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APPARATUS FOR STORING LIQUEFIED GAS NEAR ATMOSPHERIC PRESSURE

Filed July 31, 1963

Fig. 1

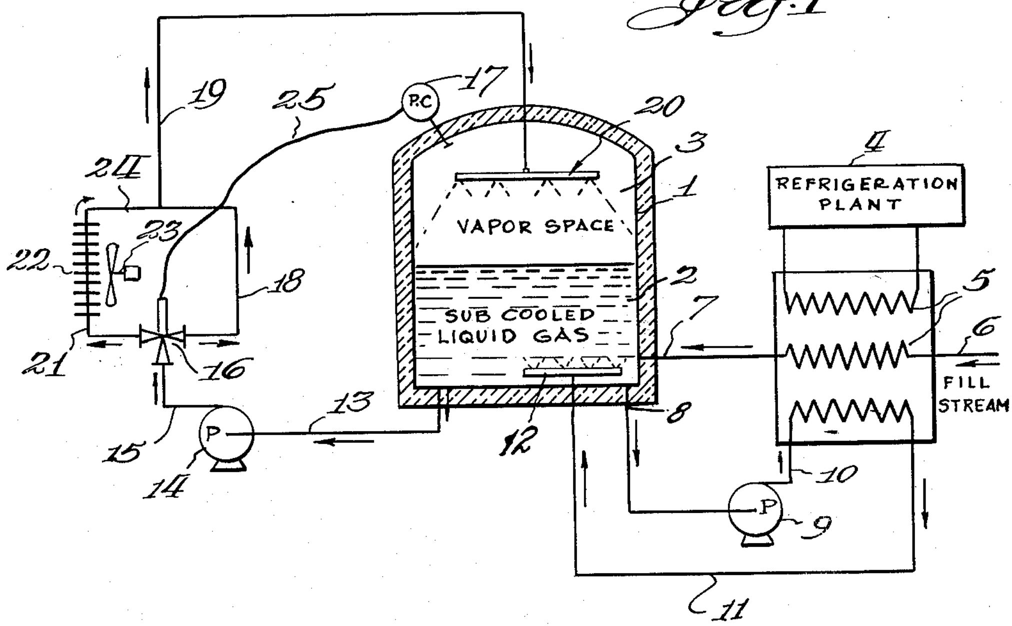
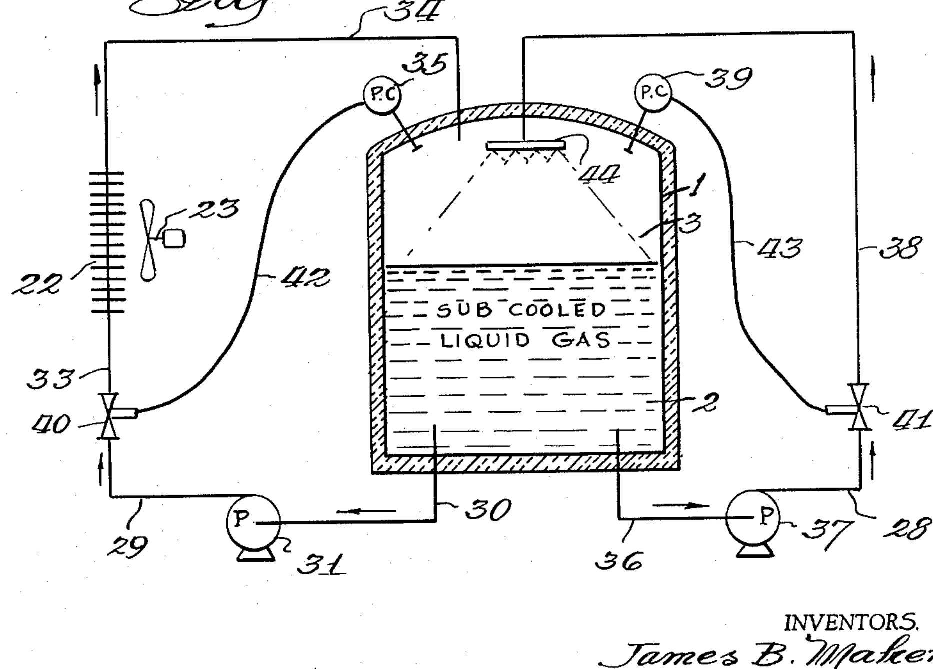


Fig. 2



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APPARATUS FOR STORING LIQUEFIED GAS NEAR ATMOSPHERIC PRESSURE

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This invention relates to the storage of liquefied gases. More particularly, this invention is concerned with novel apparatus and methods for regulating the vapor pressure in storage tanks containing liquefied gases.

Large quantities of liquefied gases are stored in insulated storage tanks. A large high capacity refrigeration system is provided to convert the filling stream of gas to a liquid, or to cool a warm liquid stream, before it is pumped into the tank. Normally a second, smaller refrigeration system is used to compensate for heat-leak through the tank and maintain the gas in the liquefied condition.

Gases which are vapors at normal temperatures and pressures are stored in this way, including the hydrocarbons containing from 1 to 4 carbons such as methane, ethane, propane, isopropane and butane, as well as other gases including ammonia, carbon dioxide and oxygen.

It is common practice in most storage facilities to hold the liquefied gas almost exactly at a temperature which in theory is calculated to exert the desired vapor pressure in the tank. For example, if the tank is designed for 1.0 p.s.i.g. then the liquefield product is normally held at a temperature which gives a vapor pressure of about 0.5 p.s.i.g.

It is also customary to include means ancillary to the storage tank for providing either replacement vapor to the vapor space of the storage tank during periods of pump-out or a rise in barometric pressure, or for receiving expelled vapor when the pressure builds up, to maintain a fairly uniform vapor pressure in the tank.

In order to prevent the build-up of excessive vapor pressure in the tank, it is the practice to withdraw gas vapor from the tank and liquefy it through the holding refrigeration system and then return it to the storage tank. Such a system involves a continuous starting and stopping of the refrigeration unit and this, in itself, is costly and undesirable and also involves the investment in, and maintenance of, a second refrigeration system.

Although it has ben assumed in the past that the pressure in the vapor space in the storage tank would be determined by the temperature of the liquefied gas stored in the tank, it has been found that the pressure in the vapor space is greatly affected and substantially determined by the heat-leak through the unwetted portion of the storage tank above the liquid, and that the vapor is often at a condition of super-heat regardless of the temperature of the stored liquid, provided, of course, that the temperature is low enough to prevent boiling of the liquefied gas.

Because in practice the vapor pressure in the tank is not determined by the temperature of the liquefied gas, but rather is determined by the heat-leak in the unwetted portion of the vessel, the liquefied gas can be stored at a sub-cooled temperature without subjecting the tank to a vacuum through a reduction in vapor pressure which might cause its collapse. The vapor in a tank containing subcooled liquefied gas will be in a super-heated condition because of the heat-leakage. As a result, the pressure of the vapor will be considerably higher than the pressure would be if determined by the temperature of the subcooled liquefied gas. Because a liquefied gas can be stored in such tanks at subcooled temperatures, it is practical to "store refrigeration" in the product itself by

subcooling it below normal temperature of storage required to keep it liquid.

It has now been discovered that use can be made of stored refrigeration in, or subcooled temperatures of, a liquefied gas to regulate the vapor pressure in the vapor space of the storage tank containing the subcooled liquefied gas during the filling, holding or emptying operations. It has been found that subcooled liquefied gas can be withdrawn from the storage tank and conveyed to the vapor storage space of the tank in liquefied form to reduce the vapor pressure therein or the withdrawn subcooled liquefied gas can be vaporized and the resulting vapor conducted to the vapor space of the tank to raise the vapor pressure therein.

More particularly, there is provided by this invention a method of controlling the vapor pressure in an enclosed, insulated storage tank partially filled with a subcooled liquefied gas which comprises determining the vapor pressure in the tank and its difference from a preselected pressure range, withdrawing subcooled liquefied gas from the tank and, when the vapor pressure in the tank is above the preselected pressure range, delivering the liquefied gas to the vapor space in the tank to condense some of the vapor and thereby lower the pressure and, when the vapor pressure in the tank is below the preselected pressure range, vaporizing the withdrawn liquefied gas and delivering the gas vapor so formed into the vapor space in the tank to raise the vapor pressure therein to the preselected pressure range, and discontinuing withdrawal of liquefied gas when the vapor pressure in the tank is in the preselected pressure range.

The invention will now be described in conjunction with the attached drawings which show the process, and novel combinations of apparatus useful in practicing the process.

FIG. 1 shows in schematic form a storage facility for liquefied gas and a novel combination of apparatus for regulating the vapor pressure in the storage tank, and

FIG. 2 is a schematic drawing showing an alternative novel combination of apparatus for regulating the vapor pressure in a tank containing liquefied gas.

The drawing of FIG. 1 shows an insulated storage tank **1** for holding liquefied gas **2** at a subcooled temperature. The tank is designed to be partially filled, with a vapor space in the upper part **3**. A refrigeration plant **4** is provided having cooling coils **5**. The inlet conduit **6** supplies gas, or already liquefied gas, to the refrigerating coils **5** from which liquefied gas emerges and is conveyed by conduit pipe **7** into the storage tank **1**. The liquefied gas may be cooled by the refrigerating coils to a pressure corresponding to the atmospheric pressure storage temperature, such as 0.5 p.s.i.g., or it may be immediately subcooled. The refrigeration system need only be of sufficient capacity and horsepower to bring the incoming stream down to atmospheric pressure storage temperature after which the same system can be used to cool the liquefied gas down to a subcooled temperature.

To bring and maintain the liquefied gas at a subcooled temperature, there is provided withdrawal conduit pipe **8** for removing liquefied gas from the storage tank by means of pump **9** from which the liquefied gas is conveyed by conduit **10** to the refrigeration coils **5** where it is subcooled and returned to the storage tank by conduit pipe **11**. Suitable insulation is provided on all equipment and pipes described or forming part of the system as is warranted to maintain the product at the temperature necessary or desirable. A spray ring **12** is provided inside the storage tank for feeding the subcooled liquefied gas from conduit **11** substantially throughout the mass of liquefied gas in the tank.

The combination of apparatus used to control the vapor pressure in the vapor space **3** of the storage tank by use of the subcooled liquefied gas 2 in the tank in part comprises means for withdrawing subcooled liquefied gas from the tank such as conduit pipe 13 which communicates with pump 14 for facilitating removal of the liquefied gas. The liquefied gas is then conveyed in a conduit pipe 15 to a three-way valve 16. The valve 16 is responsive to, and actuated by, pressure controller 17 which in turn is responsive to the vapor pressure in the vapor space of the tank. The pressure gauge 17 actuates the three-way valve 16 by any suitable pneumatic or electrical means 25.

Communicating with the valve 16 is conduit pipe 18 which is capable of conveying liquefied subcooled gas to conduit pipe 19 which delivers the liquefied gas into the vapor space 3 of the tank. Conduit 19 desirably communicates with a spray ring 20 in the tank for uniformly distributing the liquefied gas into the vapor space.

Also communicating with valve 16 is conduit pipe 21 which delivers liquefied gas to vaporizer 22. As shown in the drawing, the vaporizer comprises a heat exchanger over which air is circulated by means of fan 23 to vaporize the liquefied gas in the heat exchanger. After the gas has been vaporized, it is conveyed by conduit 24 into conduit pipe 19 and then into the vapor space of the tank. The vapor can also be distributed into the vapor space by means of spray ring 20.

The pressure controller 17 is set at a preselected pressure range which completely shuts a valve 16 and thereby closes access to conduits 18 and 21 when the vapor pressure in the tank is in a preselected pressure range. When valve 16 is completely closed, pump means 14 is off. When the vapor pressure in the tank falls below the preselected pressure range, pressure controller 17 actuates valve 16 to open selectively so that liquefied gas can pass into conduit 21 while maintaining the access port to conduit 18 closed. The subcooled liquefied gas is then conveyed from conduit 21 to the vaporizer 22 and the vapor therefrom is conveyed into the vapor space to raise the pressure in the tank.

An increase in the vapor pressure in the tank above the preselected pressure range causes pressure controller 17 to actuate valve 16 to open selectively the port communicating with conduit 18 so that liquefied gas can be routed into it while simultaneously keeping the access port of the valve leading to conduit 21 closed. As a result, subcooled liquefied gas is conveyed from conduit 15 through the valve to conduit 18 and thence into conduit 19 for delivery to the vapor space in the tank. The introduction of the subcooled liquefied gas into the vapor space condenses the vapor therein and thereby lowers the vapor pressure.

The system shown in FIGURE 2 is similar to that of FIGURE 1 but the means for supplying liquefied gas or gas vapor to the vapor space of the tank are separate of each other. Those parts of the apparatus in FIGURE 2 which are common to FIGURE 1 have been numbered identically.

Conduit 30 in FIG. 2 withdraws subcooled liquefied gas from the tank by means of pump 31. It is conveyed by conduit 29 through valve 40 to conduit pipe 33 and then to vaporizer 22. The resulting vapor is conveyed by conduit pipe 34 to the vapor space 3 of the storage tank. Pressure controller 35 is responsive to the gauge vapor pressure in the tank and, by electric or pneumatic means 42, it actuates valve 40 to supply liquefied gas to the vaporizer when vapor is needed to raise the pressure in the tank. Pump 31 is controlled to operate when valve 40 is open and to be off when the valve is closed. The resulting vapor is conveyed by conduit 34 into the tank. No spray ring is necessary for vapor.

To decrease the pressure in the vapor space of the tank, subcooled liquefied gas can be withdrawn in conduit pipe

36 by means of pump 37 and conveyed by conduit 28 through valve 41 to conduit 38 and then into the vapor space 3 of the tank. Pressure controller 39 is responsive to a preselected vapor pressure in the tank and it actuates, by electric or pneumatic means 43, valve 41 to open the same when the vapor pressure in the tank goes above the preselected level. Subcooled liquefied gas is then conveyed by conduit 38 to the vapor space of the tank. If desired, it can be sprayed in by spray ring 44. Of course, refrigeration means are provided with the apparatus of FIG. 2 similar to that shown in FIG. 1 to maintain the liquefied gas in the storage tank at a subcooled temperature.

During the filling operation the vapor pressure in the tank can be controlled by withdrawing subcooled liquefied gas and spraying it into the vapor space to condense the vapors and thereby lower the pressure.

Since rapid withdrawal of liquefied gas can lead to excessive lowering of the vapor pressure in the tank, the vapor pressure can be regulated by the described invention by withdrawing subcooled liquefied gas, vaporizing it and feeding the vapor into the vapor space of the tank.

Various changes and modifications of the invention can be made and, to the extent that such variations incorporate the spirit of this invention, they are intended to be included within the scope of the appended claim.

What is claimed is:

Apparatus comprising an enclosed insulated storage tank capable of holding subcooled liquefied gas in the tank with a vapor space above the level of the liquefied gas, a pressure controller communicating with, and responsive to, variations in pressure of the gas vapor in the tank, means for pumping subcooled liquefied gas from the tank to a distribution valve responsive to, and actuated by, the pressure controller, first conduit means communicating with the valve and the vapor space of the tank for delivering liquefied gas from the valve to the vapor space in the tank when the vapor pressure is higher than a preselected pressure, a second conduit means communicating with the valve and a vaporizer for vaporizing the liquefied gas, and a conduit means leading from the vaporizer to the vapor space in the tank for delivering vaporized gas thereto from the vaporizer when the vapor pressure in the tank is lower than a preselected pressure, access to the first conduit being selectively closable and open to the second conduit by the valve in response to the pressure gauge when the vapor pressure in the tank reaches a preselected minimum pressure and gas vapor is to be introduced therein, and access to the second conduit being selectively closable and open to the first conduit by the valve in response to the pressure gauge when the vapor pressure in the tank reaches a preselected maximum pressure, said valve further being closed to both the first and second conduits when the vapor pressure in the tank is within a preselected range between the said preselected maximum and minimum pressures.

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