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STORAGE OF LIQUEFIED GAS

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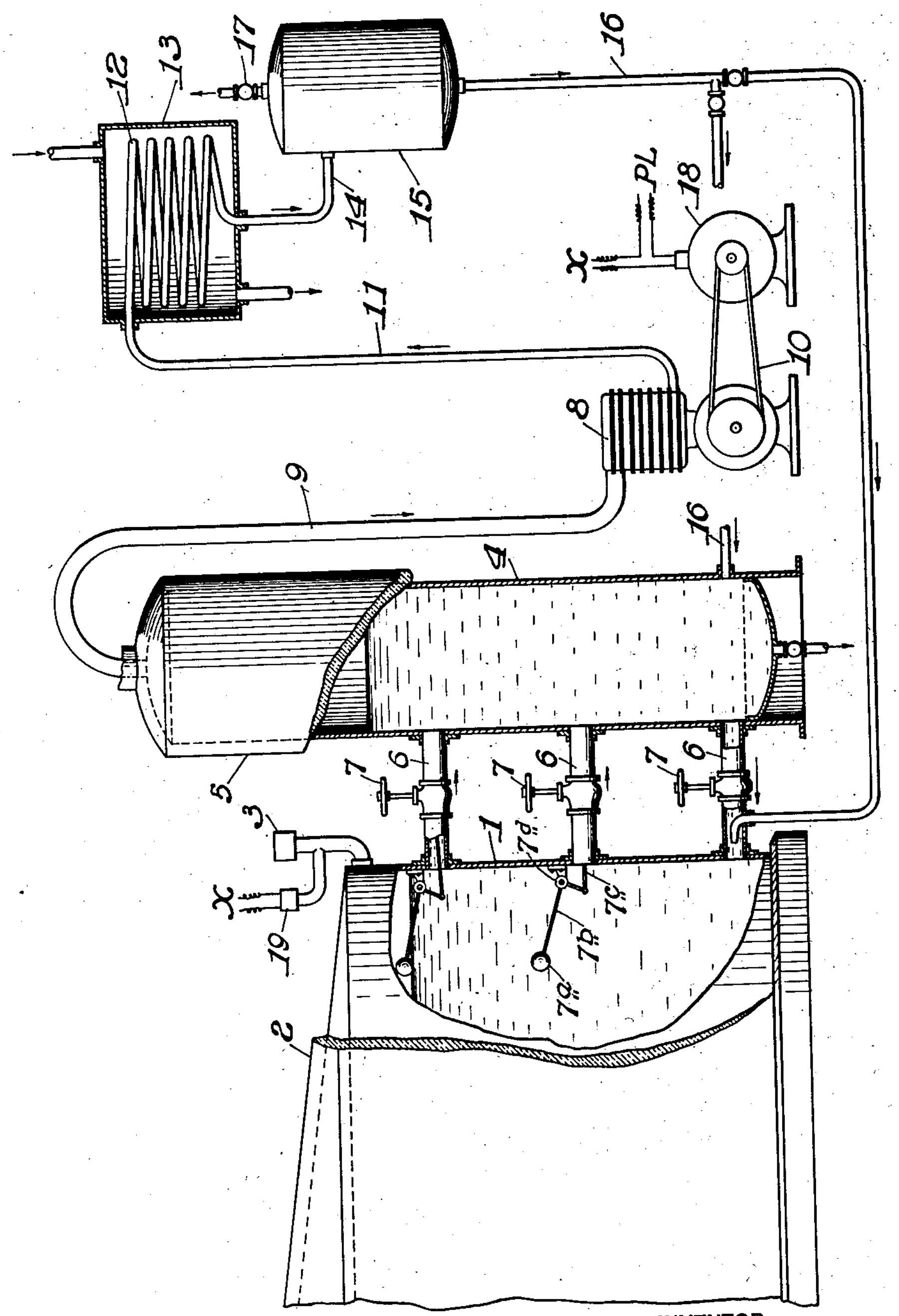

INVENTOR
Jack Robinson
BY Donald E. Payne
ATTORNEY

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STORAGE OF LIQUEFIED GAS

Jack Robinson, East Alton, Ill., assignor to Standard Oil Company, Chicago, Ill., a corporation of Indiana

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This invention relates to an improved system for storing liquefied gases and it pertains more particularly to a method and apparatus for storing large volumes of butane, propane, and other normally gaseous light hydrocarbons.

In petroleum refineries where large volumes of butane are collected and stored during the summer for use in winter gasoline or where large volumes of propane are stored for use is deasphalting, dewaxing, or solvent extraction processes, it is necessary to store large volumes of these liquefied gases under conditions of hot and widely varying temperatures. Pressure storage tanks could be designed which would hold the liquefied gases even at high temperatures, but the cost of such vessels would be prohibitive in storage tanks of one hundred thousand gallons capacity. Ordinary petroleum storage tanks may be employed if liquefied gases are maintained at sufficiently low temperatures, but these large diameter tanks will not stand wide variations in pressure; they must be provided with pressure-vacuum release valves which will permit rapid admission of air when the temperature drops or liquid is withdrawn from the tank, and which will permit the rapid exhaust of gases and vapors with rises in temperature or with the admission of liquid into the storage tank. This so-called "breathing" results in the loss of large quantities of the stored material and sometimes incurs a serious health, fire, and explosion hazard.

An object of my invention is to minimize this breathing action and to avoid as far as possible the opening of the pressure or vacuum release valves or, in other words, my object is to maintain the pressure in the vapor space of the storage tank between certain upper and lower limits.

Brine chillers, ammonia refrigeration systems, etc. for cooling the liquefied gas in the storage tank are not only expensive and cumbersome to install and to operate, but they lack the necessary ease of control,—they cannot respond quickly enough to large temperature changes and they are not amenable to automatic control.

Another cooling method is to withdraw vapors from the top of the storage tank, so that the refrigeration is effected by vaporization of the liquefied gas itself. This provides a means for rapid and inexpensive chilling, but the vapors which are withdrawn are necessarily mixed with air which has been sucked in through the vacuum release valve. It is therefore necessary to compress this air as well as vapors, which results in increased compressor costs, and it is necessary to provide a means for separating air and non-condensable gases from the liquefiable gas which is to be returned to the storage tank. In many refineries it is possible to vent propane or butane gases together with air to a gas main which in turn leads to an absorption system or stabilizer for recovering the valuable hydrocarbons, but the wide fluctuations in the amount of vapor and air which is thus injected into the system may impair the function of the stabilizers and absorption systems. When vapors are being withdrawn from the storage tank by a compressor, it is practically impossible to prevent the vacuum release valve from opening and this in turn increases the vexatious problem of separating air from condensable vapors.

An object of my invention is to provide a system wherein the temperature of the stored liquid is regulated by controlled vaporization of a part of the liquid, but wherein it is impossible for air to be admixed with the vapors which are to be compressed and condensed. In other words, my object is to provide a system wherein the cooling can be effected by the simplest and most inexpensive methods and wherein there will be no problem of separating air from condensed vapors.

Another object is to provide a system of this type which is extremely sensitive to automatic control.

A further object is to avoid any possible injury to the storage tank by abrupt pressure changes and at the same time to minimize "breathing" with its consequent loss of vapors.

Other objects will be apparent as the detailed description of my invention proceeds.

In practicing my invention, I employ the conventional petroleum storage tanks which may be forty or fifty feet in diameter and ten or twenty feet high. These storage tanks are provided with the usual pressure-vacuum release valves which will permit a variation in pressure of about two or three inches of water. Alongside of the storage tank I erect a tower which is slightly higher than the storage tank, which is only a few feet in diameter, and I connect this supplemental chilling tower with the storage tank by a series of vertically spaced pipes of relatively large cross sectional area. I provide means for preventing communication between the vapor space of the storage tank and the vapor space of the cooling tower, but I allow liquids to flow freely from the tower to the tank and back again; in other words, if the liquid level in the storage tank falls below one of the upper connecting pipes, that pipe is closed so that the vapors in the storage tank can never find their way to the cooling tower. I withdraw vapors from the top of the cooling tower by a compressor, the operation of which is regulated either by a thermostat or pressure control in the storage tank, the compressed vapors being condensed and returned to the base of the chilling tower. This evaporative refrigeration in the chilling tower causes a very rapid cooling therein and this in turn sets up a thermosiphon flow of liquids from the lower part of the chilling tower to the storage tank and from the upper part of the storage tank to the chilling tower. The chilling tower, being relatively small, can easily be designed to withstand relatively high pressures or vacuums. A high vacuum in the chilling tower means that the liquid level in the chilling tower is higher than that in the storage chamber, but since their cross sectional areas are so vastly different a considerable elevation of level in the chilling tower will produce a negligible decrease in level in the storage tank. Thus a high vacuum may be obtained in the chilling tower and extremely rapid chilling may be effected without causing any pressure strains on the storage tank. The compressor does not have to handle any air at all and it therefore operates at maximum efficiency. Furthermore, the compressor may be started and stopped by a sensitive mercoid switch so that the compressor may be started just before the pressure relief valve opens and the compressor may be cut off just before the vacuum relief valve opens. Thus I have provided an extremely simple, inexpensive, automatic means for cooling liquefied gases, which does not require the use of air separation means, which eliminates all danger of damage to the storage tank, and which minimizes the "breathing" action and loss of valuable stored material.

My invention will be more clearly understood by reference to the accompanying drawing, which forms a part of this specification and which represents partially in section an elevational plan of my improved apparatus.

Storage tank 1 may be forty or fifty feet in diameter and ten or twenty feet high, although it should be understood that the invention is equally applicable to smaller tanks, to horizontal, cylindrical tanks, or to any storage means designed to hold large volumes of liquefied gases or volatile liquids. The storage tank does not have to be designed to withstand high pressures,—it may be built as if it were intended to serve as a holder for water or oil. However, since the contents of the tank will have to be maintained at a temperature far below ordinary summer temperatures, I prefer to insulate the storage tank with two or three inches of air felt, rock wool, or equivalent insulating material 2. At the upper part of the storage tank and connected to the vapor space therein I provide a suitable pressure-vacuum release valve 3 which may be of the type described in United States Atwell Patent No. 1,628,348. Any device may be employed, however, which will permit a ready inlet for air when the pressure falls below a critical value and which will permit the escape of air and gases when the pressure exceeds a critical value. I may, of course, employ a balloon such as described in Wilson United States Patent No. 1,596,385, or other suitable means for preventing loss of material through "breathing" action.

Adjacent to the storage tank 1, I erect a chilling tower 4 which is preferably only three or four feet in diameter, which is about five or ten feet higher than the storage tank, and which is designed to withstand a relatively high vacuum. The chilling tower is likewise insulated with rock wool or other suitable material 5 and it is connected to the storage tank by a vertical series of spaced horizontal connecting pipes 6 of relatively large cross sectional area. Each of these pipes is provided with a manually operated cut-off valve 7 and all of them except the bottom pipe is provided with an automatically controlled valve operated by float 7*a* through bell crank 7*b* and operating rod 7*c*, the rod being pivoted to the bell crank and the bell crank being pivotally supported by bracket 7*d*. Floats 7*a* normally hold these automatically operated valves wide open to allow for the thermosiphon flow of liquefied gas therethrough, but when the liquid level permits the float to fall, rod 7*c* closes a clap valve which prevents any gases from the storage tank from entering the chill chamber.

The intake of compressor 8 is connected by pipe 9 to the top of chilling tower 4, the compressor being driven by an electric motor through a driving belt or chain 10. Compressed vapors are passed from the discharge side of compressor 8 through pipe 11 to condenser coils 12, which are preferably immersed in a cooling fluid such as cold water or brine in condenser box 13. The liquefied gas is then introduced by pipe 14 into collector 15 from which it is returned through pipe 16 to the base of chilling tower 4. If any air or non-condensable gas should happen to get into the system, it may be released through valve 17, but this valve is normally closed.

The compressor is driven by an electric motor 18 which is started and stopped by a mercoid switch or equivalent device in response to the pressure in storage tank 1. For example, I may employ an auxiliary pressure-vacuum device 19 of the tilting seal type described in the Atwell patent and I may mount mercoid switches on said devices (which are designed to operate just prior to the operation of the main pressure release valve), so that the motor 18 is started just before the main pressure valve 3 is opened, and so that the motor is cut off just before the main vacuum release valve 3 is opened. I do not limit myself to any specific means for controlling the operation of the compressor pump in response to pressure conditions in the storage tank since these expedients are familiar to those skilled in the art. Furthermore, I may, if desired, control the pump by thermostatic means instead of pressure means. It will be noted that even though a substantial vacuum is created in the upper part of the chilling tower and even though there is an appreciable difference in the level of liquids in the chilling tower and the storage tank, there will not be a sufficient variation in the pressure of the storage tank to cause the immediate opening of the vacuum release valve. The raising of the level of the liquid in the chilling tower at the beginning of the cooling operation tends to remedy immediately the high pressure conditions in the storage tank and, likewise, when the motor is shut off there is a slight backflow of liquid from the chilling tower to the storage tank, which tends to prevent the opening of the vacuum release valve.

If the liquid level in the storage tank falls below one of the cross pipes 6, float 7*a* will automatically be lowered and a clap valve in the pipe will be closed by rod 7*c*. Thus it is always impossible for air to be sucked into the compressor, the compressor load is not unduly augmented, and it is unnecessary to provide an expensive system for separating air from liquefied vapors. It will thus be seen that I have largely eliminated the danger of damaging the main storage tank due to excessive pressure changes, I have provided a system wherein only condensable gases are handled by the compressor, and I have provided a system which is adapted to automatic control and which is extremely sensitive and quick to react in accordance with temperature and pressure changes.

While I have discovered a system for storing propane, butane, and the like, it will be understood that the invention is equally applicable to the storage of any other liquefiable gases, particularly liquid sulfur dioxide, liquid prussic acid (HCN), liquid ammonia, dimethyl ether, etc. Also, the invention is applicable to the storage of gasoline or other liquids containing volatile constituents.

The invention is not limited to the storage problem, but it may be useful also in processes which require the chilling of mixtures containing liquefiable gases; for example, in propane dewaxing systems, propane deasphalting systems, solvent extraction systems, etc.

In many cases, the thermosiphon action may not be sufficient to maintain an even temperature throughout the chilling tower and the storage tank. In such cases, I may provide mechanical propellers or injectors for forcing the liquid from the base of the chilling tower to the storage tank and from the top of the storage tank to the chilling tower.

Also the return line 16 may go back to the storage tank instead of to the chilling tower. In fact line 16 may terminate in an injector in lower pipe 6 so that the return of condensate will of itself promote the flow of cold liquid from the base of the chiller to the base of the storage tank. It may sometimes be advantageous to have liquid enter the bottom of the chiller and leave it at the top, in which case the injection action of the returned liquid or equivalent mechanical means may be used to cause a flow in the opposite direction from that shown in the drawing.

While I have described my invention in detail, it should be understood that I do not limit myself to any of said details except as defined by the following claims, which should be construed as broadly as the prior art will permit.

I claim:

1. A method of storing hydrocarbon liquids of high vapor pressure which consists, in placing the liquid in a closed storage tank, in withdrawing liquid from the tank, in reducing the temperature of the liquid thus withdrawn by evaporating a part thereof, and in returning the cooled liquid to the storage tank.

2. A method of storing hydrocarbon liquids of high vapor pressure which consists, in withdrawing some of the liquid from the tank, in subjecting the liquid withdrawn to reduced pressure to reduce the temperature thereof by evaporation, in returning the liquid thus cooled to the storage tank, in condensing the vapors thus formed, and in returning the condensate to the cooled liquid.

3. A method of storing liquefied gases which consists, in placing the liquid in a closed storage tank, in withdrawing liquid from the tank, in reducing the temperature of the liquid thus withdrawn by evaporation, in controlling the evaporation in accordance with the pressure in the storage tank, and in returning the cooled liquid to the storage tank.

4. A storage system for liquefied gases comprising, a normally closed storage tank, a tower located adjacent to the tank, means providing for the circulation of liquid through the tank and the tower, and means for reducing the pressure within the tower to cause liquid therein to evaporate thereby to effect cooling.

5. A storage system for hydrocarbon liquids capable of vaporizing at the pressures at which they are normally stored comprising, a normally closed storage tank, a tower located adjacent to the tank, means providing for the circulation of the liquid through the tank and the tower, means for reducing the pressure within the tower to cause liquid therein to evaporate thereby to effect cooling, and means for condensing the evaporated liquid and for returning the condensate thus formed to the circulating liquid.

6. A storage system for volatile hydrocarbon liquids comprising, a normally closed storage tank, a tower located adjacent to the tank, means providing for the circulation of the liquid through the tank and the tower, a suction pump connected with the upper end of the tower for reducing the pressure therein, and means for condensing the vapors drawn off by said pump.

7. A storage system for volatile hydrocarbon liquids comprising, a normally closed storage tank, a tower located adjacent to the tank, means providing for the circulation of the liquid through the tank and the tower, a suction pump connected with the upper end of the tower for reducing the pressure therein, means responsive to pressure in said storage tank for controlling the operation of said pump, and means for recovering vapors drawn off by said pump.

8. The method of storing liquefied gases in a warm environment without the use of high pressures which comprises maintaining a chilling zone separate from the storage zone, causing a liquid flow to and from the chilling zone and the storage zone respectively, maintaining separate vapor spaces above the storage zone and the chilling zone, respectively, and preventing any communication between the respective vapor spaces, withdrawing vapors from the space above the chilling zone, liquefying said vapors, and returning the liquefied vapors to the circulating liquid.

9. The method of claim 8 which includes the step of regulating the withdrawal of vapors from the space above the chilling zone in accordance with pressure conditions above the space in the storage zone.

10. In apparatus of the class described, a storage tank of large cross sectional area, a chilling tower of small cross sectional area adjacent to said storage tank, means for permitting the flow of liquids between the storage tank and the chilling tower at different elevations and for preventing communication between the vapor space of the storage tank with the vapor space of the chilling tower, means for withdrawing vapors from the top of the chilling tower, and means for compressing said vapors and for liquefying them and returning them to said storage tank.

11. The combination of claim 10 which includes pressure operated means in the vapor space of the storage tank for controlling the operation of the compressing means.

12. The combination of claim 10 which includes means for creating a flow of liquids between the storage tank and the chilling tower.

13. The combination of claim 10 which includes automatic means for closing the com-

munication between the storage tank and the chilling tower when the liquid level reaches said communication.

14. In apparatus of the class described, a storage tank of relatively large cross sectional area, a chilling tower adjacent thereto which is taller than said storage tank and which is smaller in cross sectional area, a plurality of cross pipes connecting the storage tank to the chilling tower at different levels, and means for automatically closing each of said pipes except the lower one when the liquid level in the storage tank falls to the level of said pipe whereby communication of the vapor space in the storage tank with vapor space in the chilling tower is prevented.

15. An apparatus for chilling a liquefied gas which comprises a storage tank of large cross sectional area, an adjacent chilling tower of small cross sectional area, said tower being higher than said tank, a plurality of pipes connecting said tank with said tower at spaced elevations, and means for evaporatively refrigerating the liquefied gas in the chilling tower whereby a thermosiphon flow of liquids between said chilling tower and said storage tank is effected.

16. In apparatus of the class described, a storage tank, a chilling tower adjacent thereto, pipes connecting said chilling tower with said storage tank at different elevations, a pressure release valve mounted at the top of said storage tank, a compressor, means for connecting the intake of said compressor to the top of said chilling tower and the outlet of said compressor through a condenser to the base of said chilling tower, means for driving said compressor, and means for controlling said driving means in response to pressure conditions in the top of the storage tank whereby an increase in pressure sufficient to open the pressure release valve will start said driving means and thereby cause a raising of the liquid level in the chilling tower and a decrease in pressure in the storage tank and whereby a decrease in pressure in the storage tank cuts off the driving means which in turn causes a lowering of the liquid head in the chilling tower and an equalization of pressure in the storage tank.

JACK ROBINSON.