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TANK FOR THE STORAGE AND TRANSPORTATION
OF A LOW BOILING LIQUID

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FIG. 1

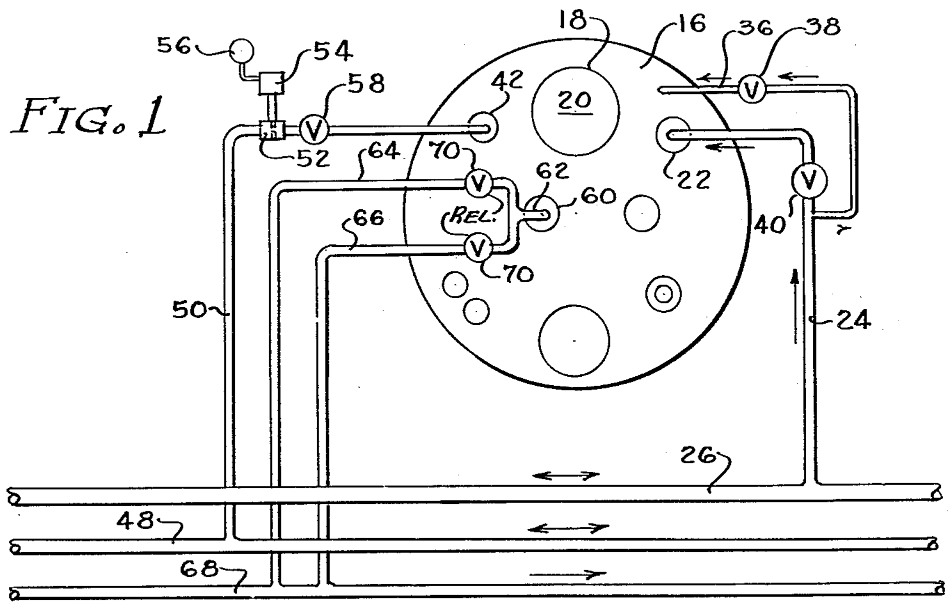


FIG. 2

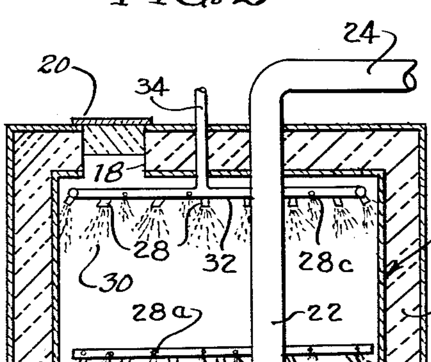
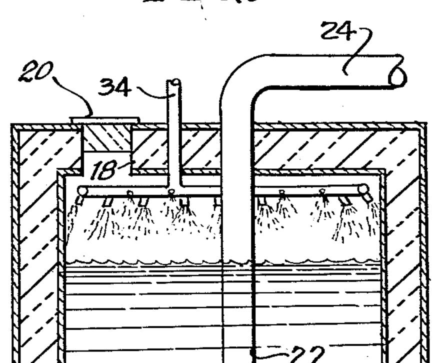


FIG. 3



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TANK FOR THE STORAGE AND TRANSPORTATION OF A LOW BOILING LIQUID

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4 Claims. (Cl. 62—54)

This invention relates to the storage and transportation of a liquefied gas or other liquid that needs to be maintained at extremely low temperatures, and it relates more particularly to the filling of a large tank with such cold boiling liquefied gas for storage or transportation.

Description of the invention will be made with reference to the storage and transportation of a liquefied natural gas. It will be understood, however, that the concepts of this invention can be employed also for the storage or transportation of other low boiling liquefied gases or other liquids that need to be maintained at low temperature, such as helium, nitrogen, air and the like gases capable of liquefaction.

For the storage or transportation of natural gas or other liquefied gases, it is most economical and practical to house the liquid in storage tanks of large capacity. From a practical standpoint, such containers of large capacity should be designed for operation at low pressure, otherwise the walls of the container would have to be fabricated of such thickness as markedly to increase the cost of the tank and to provide an excessive amount of dead weight.

Liquefied natural gas is composed chiefly of methane which boils at −258° F. at atmospheric pressure. It usually contains small amounts of higher boiling hydrocarbons which will raise the boiling point slightly. Thus, it can be considered that, at atmospheric pressure, the liquefied natural gas will have a boiling point of about −240 to −258° F., depending upon the amount and type of heavier hydrocarbons in the gas. Liquefied oxygen, nitrogen, air, helium, and the like will have still lower boiling points at atmospheric pressure.

In the storage or ship transportation of liquefied natural gas from a source of plentiful supply to an area where a deficiency exists, use is made of large containers which are insulated to minimize heat loss, so that very little of the liquefied cargo will be vaporized by the heat which naturally enters the tank by reason of the wide temperature differential between the ambient atmosphere and the temperature of the cargo. Insulated tanks of thousands of barrels capacity have been constructed in which the heat loss has resulted in the separation of less than one-half of one percent of the liquid per day. The vapors released can easily be handled either for use to power the ship, or for re-liquefaction and returned to the storage tank in ship transportation or for an end use as a raw material, refrigerant and fuel in land storage.

One of the major problems that arises is in the filling of the tank with the liquefied gas when the tank, or portions thereof, is at an elevated temperature by comparison with boiling-point temperature of the liquid cargo. The elevated temperature condition may result from the return of the tank while empty, or with a cargo other than a cold liquefied gas, or when the tank is first put into service. Whatever the reason, it has been found that unless the tank is cooled down to about the temperature of the cargo, such vigorous boiling takes place as the liquid cargo is introduced into the warmer areas of the tank as to cause excessive and vigorous boiling, which releases forces sometimes incapable of being properly harnessed, and releases vapors in an amount incapable of being properly handled.

The combination of excessive vaporization coupled with violent agitation appears also to develop a frothing condition which often results in overflow of the liquefied gas. Forces developed by the tremendous amount of vapor suddenly released can also cause destruction of the tank and elements associated therewith. These conditions are undesirable with any liquid, let alone a liquid as combustible as natural-gas liquids.

Thus it is an object of this invention to produce a fluid-handling system for safely and efficiently filling large storage tanks with a low-boiling liquefied gas, and it is a related object to provide a tank for the storage and transportation of liquefied gas characterized by means for cooling down the tank to a desired low temperature level sufficient to enable the liquefied gas to be poured into the tank at a high rate for filling without uncontrolled or excessive vaporization, and without the development of pressures and forces, frothing or agitation which leads to spilling over of the liquids or deterioration of the tank.

These and other objects and advantages of this invention will hereinafter appear and for purposes of illustration, but not of limitation, an embodiment of the invention is shown in the accompanying drawings, in which—

Figure 1 is a diagrammatic view of an arrangement of parts which may be employed in the practice of this invention;

Figure 2 is a sectional elevational view of a tank embodying the features of this invention and representing the conditions existing during the cool-down stage; and

Figure 3 is a sectional elevational view similar to that of Figure 2 but illustrating a modification in the spray means in a tank during the filling stage.

In accordance with the practice of this invention, the tank is filled at a normal rate for rapid loading, but not until the tank is processed to reduce the temperature of the walls of the tank to a point where they can remain wet with the liquid without immediate vaporization by previous introduction of the liquid, at a slow rate, preferably as a spray onto the inner side walls of the tank.

Introduction until the liquid is able to wet the walls of the tank is indicative of the reduction of the walls of the tank to a temperature at which the liquid can be introduced at a rapid rate for filling without excessive boiling. This is further indicated by a differential in the amount of liquid introduced by comparison with the amount of vapors coming off during the cool-down step, or a reduction in the vapor pressure when the liquid is sprayed into the tank at a constant rate. Instead of using reduction in the amount of vapor given off as an end point to the spraying of the material onto the walls of the tank, use can be made of thermocouples or other recording means for following the temperature change in wall portions of the tank to indicate the reduction of temperature in the tank to a level where the tank can be safely filled at a high rate without boiling or without vaporization in amounts incapable of being handled or controlled.

Referring now to the drawings, **10** indicates a tank preferably formed of a metal which is capable of retaining its ductility at the temperatures of the liquefied gas. Ordinary mild steel is impractical for this purpose since it loses its ductility at temperatures below −100° F. and is therefore subject to deterioration and cracking at the low temperatures to which it would be exposed when filled with the liquefied gas. It is preferred to make use of such metals as aluminum, alloys of aluminum, copper, or austenitic steels, such as 18–8 stainless steel, which metals are capable of retaining their strength at the extreme low temperatures of use.

The tank is insulated with a thick layer **12** of a material having low heat conductivity to minimize heat loss into the tank. For this purpose, use can be made of a structurally strong insulation, such as panels of balsa wood, quippo wood, or the like highly porous woody materials, or panels of foamed glass or plastics built up on the outer walls of the tank **10**. When use is made of an outer shell **14** in spaced relation with the inner tank **10**, the space between the tank and the shell can be either evacuated or else filled with insulating material of the type described, or a packed insulation, such as glass wool, ground cork, exfoliated vermiculite, "Santocel," and the like, preferably with separators to divide the space into a sufficient number of compartments to minimize settling of the insulation in response to repeated expansions and contractions of the tank occasioned by the wide temperature changes which take place in use. When use is made of an outer shell or tank **14** with an insulated space in between, the outer tank can be formed of mild steel or any other suitable metal or structural material, because it will be protected by the insulation layer **12** from the low temperatures of the liquid content material.

The tank is completely sealed but various openings are provided in the walls, and preferably in the top wall, for gaining access into the tank for various purposes which will hereinafter be described. The top wall **16** is provided with a manhole **18** dimensioned to be sufficiently large to enable a person to gain access to the interior of the tank for purposes of inspection, repair, or replacement of parts. A cover **20** is provided for the manhole with means to secure the cover in sealing relation over the manhole when the latter is not in use.

A down pipe **22** of large diameter extends downwardly through the top wall to a level adjacent the bottom of the tank for use in filling the tank with liquid. Discharge is effected by a similar pipe having a pump on the upper end thereof. Instead, the filling pipe may extend through the side wall or the bottom wall of the tank into the bottom portion thereof. The feed and discharge pipe **22** is connected by the trunk line **24** to the filling and discharging header **26** which extends from the tank to a source of supply or a source of storage or use of the liquefied gas. The header **26** may be used for the transmission of liquid into and from a number of tanks of the type described.

A plurality of spray heads **28** are arranged within the tank with the heads preferably positioned to direct the spray **30** of liquid onto the adjacent wall portions of the tank. The spray heads **28** (also shown in the form of openings **28***c* in the pipes) can be arranged at about the same level in the upper portion of the tank with preferably uniform lateral spacing therebetween substantially completely to cover the inner surface of the tank with the spray issuing from the heads. Instead of arranging the spray heads or openings at the same level, they can be arranged at different levels as illustrated by the group **28***a* in Figure 2, and some of the spray heads or spray openings can be positioned to direct the spray onto the walls of the tank, while others can be positioned to direct the spray into the interior of the tank for optimum coverage during cool-down. It is desirable to provide for a substantially uniform and complete coverage of the walls of the tank to minimize the existence of wide temperature differentials during cool-down.

The spray heads are connected to a header **32** extending about the interior of the tank, and the header is connected by line **34** to a spray line **36** which branches off of the trunk line **24**. The branch line **36** is of considerably smaller capacity than the main header **26** or the trunk line **24**, since the liquefied gas is adapted to be fed to the spray heads at a rate which is much lower than the rate of filling through the trunk line **24**. The branch line **36** is provided with a valve **38** to control the flow of fluids, and the trunk line **24** is also provided with a fluid-control valve **40** at a point preferably beyond the branch line **36**. In the illustrated modification, a branch line of about 2 inches outside diameter could be used in combination with a trunk line of about 6 inches in diameter whereby an amount of liquid could be carried in the branch line to the spray heads to cool down the tank without generation of so much vapor as would exceed the amount that could be handled or vented, or would cause build-up of excessive pressures within the tank to cause destruction or deterioration thereof.

The tank is provided with an outlet **42** in the top wall for the removal of vapors **44** generated from the liquid **46** introduced into the tank. The vapor outlet communicates with a vapor header **48** through a connecting vapor branch line **50**. The header **48** can connect with the shore if the tank is on ship or it can connect either with a transmission pipe for use as refrigerant, fuel, raw material or the like, or it can connect with a reliquefaction unit for reconversion of the vapor into a liquefied state for possible return with the feed to the tank. The trunk line **50** is usually provided with means to record the amount of vapor being generated, as illustrated by the calibrated orifice **52** connected to a flow transmitter **54** and recorder **56**. A shutoff valve **58** is also provided in the trunk line either before or after the recorder.

To avoid the build-up of excessive vapor pressure within the tank, an additional venting means is adapted to be provided in the form of a vapor outlet **60** which communicates with a line **62** that divides into a pair of trunk lines **64** and **66** of smaller dimension to communicate the relief vent **60** with a relief header **68**. Since the relief lines are adapted to come into operation only when an emergency exists which will cause the sudden development of vapors in the tank, it is desirable to construct the relief lines for handling a large vapor load. Thus, the trunk lines **64** and **66** and the relief header **68** are usually of greater capacity than the vapor lines **50** and **48** that are used to remove the vapor formed in the course of normal operation of the tank.

The trunk lines **64** and **66** are each provided with a pressure valve **70** set to open at predetermined maximum pressures, such as 2 pounds per square inch. The relief valves can also be set to open when vacuum conditions develop in the tank, as in response to the drop in pressure when the liquid cargo is being removed at a too rapid rate. Opening of the valves, such for example as at a setting of ½ pound vacuum, will enable air or vapor, or preferably an inert gas, to flow into the tank to relieve the vacuum and thereby minimize the possibility of collapse of the tank. It is desirable to subdivide the trunk lines of the relief into two sub-lines, as illustrated, and to provide separate pressure control valves for each so that better and more certain control can be achieved.

Other elements for operation of the tank are provided but these need not be described herein in detail since they do not enter into the concepts forming the subject matter of this invention. The following dimensional characteristics of the various units are given by way of illustration in a commercial operation for the shipment of liquefied natural gas in large volumes in insulated tanks from a source of plentiful supply to an area where a deficiency exists. It will be understood that the dimensional characteristics of the units can be changed, depending upon the capacity of the tanks, the capicity of the equipment associated with the storage tanks, the material which is being transported or stored as cargo, and the location of the tanks.

For a ship's tank having a capacity of better than 50,000 barrels, and calculated to filled at a rate of about 10,000 barrels per hour per tank, and to have a normal vaporization of about .25–.50 percent of the liquid per day, which is equivalent to about 100,000 to 200,000 cubic feet of vapor flow per hour, the following specifications will be sufficient:

	Inches		Inches
Header **26**	12	Trunk line **50**	6
Trunk line **24**	6	Relief pipe **62**	10
Branch line **36**	2	Trunk line **64**	8
Header **48**	10	Relief header **68**	16

In operation, when starting to fill a tank which is at an elevated temperature, because of non-use for the storage of the liquefied gas immediately prior to filling, the valve **40** in the trunk line **24** will be closed and the valve **38** of the spray line **36** is opened. The valve **38** is adjusted to permit flow of cargo to the spray heads in an amount which, when instantaneously converted to vapor, can be easily handled by the vapor lines **50** and **48**. Exposure of the liquid to temperatures above its boiling point (−258° F. for methane at atmospheric pressure) causes the liquid immediately to vaporize with a resulting reduction in temperature. Thus, the liquid is sprayed into the tank at a slow rate until the tank has been cooled down in temperature to a level at which immediate vaporization of the liquid does not take place. When this occurs, the liquid will be able to stay on the walls of the tank to wet the walls, and the amount of vapor issuing from the tank to the vapor connections will diminish. This decrease in the amount of vapor generation will be evident from the readings on the flow meter so that it can be determined either visually by the wet walls or by the rate of vapor flow as to when the tank is in a cooled down condition to enable the liquid cargo to be introduced at a rapid rate for filling without turbulence and without generation of excessive amounts of vapor. When this condition is reached, the valve **40** is openend. The valve **38** may be closed or it may be allowed to remain open to feed liquid into the tank through the trunk line **24** and the branch line **36**. When filled, all of the feed valves **40** and **38** are closed and the valve **58** in the vapor line is left open to permit the removal of vapors which are normally generated from the natural heat gain which takes place through the insulated walls of the tank.

It will be understood that the concepts described may be embodied in a shore installation or in a ship installation of large tanks for the storage and transportation of a low-boiling liquefied gas. It will be further understood that the dimensional characteristics described for the respective elements may be varied, depending upon the number of tanks employed, their capacity, and others of the variable conditions previously described.

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

I claim:

1. A storage tank for containing a large volume of a low-boiling liquified gas comprising

A. an insulated housing of large capacity, and means for filling the housing with a low boiling liquefied natural gas composed mostly of methanol consisting of

B. (1) a filling tube of large dimension extending into the housing,
   (2) a header for the transmission for the liquefied gas, and
   (3) a trunk line connecting the header with the filling tube,

C. (1) a spray tube extending into the housing,
   (2) a spray means arranged in spaced-apart relation in the container and in communication with the spray tube,
   (3) a branch line communicating the spray line with the trunk line,

D. (1) a vapor outlet in the upper portion of the housing in communication with the vapor space above the liquid level in the housing,
   (2) a vapor header for the transmission of vapor released from the housing, and
   (3) a vapor line communicating the vapor outlet with the vapor header.

2. A storage tank as claimed in claim 1 which includes a flow valve in the branch line for controlling the flow of liquefied gas to the spray means to an amount which, when immediately converted to vapor, can be handled by the vapor lines.

3. A storage tank as claimed in claim 1 which includes a means for measuring the flow of vapors from the vapor outlet.

4. A storage tank for containing a large volume of a low boiling liquefied gas as claimed in claim 1 which includes

E. (1) a relief opening in the top wall of the housing,
   (2) a relief header for the transmission of vapors,
   (3) conduit means connecting the relief opening with the header, and
   (4) pressure-responsive means in the relief conduit for normally closing the conduit to the transmission of vapors but which opens to permit the passage of vapors therethrough when the pressure within the housing exceeds a predetermined positive pressure and a predetermined sub-atmospheric pressure.

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UNITED STATES PATENT OFFICE

CERTIFICATION OF CORRECTION

Patent No. 2,966,040 December 27, 1960

James J. Henry

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 6, for "methanol" read -- methane --.

Signed and sealed this 23rd day of May 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents