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METHOD AND MEANS FOR THE TRANSPORTATION OF LIQUEFIED NATURAL GAS

Cedomir M. Sliepcevich, Norman, Okla., assignor, by mesne assignments, to Conch International Methane Limited, Nassau, Bahamas, a corporation of the Bahamas

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This invention relates to the storage and/or transportation of liquefied natural gas.

As is well known, natural gas is available in some areas in amounts in excess of local requirements while, in other areas, deficiencies exist with respect to natural gas or other fuel gases which might be used in lieu thereof. When such areas are connected by land, transmission of natural gas from the source of plentiful supply to an area where a deficiency exists can be effected while in a gaseous state by transmission through a pipeline. Where the area is separated by a large body of water, pipeline transmission is not so practical.

Thus it is desirable to formulate means other than pipeline for the transmission of natural gas. Natural gas could be housed in containers for transportation, but the amount of gas capable of being confined in suitable containers for transportation to the area where a deficiency exists in insufficient to justify the cost of the containers and shipment. The concept which has been developed relies upon the reduction of the natural gas to a liquefied state at the source of plentiful supply for shipment in the liquefied state to an area where the deficiency exists where the liquefied gas is re-formed to the gaseous state for use. By reduction of the gas to the liquefied state, a reduction in volume in the ratio of 600:1 is achieved, thereby making it practical to house the liquefied gas in suitable containers for transportation from the source of plentiful supply to the area where a deficiency exists.

To make the system practical, it is desirable to ship large quantities of the liquefied gas. Containers of large capacity cannot practically be constructed to house the material at high pressure. As a result, the liquefied gas is to be housed in the containers at about atmospheric pressure or slightly above. Liquefied gas is composed mostly of methane which has a critical boiling point at a temperature of about —258° F. at atmospheric pressure. Thus the liquefied natural gas will be housed in the containers at a temperature somewhat below —240° F., depending upon the amount of heavier hydrocarbons that are present.

Insulation will be used to minimize the transfer of heat from the ambient atmosphere into the liquefied gas but, even then, some heat will naturally flow from the ambient atmosphere at about 70–100° F. to the cold liquid housed in the insulated containers at about —240° F. or below. When the liquid is at its boiling point temperature, such amounts of heat as are transmitted through the insulation will cause some of the liquid to boil, with resultant vaporization. While the vapors can be reliquefied or used as a fuel to drive the transportation means, it is desirable to minimize the loss of natural gas by vaporization, otherwise the process becomes economically less desirable.

Further, the vapors released are combustible and therefore present a problem from the standpoint of disposal without endangering men, material and equipment accompanying the liquefied gas in storage or shipment.

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It is an object of this invention to provide a method and means for minimizing the loss of natural gas during storage and transportation, and it is a related object to avoid the build-up of an atmosphere in and about the containers which embodies natural gas vapors in an amount to present dangerous conditions.

Another object is to provide a method and means for the build-up of a safe and inert atmosphere in preference to an atmosphere of natural gas vapors, thereby to provide a protective atmosphere as a consequence of the natural forces operative to cause heat transfer to the liquid and some vaporization thereof.

The concepts of this invention reside in the admixture with the liquefied natural gas of a small quantity of another liquefied gas having a lower boiling point than the liquefied natural gas under the pressure conditions existing in the tank or having a considerably higher vapor pressure than the natural gas liquid at the temperature and pressure conditions existing. Under such circumstances, the other gas will vaporize off in preference to the natural gas upon the absorption of heat to conserve the natural gas and to minimize the vaporization thereof. As the other lower boiling liquefied gas, it is desirable to make use of an inert gas so that the vapors given off in preference to the natural gas will present an inert atmosphere in and about the storage tanks. Thus, problems of disposal will be substantially completely eliminated.

It is desirable to make use of an amount of said other lower boiling liquefied gas to correspond to the amount of material calculated to be reduced to a gaseous state by vaporization from the time that the container is filled for transportation or storage until the time that the material is removed from the container for use. For example, when it is calculated that about 0.5% of the liquid is vaporized per day in response to heat transfer from the ambient atmosphere, then for a 20-day storage or voyage it would be desirable to admix an amount of said lower boiling gas to make up about 10% of the material introduced into the storage tank.

It will be understood that the natural gas will have a vapor pressure at the boiling point temperature of the other liquefied gas so that the two liquids will vaporize simultaneously in response to the absorption of heat, but the liquefied natural gas will have a much lower vapor pressure so that it will constitute a minor proportion of the vapors that are given off. Thus, the liquid in the storage tank will be maintained at a desirably lower temperature and little of the natural gas liquids will be lost by vaporization. Further, the vapors released will be made up mostly of the other liquid, thereby to provide an inert atmosphere in and about the storage tank when said other liquefied gas represents an inert gas.

It will be apparent that considerable benefit is derived from the admixture of a lower boiling gas with the liquefied natural gas in storage and in shipment. A further concept of this invention resides in the use of the lower boiling gas as a component in the tank during the return of the tank from the area where the deficiency exists for refilling with the liquefied natural gas at the area of plentiful supply. If all of the liquid were removed from the tank at the area of use, the empty tank would slowly rise in temperature. By the time that the empty tanks were returned for refilling, the temperature conditions would be such that the cold liquefied gas could not safely be introduced into the tank for filling without such vigorous boiling as would lead to considerable loss of material and the possibility of building up dangerous conditions including excessive pressures within the tank, and problems of disposal of the large amount of vapors released.

The additional time that the transportation means is tied up for cooling down the tanks prior to introduction of the liquefied natural gas for filling can materially affect the economics of the entire process. The excessive vaporization of the natural gas will further tax the devices for handling such vapors to the end that an expense would be involved in additional material-handling equipment and excessive losses would occur in the desirable product, namely, the natural gas.

When the lower boiling liquefied gas is embodied in desirable amounts in the tank for return, it is unnecessary to leave a substantial portion of the liquefied natural gas in the tank for purposes of maintaining the tank at the desired low temperature during the return voyage. Further, the lower boiling liquefied gas will be able to retain the tank at a temperature lower than that of the liquefied natural gas so that cool-down can be eliminated or at least greatly minimized and vaporization of the natural gas upon loading can be greatly reduced. Thus, excessive losses of natural gas vapors will be avoided and it will be unnecessary to make use of additional material-handling and processing equipment.

Of considerable importance is the protection made available by the use of an inert liquefied gas in the tanks during such return voyage. The vapors released will fill the available space in and about the tanks to provide a safe and inert atmosphere. It will also eliminate the necessity to purge the tanks for removal of air, oxygen and the like materials which might form a combustible mixture with natural gas vapors.

While it is desirable to make use of an amount of the lower boiling liquefied gas calculated to last for the entire return voyage from the source of supply to the source of use, the amount introduced into the tank for the return voyage is not so critical since the residual lower boiling liquefied gas remaining in the tank can be admixed with the new load of liquefied natural gas introduced to refill the tank. In fact, where such lower boiling liquefied gas can be made available at lower cost by utilization of refrigeration available in large amounts in the liquefied natural gas at the point of use, it would be feasible to introduce an amount of such liquefied gas calculated to be sufficient for the complete voyage to the source of plentiful supply and back.

Liquefied nitrogen may be taken as representative of a gas preferred for use in the practice of this invention. Nitrogen is a relatively inert gas which, in the liquefied state, has a lower critical boiling point than liquefied natural gas at atmospheric pressure. It is capable of admixture with liquefied natural gas to provide a system wherein preferential vaporization of nitrogen occurs at a temperature below the critical vaporization temperature of liquefied natural gas. Further, nitrogen is freely available in unlimited quantities in air, and it can be procured rather inexpensively by the liquefaction of air and the subsequent separation of nitrogen from oxygen by fractionation, utilizing the large amount of refrigeration available from the liquefied natural gas upon reconversion to the gaseous state. It will be understood that other liquefiable, lower boiling gases may be used as represented by helium, argon and the like. For this application, it would be undesirable to make use of gases capable of forming a combustible mixture with the hydrocarbon vapors, such as oxygen or air.

In practice, the liquefied natural gas introduced into the storage tanks for transportation would contain about 10% by weight of liquefied nitrogen when experience indicates loss by vaporization of about 0.5% per day, and a period of about 20 days from the time that the tanks are filled at the source of plentiful supply until the tanks are emptied at the point of discharge or use.

For the return voyage, an equivalent amount of liquefied nitrogen would be introduced into the emptied tanks for maintaining the cold temperature in the tanks during the return voyage and for providing an inert atmosphere. In the event that the liquefied nitrogen is more readily available or available at lower cost at the point of use of the natural gas, twice the amount of liquefied nitrogen may be introduced to leave about one-half thereof in the tanks for admixture with the liquefied natural gas during the return voyage for transportation of the filled tanks.

In accordance with the described concepts, the material lost from the time the tanks are filled until the load of liquefied natural gas is discharged would be made up mostly of the vapors of the lower boiling liquefied gas, thereby to minimize the amount of natural gas lost by vaporization. The low cost of the nitrogen and its ready availability makes it unnecessary to provide recovery units on the ship, thereby materially to reduce the cost of equipment and operation in transportation.

In practice, it would be unnecessary to achieve complete removal of the liquid from the tanks at the point of use, since the nitrogen liquid introduced would conserve the liquefied natural gas remaining in the tanks and minimize the losses which otherwise would occur during transportation.

It will be apparent that I have provided a conservation means in the storage and transportation of a liquefied natural gas whereby the natural gas is conserved as a product during the delivery voyage and whereby cold is conserved as a desirable condition during the return voyage. It will be apparent further that the amount of vaporization that does take place would be beneficial from the standpoint of maintenance of an inert atmosphere, thereby materially to contribute to the safety and success of the operation.

It will be understood that changes may be made in the details of construction, arrangement and materials without departing from the spirit of the invention, especially as defined in the following claims.

I claim:

1. In the storage and transportation of natural gas in a tank in a liquefied state at extremely low temperature, the method of minimizing the loss of natural gas by vaporization comprising admixing with the liquefied natural gas a liquefied nitrogen gas in an amount to last substantially throughout the period of time that the liquefied natural gas in the tanks, said liquefied nitrogen being present in an amount up to 20 percent by weight of the liquid in the storage tank.

2. In the storage and transportation of a natural gas in a liquefied state housed in a tank at extremely low temperature for transportation from a source of plentiful supply to an area where a deficiency exists, the method of minimizing loss of natural gas by vaporization and maintaining an inert atmosphere within the tank comprising admixing with the liquefied natural gas another inert gas in a liquefied state having a vapor pressure substantially higher than the vapor pressure of the liquefied natural gas at the temperature conditions existing and present in an amount to last substantially throughout the time that he tank is filled at the source of supply until discharged at the area where the deficiency exists, said other liquefied inert gas being present in an amount up to 20 percent by weight of the liquid in the tank.

3. In the storage and transportation of a natural gas in a liquefied state housed in a tank at extremely low temperature for transportation from a source of plentiful supply to an area where a deficiency exists, the method of retaining the refrigeration in the emptied tank during transportation from the area where the deficiency exists back to the area of plentiful supply for refilling the tank, comprising introducing into the tank following discharge of the natural gas at the area where a deficiency exists another liquefied inert gas in an amount less than 20 percent of the volume of the empty tank, said other liquefied gas having a vapor pressure substantially higher than the vapor pressure of the liquefied natural gas at the temperature conditions existing.

4. In the storage and transportation of natural gas in a liquefied state housed in a tank at extremely low temperature for transportation from a source of plentiful supply to an area where a deficiency exists, the method of

minimizing the loss of natural gas by vaporization during transportation from the source of plentiful supply to the area where a deficiency exists and minimizing the loss of refrigeration from the tank during transportation from the area where the deficiency exists back to the area of supply for refilling of the tank comprising introducing into the tank following discharge of the liquefied natural gas at the area where a deficiency exists another liquefied inert gas in an amount up to 20 percent by volume of the tank, said other liquefied gas having a vapor pressure substantially higher than the vapor pressure of the liquefied natural gas at the temperature conditions existing.

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