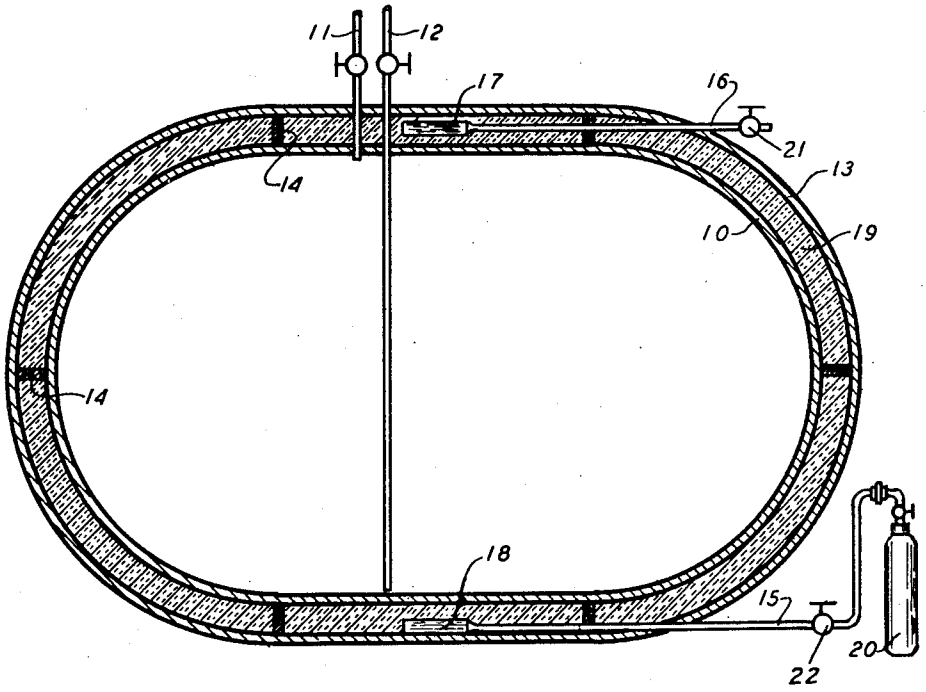
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INSULATED CONTAINER AND METHOD OF INSULATING THE SAME

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INSULATED CONTAINER AND METHOD OF INSULATING THE SAME

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This invention relates to the insulation of vessels used for the storage of liquefied gases, as for example nitrogen, oxygen, air, methane and ethylene.

It is very old practice to store liquefied gases in so-called vacuum vessels, having an evacuated jacket surrounding a storage space maintained at or close to atmospheric pressure. On the small scale in which it is possible to use glass vessels, this method is highly effective in retarding heat flow into the liquid and thereby minimizing evaporation.

The same principle has been applied to storage in quantity, but the difficulty has been encountered that metallic vessels, however carefully constructed, are liable to slow inward leakage of air by which the vacuum is reduced and finally destroyed. To again evacuate the jacket, after this occurrence, requires apparatus the cost of which is not burdensome in a stationary plant including numerous storage vessels but is prohibitive in connection with single or portable tanks.

The objective of the present invention is to provide means for producing a vacuum of useful degree in a heat insulating jacket surrounding a storage tank of any size and for reinstating the vacuum in the event it becomes impaired after prolonged use of the container, both without the use of exhaust pumps or other evacuating machinery.

Referring to the attached drawing, which is a longitudinal section through an exemplary storage tank and its jacket: 10 is a liquefied gas storage tank of any preferred form and dimensions. This tank is provided with top and bottom pipe connections 11 and 12, and with such other fitments as may be desired.

An outer jacket 13 surrounds the storage tank and is spaced from it by members 14—14, which should be of a material of low heat conductivity. The jacket should be as nearly air-tight as it is practicable to make it. Tightness is relative and while it is possible to construct a jacket which, when evacuated, will show no appreciable pressure rise over a considerable period, it is very difficult to build a metallic shell which will maintain a vacuum indefinitely.

The jacket is provided with an inlet connection 15 for the introduction of the functioning vapor and with a vent connection 16 for the displacement of air. These tubes are illustrated as entering the jacket near its periphery. It is preferred that these tubes terminate approximately at the center of length of the tank, and that each be provided with a filter as at 17 and 18 and with

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tight valves as at 21 and 22. The points at which the tubes are brought out of the shell may be as convenient.

While not strictly essential, it is preferable to fill the space 19 between the jacket and the storage vessel proper with some light, porous, incombustible material, such as glass wool, finely comminuted diatomaceous earth or an aerogel, for example, the form of silica known commercially as "Santocel." This filling reduces radiation across the insulating space, prevents convection currents and assists in the displacement of air by vapor in a step later described. The packing should be placed with care so as to be evenly porous throughout.

The establishment of a low subatmospheric pressure, which may approach a complete vacuum, in space 19 is produced by first filling it with a suitable vapor, which is afterward liquefied, or liquefied and solidified. The air initially filling the jacket must be removed as completely as possible. In the shop, where the necessary apparatus is available, the jacket may be evacuated and vapor admitted to take the place of the removed air, thus economizing vapor. In the field, or in any location at which vacuum-producing machinery is not at hand, the jacket may be charged by admitting a gas or vapor to the jacket space, through one of the connections 15—16, and venting displaced air through the opposite connection. This displacement should not be hastened but should be continued until the vent gas shows a sufficiently low air content. If the displacing gas or vapor is materially heavier than air it will naturally be admitted through the lower connection 15 and the air displaced upwardly, while if lighter than air the displacement should be in the opposite direction.

The choice of a gas or vapor for the above purpose will be governed by the boiling point of the liquid to be stored and by the judgment of the operator as to the degree of pressure reduction which it is desirable to produce in the jacket. If it is preferred to have a close approach to complete vacuum in the jacket space the substance used to displace the air should have a vapor pressure not substantially exceeding 1 mm. mercury at a temperature corresponding to the atmospheric pressure boiling point of the stored liquid, and the quantity of residual air must be reduced to the minimum. But if the nature of the operation is such that less perfect insulation is required, a substance having a higher vapor pressure may be used or less care need be exer-

cised in reducing the quantity of residual air, or both. It is possible to obtain a very useful degree of heat exclusion with the use of substances having materially higher relative vapor pressures than that above set forth, and with the presence in the jacket of a material quantity of residual air.

The following list of substances is suggested as including members suitable for the storage of almost all liquids boiling materially below atmospheric temperature under normal atmospheric pressure:

	Melting Point	Boiling Point
	°K.	°C.
Carbon dioxide	216	−78
Freon 114 (dichlorotetrafluoroethane)	203	3
Sulfur dioxide	200	−10
Freon 12 (dichlorodifluoromethane)	195	5
Acetylene	191	−84
Freon 21 (dichloromonofluoromethane)	173	−9
Ethylene oxide	162	11
Ethyl ether	150	35
Methylene chloride	173	40

Any of the above substances can be used in the storage of liquefied nitrogen, oxygen, air, methane or other gas boiling below 150° K. For storing liquid ethylene (boiling at 169° K.) neither ether nor ethylene oxide would be suitable as the melting points are too low. In the use of substances boiling above normal atmospheric temperature, such as ether and methylene chloride, it would be necessary to bring the unit to a superatmospheric temperature in order to vaporize the agent and thus displace the jacket air.

The above examples should be considered illustrative only as any substance may be used which has the requisite relation of melting point and boiling point for the specific conditions existing in each case. The Freons and other halogenated hydrocarbons are preferred displacing agents by reason of their high molecular weight.

When the inner or storage vessel is charged with a liquefied gas, such as one of those above mentioned, and is maintained at atmospheric pressure, the wall of the inner vessel ultimately comes to the atmospheric pressure boiling point of the liquid. The vapor filling the jacket begins to congeal on the wall of the inner vessel as the freezing point is reached and, assuming the vapor to be air-free, diffusion of vapor toward the inner wall and solidification thereon proceed until the pressure within the jacket equals the vapor pressure of the solid at or slightly above the temperature of the boiling liquid. A high degree of rarefication of the atmosphere within the jacket is thus produced and the flow of heat through the jacket space and, in consequence, the evaporation of the contents of the inner vessel, substantially cease.

When the evacuation is not complete and some residual air remains in the jacket space, the vapor is largely congealed on the outer surface of the inner container, as previously described, and is thereby largely eliminated as a heat conducting material. The mean temperature of the residual air in the insulating space is reduced, and its heat conductivity is thereby lessened as the vacuum is improved.

To avoid wastage of valuable liquids such, for example, as liquid oxygen, a partial or complete precooling of the inner vessel and establishment of the reduced pressure in the jacket space may be produced by initially filling the container with some less valuable liquid of low boiling point, or by passing through it a stream of a cold gas.

When, with the passage of time, air leakage into the jacket space appreciably reduces its heat insulating value, the process of charging the jacket may be repeated. Two procedures are available, differing somewhat in manipulation but producing approximately the same ultimate result.

In the first procedure, the inner vessel is emptied and the unit allowed to come to atmospheric temperature. A gas bottle indicated at 20 is then connected to inlet tube 15 and vent 16 is opened, the heavy vapor being introduced slowly until air is completely or substantially displaced. The two openings are then closed and sealed and liquefied gas again placed in the inner vessel, this step reestablishing the heat insulating value of the jacket space.

Alternatively, the recharging operation may be begun immediately after emptying the inner container and while the unit is still cold. In this operation a heavy vapor, such as that of a halogenated hydrocarbon, is first introduced through the bottom connection 18, this vapor freezing in contact with the cold inner vessel as it enters the jacket. When a quantity of vapor equal to or somewhat greater than that which would fill the jacket space at atmospheric temperature and pressure has been introduced the supply is shut off, the unit allowed to warm up by absorbing atmospheric heat and, when the jacket space has reached at least atmospheric pressure, the valve in upper connection 16 is opened. As the temperature rises the congealed substance is slowly vaporized, forming a vapor pool which displaces the air upwardly as it increases in volume. This displacement is at a low rate which avoids turbulence and intermixture of air with vapor, and accomplishes the recharging with the minimum consumption of Freon or other congealable substance.

If the vapor used should be lighter than air it would, of course, be introduced at the top of the jacket and the air would be displaced downwardly, the operation in all other respects being as above described.

During periods of nonuse of the unit it returns to atmospheric temperature and the vapor in the jacket space comes back to the pressure at which it was originally charged, plus that due to air leakage, if any has occurred. This may be atmospheric or materially above atmospheric, as may be preferred. In either case, no inward leakage of air can occur during such periods of idleness.

In the event of severe leakage of air into the jacket space, a material improvement in insulating value may be produced, even in the absence of a supply of Freon or other vapor suitable for recharging. A considerable proportion of the leakage air may be eliminated by merely allowing the unit to warm up, or even heating it to a temperature materially above atmospheric, and venting the jacket space, preferably on the side opposite that which the vapor would seek by reason of its relative weight. This will cause air containing only a minor proportion of vapor to be discharged and on again sealing and cooling the jacket space a material reduction in pressure and a correspondingly improved insulating value will be observed.

The above descriptions refer to the storage of the liquid at atmospheric pressure, but it will be understood that this is by no means essential.

The stored liquid may be maintained at any pressure to which the inner vessel is adapted. A superatmospheric pressure on the stored liquid raises the actual temperature at which it boils and, in consequence, the maximum temperature at which the vapor must congeal, permitting the use of a wider variety of substances as the source of vapor. The essential is that the vapor should solidify, and should have a low vapor pressure, at a temperature determined by the boiling point of the stored liquid at the pressure under which it is stored.

I claim as my invention:

1. A storage tank adapted to retain a liquefied gas, comprising: an inner, liquid-retaining shell; a jacket surrounding and spaced from said shell to form a sealed insulating space, said space containing at the most some residual air at a very low partial pressure and containing the vapor of a substance which is in the vapor phase at atmospheric temperature and pressure and which solidifies at a temperature above the boiling point of said liquefied gas at the pressure existing in said tank and which has a very low vapor pressure at said boiling point.

2. Apparatus as and for the purpose set forth in claim 1, in which the vapor contained in said space is the vapor of a halogenated hydrocarbon.

3. Apparatus as set forth in claim 1, in which the vapor contained in said space is the vapor of dichlorodifluoromethane.

4. Apparatus as set forth in claim 1, in which the vapor contained in said space is the vapor of a substance which solidifies at a temperature above 90° Kelvin and which has a vapor pressure not substantially exceeding 1 mm. of mercury, absolute, at 90° Kelvin.

5. A storage tank adapted to retain a liquefied gas, comprising: an inner, liquid-retaining shell; a jacket surrounding and spaced from said shell to form a sealed insulating space; a filling of porous material within said space, and a vapor within the voids of said filling, said vapor being of a substance which is in the vapor phase at atmospheric temperature and pressure and which solidifies at a temperature above the boiling point of said liquefied gas at the pressure existing in said tank and which has a very low vapor pressure at said boiling point.

6. Apparatus substantially as and for the purpose set forth in claim 5, in which said filling material is an aerogel.

7. The method of insulating a storage tank for volatile liquids having a jacket providing an enclosure of space surrounding said tank, comprising: replacing the air initially present in said space with a vapor which solidifies at a temperature above the boiling point of the liquid to be stored in said tank and which has a low vapor pressure in the solid state; sealing said vapor-filled jacket to prevent leakage of air into said space when the pressure therein falls below atmospheric; placing in said tank a volatile liquid which boils at a temperature below the solidifying point of said vapor, and permitting said liquid to boil and thereby to cool the wall of said tank to the solidifying point of said vapor.

8. The method of insulating a storage tank for liquid oxygen having a jacket providing an enclosure of space surrounding said tank, comprising: replacing the air initially present in said space with a vapor which solidifies at a temperature above the atmospheric pressure boiling point of liquid oxygen; sealing said vapor-filled jacket to prevent leakage of air into said space when the pressure therein falls below atmospheric; placing liquid oxygen in said tank, and permitting said oxygen to boil until the wall of said tank is cooled to the solidifying point of said vapor, whereby the pressure within said space is reduced by the solidification of a portion of said vapor.

9. The method of insulating a liquid oxygen storage tank having a jacket providing an enclosure of space surrounding said tank, comprising: introducing into the lower portion of said space a vapor heavier than air which solidifies at a temperature above 90° K. and which has a low vapor pressure in the solid state; venting the upper portion of said space while introducing said heavy vapor and thereby replacing with said heavy vapor a material proportion of the atmosphere previously present in said space; sealing said vapor-filled jacket to prevent leakage of air into said space when the pressure therein falls below atmospheric, and causing liquid oxygen to boil in said tank until a substantial portion of said heavy vapor is solidified and the pressure in said space correspondingly reduced.

10. The method of insulating a liquefied gas storage tank having a jacket providing an enclosure of space surrounding said tank, comprising: introducing into the lower portion of said space a vapor heavier than air which solidifies at a temperature above the atmospheric pressure boiling point of said liquefied gas and which has a low vapor pressure in the solid state; venting the upper portion of said space while introducing said heavy vapor and thereby replacing with said heavy vapor a material proportion of the atmosphere previously present in said space; sealing said vapor-filled jacket to prevent leakage of air into said space when the pressure therein falls below atmospheric, and causing liquefied gas to boil in said tank until a substantial portion of said heavy vapor is solidified and the pressure in said space correspondingly reduced.

11. The method of insulating a liquefied gas storage tank having a jacket providing an enclosure of space surrounding said tank, comprising: introducing into said space a vapor which solidifies at a temperature above the atmospheric pressure boiling point of said liquefied gas and which has a low vapor pressure in the solid state; venting said space during said introduction at a point substantially opposite the point at which said vapor is introduced and thereby replacing with said vapor a material proportion of the atmosphere previously present in said space; sealing said jacket after introducing said vapor to prevent leakage of air into said space when the pressure therein falls below atmospheric, and vaporizing liquid gas in said tank until a substantial portion of said vapor is solidified and the pressure in said space correspondingly reduced.

12. The method of insulating a liquefied gas storage tank having a jacket providing an enclosure of space surrounding said tank, comprising: introducing into said space a vapor which solidifies at a temperature above the atmospheric pressure boiling point of said liquefied gas and which has a low vapor pressure in the solid state; venting said space during said introduction at a point substantially opposite the point at which said vapor is introduced and thereby replacing with said vapor a material proportion of the atmosphere previously present in said space; sealing said jacket after said introduction to exclude air from and retain vapor in said space; reducing the temperature of the wall of said tank be-

low the solidifying point of said vapor; storing said liquefied gas in said cooled tank, and permitting vaporization of the contents of said tank sufficient to maintain the wall of said tank below the solidified point of said vapor, thereby maintaining a rarefied, heat-insulating atmosphere in said space.

13. The method of insulating a liquefied gas storage tank having a jacket providing an enclosure of space surrounding said tank and a packing of porous material substantially filling said space, comprising: bringing said packing to substantially atmospheric temperature; introducing into said space a stream of the vapor of a substance which is in the vapor phase at atmospheric temperature and pressure, which is a solid at the atmospheric pressure boiling point of said liquefied gas and which has a low vapor pressure in the solid state; venting from said space gases and vapors displaced from the voids in said porous material by the introduction of said vapor; sealing said jacket after introducing said vapor to retain vapor and exclude air from said space, and cooling said tank to the boiling point of said liquefied gas, whereby said introduced vapor is partially solidified on the wall of said tank and the pressure in said space is correspondingly reduced.

14. The method of insulating a liquefied gas storage tank having a jacket providing an enclosure of space surrounding said tank and a packing of porous material substantially filling said space, comprising: introducing into the voids in said packing material the vapor of a substance which is in the vapor phase at atmospheric temperature and pressure, which is a solid at the atmospheric pressure boiling point of said liquefied gas and which has a low vapor pressure in the solid state; bringing a solid surface in contact with said vapor to a temperature at which a portion of said vapor is solidified and introducing a further quantity of said substance into said space to replace the vapor withdrawn by solidification; raising the temperature of said contact surface while venting said space and thereby vaporizing the solidified portion of said substance and displacing gases and vapors from the voids in said packing material; sealing said jacket to retain vapors and prevent ingress of air to said space, and cooling said tank to the boiling point of said liquefied gas, whereby the vapor remaining in said space is partially solidified on the wall of said tank and the pressure within said space is correspondingly reduced.

15. The method of insulating a chamber having walls and a jacket providing an enclosure of space surrounding the chamber walls comprising: at least substantially replacing the air initially present in the space with a vapor which is a solid under conditions of use of the chamber and which has a low vapor pressure in the solid state, the quantity of vapor being such that when at least a major portion is solidified a vacuum is formed in the space; sealing the vapor-filled jacket to prevent leakage of air into the space when the pressure therein falls below atmospheric; and cooling the walls of the chamber below the solidifying point of the vapor, whereby a vacuum is formed within the space.

16. The method of insulating a chamber having walls and a jacket providing an enclosure of space surrounding the chamber walls and a packing of porous material substantially filling the space, comprising: bringing the packing to substantially atmospheric temperature; at least substantially replacing the air initially present in the space with the vapor of a substance which is in the vapor phase at atmospheric temperature and pressure, which is a solid under conditions of use of the chamber and which has a low vapor pressure in the solid state, the quantity of vapor being such that when at least a major portion is solidified a vacuum is formed; sealing the vapor-filled jacket to prevent leakage of air into the space when the pressure therein falls below atmospheric; cooling the walls of the chamber below the solidifying point of the vapor whereby a vacuum is formed within the space.

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