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STORAGE AND TRANSPORTATION OF LIQUEFIED GAS

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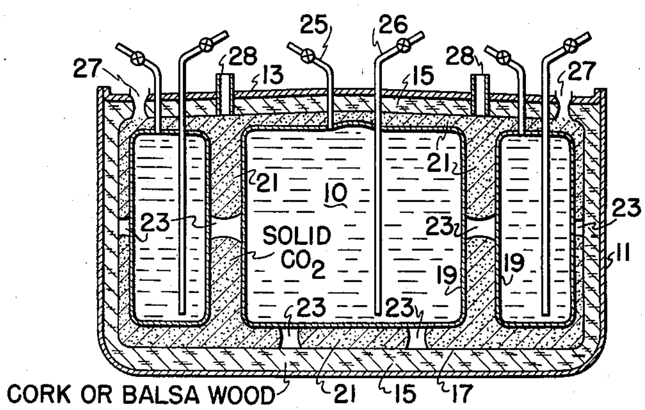

Fig. 1

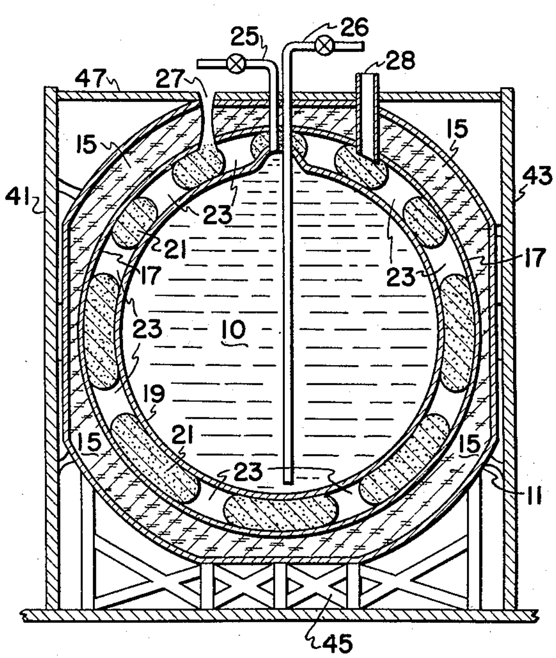

Fig. 2

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STORAGE AND TRANSPORTATION OF LIQUEFIED GAS

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1 Claim. (Cl. 62—45)

The present invention relates to a liquefied natural gas vessel and also a process for handling and shipping liquefied natural gas and other liquids of extremely low boiling point.

In the prior art, it has been suggested that very low boiling liquids, e.g. those that boil many degrees below normal atmospheric temperatures, and particularly liquefied natural gas may be transported in an insulated vessel at substantially atmospheric pressure by allowing the liquid to boil, drawing off the vapors thus formed and using them for fuel, refrigeration, and other purposes. It has also been suggested that in order to promote safety in handling very low boiling materials, a vessel of metal walls, particularly one having steel walls, should be insulated on its interior surface to prevent the metal reaching such extremely low temperatures as to make it brittle and frangible. The present invention is an improvement over the prior art suggestions just mentioned.

According to the present invention, normally gaseous materials, e.g. toxic gases such as ammonia, etc., and especially inflammable vapors such as natural gas, are liquefied and the liquid is stored at low pressure, preferably at or approaching atmospheric pressure in an insulated container which is surrounded by an extremely low melting or low boiling material which is non-toxic, or non-inflammable, such as solid carbon dioxide. The latter, in turn, is placed within an insulation lined vessel which comprises the main structure containing the materials named. This has the advantage that the low melting solids such as carbon dioxide snow, etc., not only provide a secondary insulation barrier but also can be used to reduce fire and/or toxicity hazards and also reduce evaporation losses from the liquefied normally gaseous material.

According to the present invention a vessel, such as a ship having a steel hull, or a barge, or even a railroad tank car, truck tank or the like, is lined interiorly with a thick effective thermal insulating material such as cork, balsa wood, foam rubber or plastic insulator, or combinations of these materials. The insulating materials are secured to the inside surface of the outer wall. The insulation is preferably coated with an impervious coating which is not soluble in the liquid to be stored in the vessel or in the secondary insulating material such as carbon dioxide. Within the insulated space thus provided, there is mounted in spaced relation to the primary insulation, a thin walled vessel made preferably of metal which is not highly sensitive to temperature changes and which, preferably, does not become substantially brittle at very low temperatures such as $-100°$ F. to $-250°$ F. or lower. The space thus provided between the primary insulation and the inner container or liner is then filled with a loosely packed finely divided solid material of very low boiling point, e.g. solid carbon dioxide. The packing gives additional insulating value and, as it evaporates or sublimes, it gives off vapors which are non-toxic, non-inflammable and which tend to reduce fire hazard and other hazards.

The material to be shipped is then placed within the inner liner. This material may be a liquefied petroleum gas, anhydrous ammonia, or other liquefied normally gaseous material. For purposes of describing the present invention, reference will be made primarily to a liquefied natural gas. This material usually contains large proportions of methane which boils at about $-161°$ C. or $-258°$ F. Natural gas may be liquefied by repeated expansion and cooling processes as is well known in the art. Where convenient, advantage should be taken of the pressure at the gas source which frequently is very substantial. By this means the gas may be liquefied economically.

Since vessels of the character specified above are not built of sufficient strength to withstand high pressures because of economic consideration, the liquefied product ordinarily must be carried at pressures which are not far from atmospheric pressure. In some cases the pressure may be allowed to rise moderately, e.g. to as high as 25 to 50 p.s.i.g. but as a rule, the pressure will be substantially atmospheric or only a few pounds gauge.

Obviously, no insulation system is 100% efficient and liquefied natural gas which boils, for example, around $-258°$ F. will soon warm up to its boiling point and begin to give off vapors. The same is true of materials such as ammonia, etc., which are not so low-boiling. These vapors, in the case of hydrocarbons, may be used as fuel to propel the vessel or any of them may be used as refrigerant first. Obviously, they may also be recompressed, evaporated, cooled, etc., to liquefy them again and return them to the vessel.

By suitable choice of fixed insulating material of appropriate thickness and by suitable spacing of the liner from the insulator to regulate the thickness of the protective carbon dioxide blanket or jacket, the evaporating rate of the carbon dioxide as well as of the liquid natural gas may be controlled substantially as desired. Thus the evaporation rate of carbon dioxide may be arranged to exceed that of the liquefied natural gas or the latter, as suggested above, may be returned to storage by liquefaction in which case the only vapors being lost are those from the carbon dioxide. Obviously, the latter may also be recompressed and cooled to return the carbon dioxide snow to the insulating jacket.

The invention will be more clearly understood by reference to the accompanying drawing. In this drawing

Fig. 1 shows a transverse sectional view of a typical tanker vessel in which the invention is incorporated;

Fig. 2 shows an enlarged fragmentary cross section of a modification where a storage vessel is mounted in an insulated compartment with a blanket of CO_2 or the like.

Referring first to Fig. 1, the outer vessel walls of a tanker vessel or barge are indicated at **11**. These may be of suitable metal such as carbon steel which is ordinarily employed for tanker vessels or for railroad cars, truck bodies, and the like. Complete enclosure of the liquid is necessary; hence, a cover member **13** is provided to enclose the compartment to be insulated. The entire walls and bottom of the tank or vessel, as well as the underside of the cover **13** are lined with an effective porous insulating material **15**. This material preferably is a thick layer of balsa wood, for example, 6″ to 18″ thick. Cork may be used instead of balsa wood or a combination of the two. Other expanded insulating compositions such as foam glass, foam rubber, etc., may also be used. Preferably, they are lined on the inside with a liquid proofing layer **17** although this is not always necessary where the carbon dioxide jacket is employed. The latter is better shown in Fig. 2.

The space between the fixed insulation and an inner liner **19** is indicated at **21**. Material to be shipped is contained in space **10** surrounded by liner **19**. Liner **19**, or a plurality of them (three are shown in Fig. 1) is held in spaced relation to the insulation **15** by means of struts or other supporting members indicated at **23**.

A vent **25** and a liquid feed and withdrawal line **26** are provided from the liner **19** extending through the insulation and through the cover plate or member **13**. These allow space inside the tank to be vented or pressured. Several vents may be provided if the vessel is large and they may be connected together in an obvious manner. As indicated above, the evolving vapors escaping through the vents **25** may be used as fuel if they are hydrocarbons, or they may be first used as refrigerant and then used as fuel. On the other hand, they may be recompressed, liquefied and returned to storage so that there are no appreciable losses where the value of the gas justifies such procedure.

Likewise, from the carbon dioxide jacket space **21**, vents **27** are provided. From these the carbon dioxide vapors may be allowed to escape to the atmosphere. If desired, they may be distributed over the surface of the vessel **11** by applying an extra cover or jacket so as to reduce fire hazards. Alternatively, as indicated above, they may be recompressed, cooled, evaporated, etc. to produce carbon dioxide snow for returning to the insulation layer through one or more filling pipes **28**.

Referring now to Fig. 2, similar elements are shown by the same reference characters as in Fig. 1. Here a cylindrical tank **19** is spaced by means **23** from a thick cork or balsa wood liner **15** secured to the inside wall of an outer vessel **11**. The fixed insulation **15** is provided with an impervious coating **17**. The space between fixed insulation **15** and the inner vessel **19** is filled with solid CO_2 at **21**. This arrangement shows the installation in between structural elements **41**, **43** of a vessel or vehicle. Supports **45** are provided for outer vessel **11** and a cover member **47** encloses the top thereof.

The invention described has the following advantages:

A supply of carbon dioxide gas is readily available which can be released in case of a leak or rupture in the natural gas container, or in case of collision of any other damage that might otherwise institute a fire hazard.

As a result of the safety insurance in the presence of large quantities of carbon dioxide, the personnel operating vessels containing natural gas in liquid form are better able to discharge their duties and operate more efficiently.

With the graduated system of insulation, the heat losses from outside the vessel into the liquid natural gas compartments are greatly minimized. As indicated above, any reasonable balance desired may be maintained between evaporation of liquid natural gas and carbon dioxide. Either or both may be used externally, or may be returned to the system.

It will be obvious that the use of a carbon dioxide snow which melts or sublimes at about −112° F. is a very effective insulating buffer and also adds a considerable safety factor. While reference has been made above to shipment of liquid natural gas, and application to ammonia has been mentioned, it is obvious that other materials such as propane, butane, pentane or even gasoline may be shipped in the same manner with advantages. Non-combustible or toxic materials, such as chlorine, etc. may be handled also. The safety of the system makes it more acceptable than some of those suggested in the prior art. The stored material may have a boiling range either below or above that of CO_2, or its boiling range may range above and below that of CO_2. Preferably, the boiling range of the stored or transported material is below that of CO_2, since this substantially conserves the latter, but the invention is applicable to materials boiling at any range between absolute zero and ordinary atmospheric temperatures.

It will be appreciated that various changes and modifications may be made within the spirit of the invention and it is intended to cover these so as as they come within the scope of the following claim and so far as the prior art permits.

What is claimed is:

A method of storage for bulk marine transportation of hydrocarbons such as methane which are normally gaseous at atmospheric temperature and pressure and which have critical temperatures below the sublimation temperature of solid carbon dioxide under atmospheric pressure, which method comprises liquefying said hydrocarbons and cooling them to a temperature below the boiling point thereof at atmospheric pressure; introducing said liquefied hydrocarbons at the reduced temperature into a first confined storage zone disposed within and occupying a substantial portion of the hold region of the hull structure of a marine vessel adapted for the carriage of cargoes in bulk, said hull structure being characterized by an inner liner of a substantially rigid insulation material in spaced relation exteriorly to said first confined storage zone leaving a second confined storage zone between said first storage zone and said insulation material; encasing said first storage zone with a layer of solid carbon dioxide substantially filling said second storage zone; venting said first and said second storage zones to maintain both said liquefied hydrocarbons and said solid carbon dioxide substantially at atmospheric pressure, whereby heat transfer through said hull structure and said liner thereof to said solid carbon dioxide is at least partially compensated by sublimation of the latter, and heat transfer from said solid carbon dioxide to said hydrocarbons is at least partially compensated by vaporization of the latter at atmospheric pressure.

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