed in the condenser drains back into the storage container. The liquid air supplied as refrigerant to the reflux condenser is produced from atmospheric air by heat exchange with liquid oxygen at those times when liquid is withdrawn from the storage container and gasified for useful employment. Compressed air is pumped through a vaporizer counter current to the oxygen being withdrawn from the storage container. Since the rate at which liquid oxygen is vaporized in the vaporizer during a normal withdrawal is many times greater than the rate of vaporization within the container due to heat leak, a reserve supply of liquid air can be built up which is stored in an auxiliary, insulated container.

Referring to Figure 2, 21 is a container for liquid oxygen surrounded by suitable heat insulating media 22. Liquid oxygen which is to be gasified for use is withdrawn from the bottom of the container through pipe 23, compressed to a suitable pressure by pump 24 and delivered through pipe 25 to compartment 27 of a vaporizer 26. In compartment 27 the liquid is vaporized by thermal exchange with a stream of compressed air flowing through compartment 28 and the resulting gas is conveyed through pipe 29 to the place of use or storage.

Air is drawn into compressor 30 through pipe 31 and is compressed to a suitable pressure for liquefaction by heat exchange with liquid oxygen, for example, to 4 atmospheres. The compressed air passes through pipe 32, after-cooler 33 and pipe 34 to compartment 28 of vaporizer 26. In compartment 28, the air is liquefied by heat exchange with the vaporizing oxygen flowing in counter current fashion through compartment

27. The liquid air produced in compartment 28 flows through pipe 35 to expansion valves 36 and 37. Part of the liquid air is expanded through valve 36 into compartment 38 of a reflux condenser 39. The balance of the liquid air is expanded through valve 37 and delivered into an insulated liquid air storage vessel 40.

Oxygen vaporized in container 21 by heat leakage through the insulation and supporting devices passes into coil 41 of the reflux condenser 39 where it is recondensed and drains back into the container. The liquid air boiled off in compartment 38 by the condensation of oxygen in coil 41 passes off through pipe 42. The cold evaporated air may be conducted through a coil 43 which is embedded in the insulating material 22 surrounding container 21. Heat flowing from the atmosphere through the insulating material may thus partially be absorbed by the coil air passing through the coil and prevented to some extent from reaching the liquid oxygen. When liquid oxygen is being withdrawn through vaporizer 26, compressor 30 is in operation and cold air reaching the point 44 from condenser 39 is drawn into the compressor through pipe 31, together with additional air drawn from the atmosphere through pipe 45.

When vaporizer 26 and compressor 30 are not in operation, liquid air is withdrawn from container 40 through pipe 46 and forced by pump 47 through pipe 48 into compartment 38 of condenser 39. Cold evaporated air reaching the point 44 from condenser 39 is discharged to the atmosphere through pipe 45.

Valve 53 is an over-pressure relief valve which is normally closed to prevent atmospheric air from being drawn into the condenser and depositing ice there.

Figure 3 represents an alternate arrangement for a part of the apparatus depicted by Figure 2.

Container 49, pump 50, vaporizer 51 and compressor 52 function as in the system of Figure 2. However, all of the liquid air condensed in compartment 53 of vaporizer 51 during periods when liquid oxygen is being withdrawn from container 49 is transferred through pipe 54 and valve 55 to the liquid air storage container 56. Pump 57 withdraws liquid air continuously from container 56 through pipe 58 and forces it through pipe 59 into coil 60 which is in the vapor space above the liquid oxygen in the container 49. Vaporized oxygen generated in container 49 by heat leakage is condensed by heat exchange with the liquid air flowing through coil 60. The air vaporized in coil 60, together with any liquid air remaining unvaporized, returns to container 56 through pipe 61. The vaporized air discharged by pipe 61 escapes through pipe 62, while the unvaporized liquid discharged by pipe 61 is returned to storage in container 56.

This apparatus is adaptable to a liquid oxygen storage system from which liquid oxygen withdrawals are made at irregular intervals and at variable rates. Pump 57 is run continuously at a uniform speed and supplies liquid air to condenser coil 60 in an amount somewhat in excess of that required to condense the oxygen evaporated by the normal heat leakage into container 49. Liquid air is produced by compressor 52 and vaporizer 51 at the maximum rate possible whenever liquid oxygen is withdrawn from container 49. The speed of compressor 52 may be coordinated with the speed of pump 50.

Various changes may be made in the details of construction as described and in the arrange-

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ment of the parts without departing from the invention or sacrificing the advantages thereof.

I claim:

1. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises compressing a gas material, withdrawing liquid from said container and expanding the same in heat exchanging relation with said compressed gas material to cool the same, expanding the cooled compressed gas material and bringing the same into heat exchanging relation with the stored gas material to absorb heat therefrom.

2. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises compressing a gas material withdrawn from said container in the gas phase, withdrawing liquid from said container and passing the same in heat exchanging relation with said compressed gas material to cool the same, expanding the cooled gas material and bringing the same into heat exchanging relation with the stored gas material to absorb heat therefrom.

3. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises compressing a gas material withdrawn from said container in the gas phase, withdrawing liquid from said container and passing the same in heat exchanging relation with said compressed gas material to cool the same, expanding the cooled gas material and bringing the same into heat exchanging relation with the stored gas material within said container to absorb heat therefrom.

4. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises compressing a gas material withdrawn from said container in the gas phase, withdrawing liquid from said container and passing the same in heat exchanging relation with said compressed gas material to cool and liquefy the same, and discharging the same into said container.

5. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises intermittently withdrawing liquid from said container during certain periods, compressing a gas material during such periods, expanding the withdrawn liquid in heat exchanging relation with the said compressed gas material to cool and liquefy the same, collecting at least a portion of said cooled and liquefied material in an auxiliary container, expanding at least a portion of said cooled and liquefied material and passing the same in heat exchanging relation with said stored material during said periods, and at other times withdrawing liquid from said auxiliary container and passing it in heat exchanging relation with said stored material.

6. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises intermittently withdrawing liquid from said container during certain periods, compressing a gas material during such periods, expanding the withdrawn liquid in heat exchanging relation with the said compressed gas material to cool and liquefy the same, collecting at least a portion of said cooled and liquefied material in an auxiliary container, and passing a portion of the same in heat exchanging relation with said stored material during certain periods, and at other times withdrawing liquid from said auxiliary container,

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and passing it in heat exchanging relation with said stored material.

7. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises intermittently withdrawing liquid from said container during certain periods, compressing a gas material during such periods, expanding the withdrawn liquid in heat exchanging relation with the said compressed gas material to cool and liquefy the same, collecting at least a portion of said cooled and liquefied material in an auxiliary container, and continuously withdrawing liquid from said auxiliary container and passing the same in heat exchanging relation with said stored material.

8. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises intermittently withdrawing liquid from said container during certain periods, compressing a gas material during such periods, expanding the withdrawn liquid in heat exchanging relation with the said compressed gas material to cool and liquefy the same, collecting at least a portion of said cooled and liquefied material in an auxiliary container, continuously withdrawing liquid from said auxiliary container and passing the same in heat exchanging relation with said stored material and then returning the same to said auxiliary container.

9. Apparatus for storing liquefied gas material at low temperature which comprises an insulated container for holding a body of such liquefied material, means for compressing a gas material, means for withdrawing liquid from said container and expanding the same in heat exchanging relation with gas material compressed by said compressing means to cool and liquefy the same, means for expanding the cooled and compressed gas material and bringing the same into heat exchanging relation with the stored gas material to absorb heat therefrom.

10. Apparatus for storing liquefied gas material at low temperature which comprises an insulated container for holding a body of such liquefied material, means for withdrawing a portion of said gas material from said container in the gas phase, means for compressing said withdrawn material, means for withdrawing liquid from said container, means for passing said withdrawn liquid material in heat exchanging relation with said compressed gas material to cool and liquefy the same, and means for expanding the cooled gas material and bringing the same into heat exchanging relation with the stored gas material to absorb heat therefrom.

11. Apparatus for storing liquefied gas material at low temperature which comprises an insulated container for holding a body of such liquefied gas material, means for compressing a gas material withdrawn from said container in the gas phase, means for withdrawing liquid from said container, means for passing said withdrawn liquid in heat exchanging relation with said compressed gas material to cool and liquefy the same, means for expanding the cooled gas material and bringing the same into heat exchanging relation with the stored gas material within said insulated container.

12. Apparatus for storing liquefied gas material at low temperature which comprises an insulated container for holding a body of such liquefied material, means for withdrawing gas material from said container in the gas phase, means for

compressing said withdrawn gas material, means for withdrawing liquid from said container and for passing the same in heat exchanging relation with said compressed gas material to cool and liquefy the same, and means for expanding the cooled gas material and discharging the same into said insulated container.

13. Apparatus for storing liquefied gas material at low temperature which comprises an insulated container for holding a body of such liquefied material, means for withdrawing liquid from said container during certain periods, means for compressing a gas material during such periods, means for expanding the withdrawn liquid in heat exchanging relation with the compressed gas material to cool and liquefy the same, an auxiliary container, means for supplying at least a portion of said cooled and liquefied gas material to said auxiliary container, means for expanding at least a portion of said cooled and liquefied gas material and passing the same in heat exchanging relation with said stored material during said periods, and means for withdrawing liquid from said auxiliary container and passing the same in heat exchanging relation with said stored material.

14. Apparatus for storing liquefied gas material at low temperature which comprises an insulated container for holding a body of such liquefied material, means for withdrawing liquid from said container during certain periods, means for compressing a gas material during such periods, means for expanding the withdrawn liquid in heat exchanging relation with the compressed gas material to cool and liquefy the same, an auxiliary container, means for supplying at least a portion of said cooled and liquefied gas material to said auxiliary container and means for continuously withdrawing liquid from said auxiliary container and passing the same in heat exchanging relation with said stored material.

15. Apparatus according to claim 14 in which means are provided for returning to said auxiliary container the material withdrawn therefrom and passed in heat exchanging relation with the stored material.

16. The method of preventing excessive vapor-

ization of gas material stored in the liquid state in an insulated container which comprises compressing a gas material, withdrawing liquid from said container and expanding the same in heat exchanging relation with said compressed gas material to cool and liquefy the same, expanding the cooled gas material and bringing the same into heat exchanging relation with the stored gas material to absorb heat therefrom.

17. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises compressing a gas material withdrawn from said container in the gas phase, withdrawing liquid from said container and passing the same in heat exchanging relation with said compressed gas material to cool and liquefy the same, expanding the cooled gas material and bringing the same into heat exchanging relation with the stored gas material to absorb heat therefrom.

18. The method of preventing excessive vaporization of gas material stored in the liquid state in an insulated container which comprises compressing a gas material withdrawn from said container in the gas phase, withdrawing liquid from said container and passing the same in heat exchanging relation with said compressed gas material to cool and liquefy the same, expanding the cooled gas material and bringing the same into heat exchanging relation with the stored gas material within said container to absorb heat therefrom.

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