United States Patent

Bancroft

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[54] **LIQUID PROPELLANT STORAGE TANK**

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[52] **U.S. Cl.** .....**62/45,** 220/9 LG, 200/9 F

[51] **Int. Cl.** **F17c 13/00**

[58] **Field of Search** .....62/45, 54, 61 I; 220/9 LG, 220/10, 9 F

[56] **References Cited**

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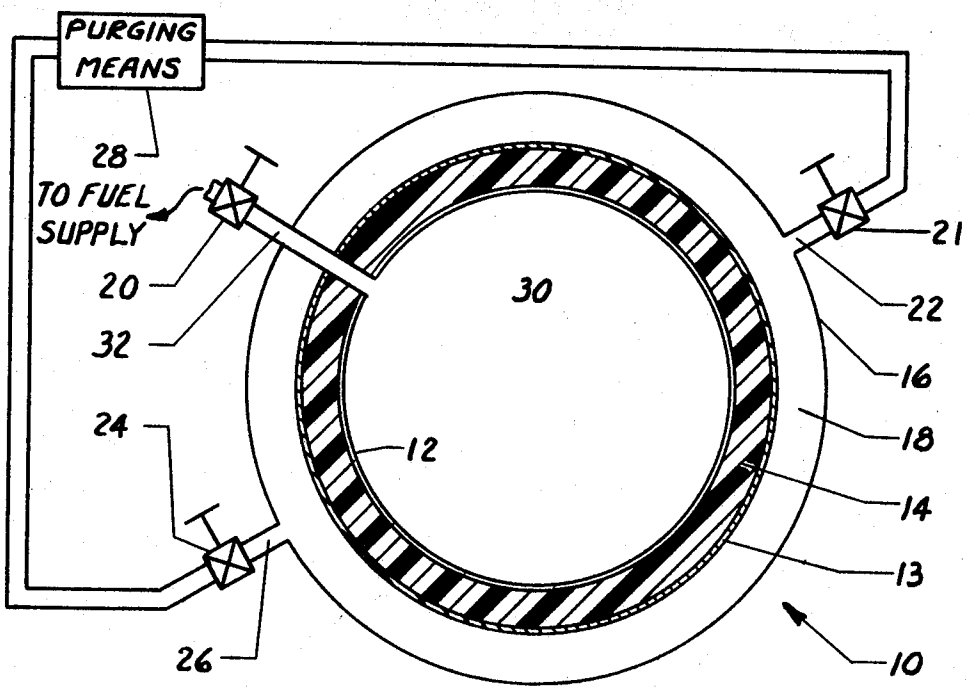
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[57] **ABSTRACT**

A multi-layer insulated tank for storing a liquid propellant. A tank is coated with a low thermal conductive gas expanded foam. The foam coated tank is encased in a plastic bag and is maintained under a low thermal conductive gas until just before the tank is charged with the liquid propellant. Just prior to charging the tank with cryogen, the low thermal conductive gas is replaced by helium or nitrogen depending upon the cryogen to prevent condensation of water vapor and/or purge gas on the outer surface of the tank.

8 Claims, 2 Drawing Figures



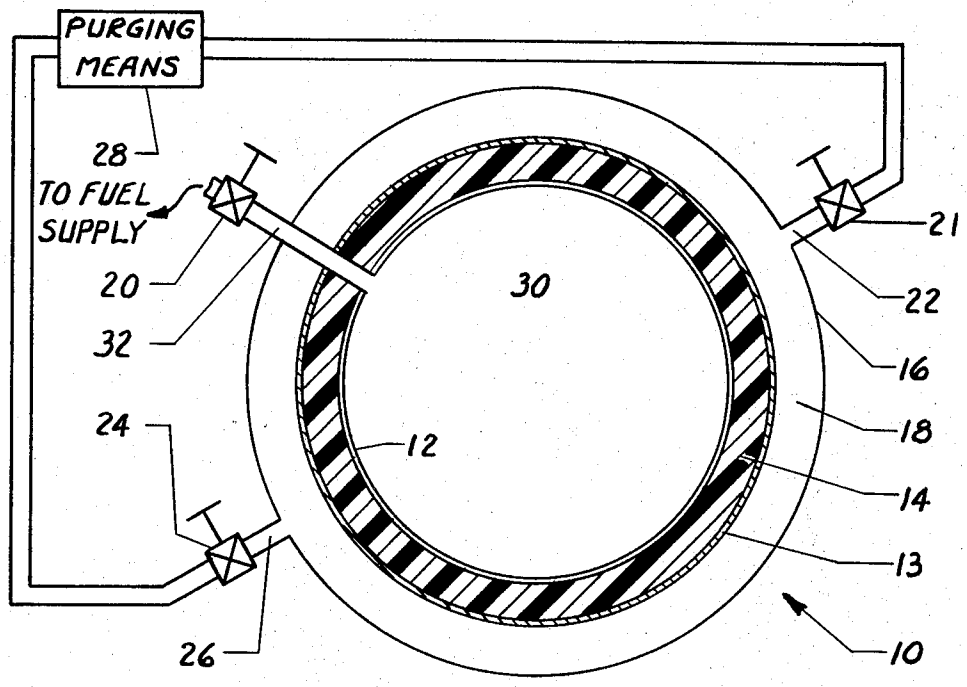


FIG. 1

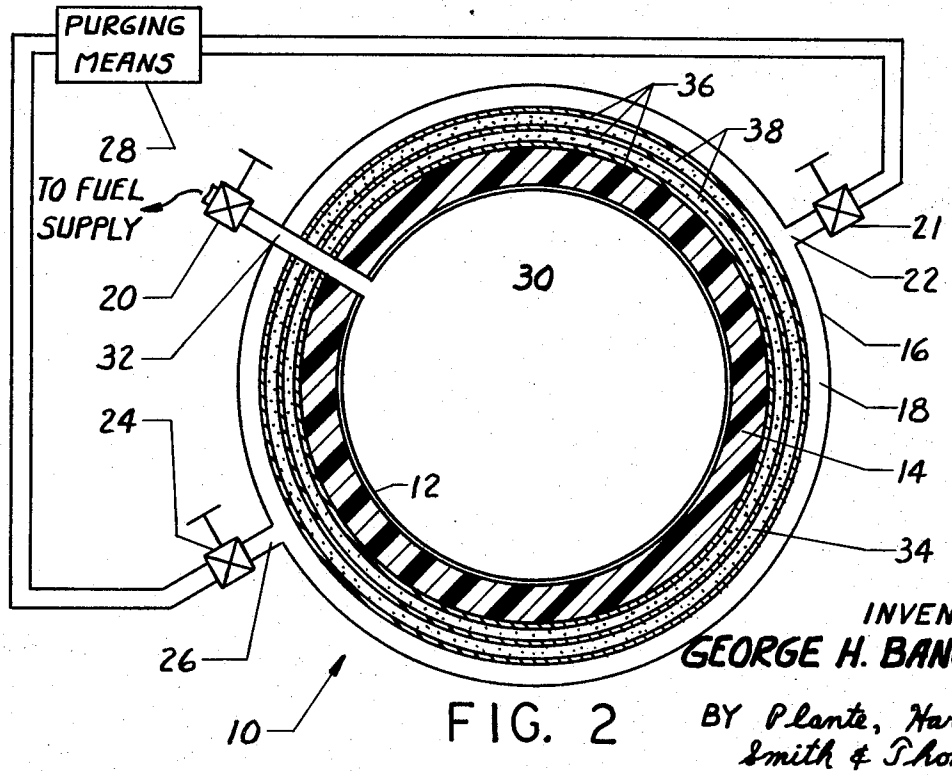


FIG. 2

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LIQUID PROPELLANT STORAGE TANK

BACKGROUND OF THE INVENTION

In the prior art, tanks for the storage of cryogens such as: oxygen nitrogen, methane and hydrogen used as a liquid propellant, are constructed as double tanks, one inside the other, with the space between them evacuated to a sufficiently low pressure to practically eliminate the gaseous conduction from one tank to the other. In the case of space boosters and particularly for large storage tanks, the second tank wall represents a large weight penalty on the payload of the booster. Once the tank reaches space, even with a single walled tank, the vacuum is no problem since it is the atmosphere of space thereby eliminating the transfer of heat by conduction. However, in space the transfer of heat by radiation affects the cryogens in the storage tank. In order to reduce the transfer of heat by radiation which is not affected by the gas pressure in the annulus between the double tanks, discreet radiation shields or multi-layer insulation is introduced into the annular space.

However, during the filling process and holding time on the ground, an uninsulated tank would experience high heat transfer and consequent loss of fluid due not only to the gaseous conduction and radiation, but also a very substantial heat loss from the action of gaseous convection. To reduce the heat loss from such gaseous convection in large liquid propellant storage tanks used in space boosters for the storage, primarily of cryogens such as liquid oxygen, liquid hydrogen and liquid methane, foam insulation is used as one member of the insulation system. It has been observed that initially following the curing period, the thermal conductivity of a FREON expanded foam is lower than after standing for a few months exposed to air. It has been proposed that, the FREON diffuses out of the closed cells of the polyurethane foam and is subsequently replaced with air which has a gaseous thermal conductivity approximately twice that of FREON. This replacement process starts immediately on formation of the foam. The longer the foam is held in storage, the larger the percentage of air and the smaller the percentage of FREON becomes, with the attendant increase in thermal conductivity.

SUMMARY OF THE INVENTION

The transfer of heat by gaseous convection to the storage tank will be the greatest at the surface of the earth. In my invention, I place a plastic membrance around the FREON expanded foam coated storage tank to form a control chamber therein. By maintaining a low thermal conductive gas which has relatively high liquidus and solidus temperatures in the control chamber during storage of the tank after fabrication, the maximum effectiveness of the foam coating in reducing heat loss will be obtained.

In addition by using a plastic membrance as the second tank wall, a substantial reduction in weight of the storage tank will be produced. Once the storage tank reaches space, the plastic membrane can be jetisoned or destroyed since the atmosphere of space is a vacuum.

It is therefore an object of this invention to provide a means for reducing thermal conduction between a storage tank and an environmental source.

It is another object of this invention to provide an improved lightweight thermal resistant cryogenic storage vessel.

It is a further object of this invention to provide means for controlling the thermal conductivity of an insulating member surrounding a cryogenic tank.

These and other objects will be readily apparent to those of ordinary skill from reading the detailed description and viewing the drawings of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cryogenic storage tank constructed in accordance with the principles of the present invention.

FIG. 2 is another embodiment of the storage tank with a multi-layer radiation shield surrounding the cryogenic storage tank.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, like members represent the same element in each embodiment.

The cryogenic storage container **10** shown in FIGS. **1** and **2** has an inner wall **12** surrounded by a FREON expanded polyurethane foam **14** to reduce the transfer of heat by convection to the inner wall **12** from an environmental source. A single layer of metalized material **13** such as MYLAR is wrapped on the external surface of the foam layer to reduce the absorption of radiation in the outer surface of the foam. A plastic flexible membrane or bag **16** encases the foam covered inner wall **12** forming a control chamber **18**. The plastic membrance **16** has a suitable control valve **21** for regulating fluid through inlet port **22** to control chamber **18** and a suitable outlet valve **24** adjacent port **26**, attached to purging means **28** for evacuating control chamber **18** in response to an operator command.

To obtain the maximum effectiveness of the FREON expanded polyurethane foam, the control chamber **18** is maintained during storage after curing under a low thermal conductive gas atmosphere having relatively high liquidus and solidus temperatures. After control chamber **18** has been evacuated of air by purge means **28**, either FREON or carbon dioxide gas is supplied to the control chamber **18** through control valve **21** which will retain the FREON expanded foam in an inert condition.

This is because carbon dioxide has approximately the same gaseous thermal conductivity as the FREON which is of the order of 0.005 BTU per hour per sq. ft. per degree rankine while air has a thermal conductivity approximately 0.0100 twice that of FREON or CO_2. On the basis of molecular size, the permeation or diffusion coefficient for CO_2 of the FREON expanded polyurethane foam should be between that for FREON and that for air, that is greater than that for FREON but less than that for air. In this way the foam will always have FREON or a mixture of FREON and carbon dioxide contained in its cells. Thus, the thermal conductivity of the foam will be maintained relatively as low as when first formed and its degradation with time should be eliminated.

Upon charging chamber **30** with a cryogen through connecting means **32** having a valve **20** controlled by an operator, the low thermal conductive gas is removed

from control chamber **18** by purging means **28**. Helium gas is now scheduled through control valve **21** to the control chamber **18**. Just prior to launch both valves **21** and **24** should be closed trapping a slight positive pressure, above atmospheric, of helium gas in the control chamber **18**. The helium gas will not condense into a liquid or a solid at the charging temperature of the cryogen as would either the FREON or carbon dioxide gas and being dry, it will prevent the formation of frost due to the presence of water vapor in the atmosphere. The thermal conductivity of helium is approximately 10 to 11 times that of either FREON or carbon dioxide. Although after an extended period of time, the helium will diffuse into the foam, during the normal hold time, the build-up of the partial pressure of helium in the foam cells would be expected to be negligibly small, much less than a small fraction of one atmosphere. The thermal conductivity of the mixture of carbon dioxide or FREON and helium will be only slightly more than that of the carbon dioxide and FREON either alone or as a mixture of the two. As the temperature in the foam falls to the liquification or solidification point of either FREON or carbon dioxide their vapor pressure is reduced and consequently the contribution to gaseous conduction from this source is also reduced.

When the foam insulated tank is projected into space, the primary heat transfer is through radiation. To reduce the effect of radiation from an environmental source, multi-layer radiation shields **34** (see FIG. **2**) are wrapped around the FREON expanded polyurethane foam. The multi-layer radiation shields have a reflective metallic material plated **36** on a backing member such as MYLAR **38**.

Since a slightly positive pressure of helium was established in the control chamber **18** on the ground, once the storage tank has been projected into space, the helium gas will expand causing the plastic membrance to rupture due to the increased differential pressure. Upon rupturing, the foam covered storage tank will then be in the absolute vacuum of space wherein the transfer of heat by convection is eliminated and the multi-layer radiation shield **34** is the primary source of thermal energy control.

I claim:

1. A storage unit, comprising:

a vessel;

means for charging said vessel with a liquid propellant;

a foam insulating member surrounding said vessel, said foam insulating member having gaseous cells formed by a low thermal conductive gas for reducing the transfer of heat to said vessel by gaseous convection;

a plastic bag encasing said foam insulating member forming a control chamber around said vessel, said bag having an inlet port and an outlet port;

evacuation means connected to said outlet port for removing the air from said control chamber; and

control means regulating the flow of said low thermal conductive gas having a relatively high liquidus and solidus temperature, through said inlet port to said air evacuated control chamber for preventing diffusion of said low thermal gas from said cells after curing during the storage period prior to said charging of the vessel.

2. A storage unit, as recited in claim **1**, wherein said evacuating means purges said control chamber of said low thermal conductive gas and said control means regulates the flow of helium to said control chamber in response to an operator signal for preventing condensation of the low thermal conductivity gas and water vapor on the outer surface of said vessel during charging of said vessel with said liquid propellant.

3. A storage unit, as recited in claim **2**, including:

a reflective metallic material plated on a backing member to form a radiation shield, said radiation shield being wrapped on the outer surface of said foam insulating member for reducing the transfer of heat to said vessel by radiation from an environmental source.

4. A method of reducing the transfer of heat between and external surface of a cryogenic storage tank and the environment, comprising the steps of:

coating said external surface with a FREON expanded polyurethane foam;

surrounding said surface with a membrance to form a control chamber therein;

purging said control chamber of air;

introducing a gas into said control chamber having a relatively low thermal conductivity and relatively high liquidus and solidus temperatures as compared to those of air for insulating said cryogenic storage tank;

wrapping said external surface of said layer of foam on the external surface of said storage tank with a reflective metallic material applied to a backing member to form an initial radiation shield; and

changing said gas to helium gas prior to charging said storage tank with a cryogen for preventing condensation of the said low thermal conductivity gas and water vapor on the outside of said storage tank.

5. In a cryogenic storage system, means for reducing the transfer of heat to the external surface of a storage tank, comprising:

a foam coating of FREON expanded polyurethane secured to the external surface of said storage tank;

a flexible membrance surrounding said coating having an inlet port and an outlet port, said flexible membrane and coating forming a control chamber therebetween; and

purging means operatively connected to said inlet port and said outlet port for removing air from said control chamber and for introducing a gas to said control chamber having a relatively low thermal conductivity as compared to that of air and having high liquidus and solidus temperatures relative to the usual cryogens for maintaining said FREON expanded polyurethane in an inert condition.

6. In a cryogenic storage system, as defined in claim **5**, wherein purging means replaces said gas in said control chamber with helium prior to charging said storage tank with cryogen for preventing consensation of water vapor or purge gas on the outside of said storage tank.

7. In a cryogenic storage system, as defined in claim **6**, including:

a reflective metallic material located on said external surface of the said foam coating to form an inner radiation shield.

8. In a cryogenic storage system, as defined in claim 7, including:

a multi-layer insulation shield located on the outside of said foam coating to form an outer radiation shield around said storage tank.

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