DOUBLE WALLED CRYOGENIC TANK

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Filed May 25, 1966, Ser. No. 560,684
13 Claims.
(Cl. 62—45)

This application is a continuation-in-part of applicants' prior pending application Ser. No. 420,998, filed Dec. 24, 1964, now abandoned.

The present invention relates in general to insulated containers for use in cargo ships adapted to transport cryogenic cargoes, such as liquefied natural gas at atmospheric pressures. More particularly, the present invention relates to improvements in insulated tank structures of the double wall type wherein a minimum of differential expansion or thermal stress is present between the primary and secondary walls of the tank.

It has been established that the transportation of gasses, such as natural gas and the like, to remote locations may be best and most efficiently be accomplished by reducing the volume of the gasses through its conversion into the liquid state. Such a conversion enables the storage volume requirements to be greatly reduced (approximately six-hundredfold for a given quantity of methane gas, for example) and, as should be appreciated, enables the most efficient transfer of the gas to a remote area.

In order to transfer liquefied gas in a practical and economical manner in relatively large volumes, it is necessary to store the liquefied gas at approximately atmospheric pressure. Since large containers built to withstand superatmospheric pressures would be impractical, if not impossible, to construct for use on seagoing tankers or the like. However, liquefied gasses maintained at atmospheric pressures have extremely low vaporization points, ranging from about —43°F for liquefied hydrogen to —28°F for liquefied ammonia, and these unusually low temperatures of the liquids present certain problems in the design and production of insulated cargo containers. Specifically, the containers must be properly thermally insulated to prevent heat losses which would lead to excessive volatilization of the stored liquefied gas and of sufficient strength to withstand the internal stresses that may be induced therein by large temperature gradients through the walls of the container. In addition, the ship must be safeguarded against uncontrolled flow of the low temperature liquid into contact with parts of the structure which could be damaged thereby. Accordingly, for the purposes of increased safety and reliability and in accordance with accepted regulatory Coast Guard codes, it has been a well-established practice to provide a primary liquid-tight barrier and a secondary liquid-tight barrier in containers used for the storage of liquefied natural gases at cryogenic temperatures, each of which barriers is independently capable of withstanding the thermal and hydrostatic stresses imposed by the liquefied gases.

With this requirement for a double wall insulated container, it has been conventional to place the necessary insulation between the two walls. While this intermediate location of the insulation material assists in the mechanical support of the inner wall, it establishes a large temperature differential between the two walls, thereby making it necessary to provide for substantial thermally induced dimensional differences between the two walls of the tank when the cryogenic liquid is stored.

The present invention, by its location of the insulation material exterior of the outer wall of the double wall container, permits each wall to operate at substantially the same temperature thereby eliminating the need to provide means for permitting dimensional changes therebetween.

In accordance with the principles of the present invention, the requisite multiple barrier protection is provided by a pair of self-supporting metal tanks housed one within the other to form, in effect, a double walled metal tank. The outer wall of the tank constitutes a secondary liquid-tight barrier and is spaced from the inner wall which constitutes a primary liquid-tight barrier. As an important aspect of the invention, the self-supporting double walled tank may be thermally insulated by a system of insulation exterior of the outer tank wall which need not be impervious to the cargo nor able to withstand the hydrostatic pressures thereof, since the barrier requirements are fulfilled by the tank walls. Therefore, the insulating system and the double wall barrier system may be constructed without expansion joints, at relatively low cost, and in a vastly simplified manner in comparison, for example, with those intricate insulating systems which also serve as liquid- and gas-tight barriers. Such intricate systems invariably employ special materials and sophisticated, integral expansion joints, or their equivalents to maintain the integrity and impermeability, i.e. the barrier status, of the insulation.

The new and improved thermally insulated double walled tank itself is generally shaped to conform with the cargo hold of a tanker and may be installed and appropriately secured therein for expansion and contraction, as a unit, as it is alternately chilled down and warmed up during thermal cycling.

Accordingly, it is an important object of the present invention to provide an improved and lower cost double wall cryogenic container not requiring means to compensate for a differential thermal expansion between the inner and outer walls.

Another object of the invention is to provide an improved double wall cryogenic container which is low in cost, economical in construction, and reliable in operation.

In accordance with a preferred embodiment of the invention, a container includes a multiplicity of internal structural members and barriers. This internal tank structure cooperates with the thermally conductive structural means separating the primary and secondary liquid barriers to form a common and integral structural cage for the liquid barriers. In this way a large capacity, substantially rigid and self-supporting LNG tank is provided, for shipboard use, assuring a maximum degree of safety. The independent structural integrity of the container thus constructed permits it to be keyed to the main hull of the ship so that normal working or flexure of the ship may occur without appreciable transfer of such stress to the LNG container.

Another, and therefore most important, object of the invention is to provide a large capacity, high structural integrity, self-supporting LNG container of a double wall construction which may be mounted within a ship cargo hold and substantially isolated from normal working of the ship's hull.

For a more complete understanding of the present invention and its attendant advantages, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a transverse sectional view of the internal walls of the tank, wherein the internal walls are spaced from each other, thereby making it necessary to provide for substantial thermally induced dimensional differences between the walls of the tank when the cryogenic liquid is stored;

FIG. 2 is an enlarged, fragmentary, cross-section of a portion of FIG. 1 showing another and preferred form of the invention;
FIG. 4 is a partially schematic horizontal plan view taken generally along the line 4—4 of FIG. 3; and FIG. 5 is a fragmentary cross-sectional view taken along line 5—5 of FIG. 3.

Referring to FIG. 1, the new and improved cryogenic container 10 is installed in a double hulled tank 9 (although a single hulled tank may be suitable) having an outer hull 12 and an inner hull 13 which defines a cargo hold 14. Where desired or found necessary, the tank 11 may include transverse cofferdams and/or bulkheads. The inner tank 15 includes a closed primary barrier or inner tank 15 of the general shape of the cargo hold 14 which is fabricated from aluminum, stainless steel, high nickel steel, aluminum alloy, or a like material which is capable of withstanding the thermal stresses induced by the cryogenic cargoes. In accordance with the principles of the invention, the inner tank 15, constituting a primary liquid and gas impermeable barrier is, itself, enclosed by a similar outer tank 16, constituting a secondary barrier, also fabricated from a material such as aluminum or the like which is not deleteriously affected by the extremely cold temperatures of liquefied gases. As shown, the inner and outer tanks 15 and 16 are mutually spaced and held together as a unit by rigid spacing members 17 secured thereto. The spacing members 17 are sufficient in size and number to support the loaded inner tank 15 and are provided with a metallic material sufficiently con- ductive to minimize temperature differences between the tanks 15 and 16 during loading and unloading. Means (not shown) may be provided to fill the dead space 18 between the tanks with a suitable noncombustible gas maintained at a predetermined pressure above atmosphere, where desirable or appropriate, to assure exclusion of air and moisture and to increase the safety of the entire container unit 10. A plurality of apertures 22 in the members 17 are provided to permit the free circulation of inert gas throughout the spaces 18 from a single gas supply.

As an important aspect of the invention, the independent tanks 15 and 16, which in effect form and may be aptly characterized as a double walled tank 9, are insulated with an exterior thermal insulation layer 19. In this way, at the service temperature, there is essentially no temperature difference between primary tank 15, secondary tank 16, and the interspersing member 17. Hence, it is not necessary to provide for differential expansion or thermal stresses between these components. This is in direct contrast to other known double wall cryogenic containers wherein the insulation is installed between the walls of the tank, thus making it necessary to provide for substantial dimensional differences between the two walls when the cryogenic liquid is stored in the inner tank. Furthermore, because of its location the insulation layer need not be self-supporting, liquid-tight, or of great strength and may be simply and expediently, externally applied and secured to the outer tank wall 16. As shown in FIG. 2, the insulation layer 19 may be composed of abutted, individual enclosed polyurethane foam panels 20, for example, applied directly to the double wall tank 9 by an adhesive 21 or other suitable means. Alternately, the individual panels may be fabricated with discrete joints 23 which provide an easily and quickly installed, skilfully and securely suited to the outer wall 16. In any event, it should be understood that the insulation chosen and its mode of application to the exterior of the outer tank 16 need only be sufficient to provide adequate thermal insulation to prevent heat transfer which would tend to volatilize the cargo of which it could tend to embrittle the ship structure. Accordingly, the applied insulation need not possess the unusual properties and/or high degree of dimensional stability that are present in the insulation of cryogenic tanks in which the insulation layer serves as one of the requisite liquid and vapor barriers and, such as a barrier, often requires elaborate means for compensation of expansion and contraction, such as expansion joints or the like. Therefore, the cost of the insulation material and its fabrication into an enveloping insulation layer 19 may be effectively reduced to a bare minimum in the system of the present invention.

As shown in FIG. 1, the insulated double walled tank 9 and its enveloping insulation 19 are stabilized and sup- ported as a unit within the cargo hold 14 by wooden blocks 23 or other appropriate means capable of with- standing the load of the tank 9 and capable of accommodating changes in dimension of the container unit 10, as a whole, when it is subjected to extreme variations in temperature from that of ambient when empty to that of –260°F. when filled with a cargo of liquefied methane, for example.

It will be apparent from the foregoing that the new and improved cryogenic tank of FIGS. 1 and 2 provides a simply constructed, yet highly reliable cargo tank which may be used to store and transport cryogenic cargoes of liquefied gases in an extremely safe and efficient manner. Moreover, through the employment of a new and improved, self-supporting, double walled tank in accordance with the invention, the cost of the insulation system may be provided at optimally low cost.

Referring to a further and preferred embodiment of the invention illustrated in FIGS. 3, 4 and 5, a cross-section of a tank 100 includes an outer hull 102 and an inner hull 104 maintained in spaced apart relationship by a primary barrier 110. The primary and secondary barriers 112 and 114 are separated by an air space maintained by a plurality of T-shaped braces 116 running both vertically and horizontally in egg-crate fashion. The braces 118 may include a plurality of apertures 119 (see FIG. 5).

The base of the LNG container 110 is supported within the hold of the tank upon a plurality of transversely running wooden beams or support members 134 which are preferably of a low density and high thermal effi- ciency material such as balsa wood. Preferably, the beams 134 have their grain running vertically so that they may take a maximum compressive load (see FIG. 10). The upper surface of the beams 134 is in direct contact with the underside of the secondary barrier 114 of the tank. The lower surface of each of the beams 134 transmits the weight of the container and its contents to the inner hull of the ship 104. The vertical walls of the tank 110 are keyed to the sides of the ship as well as to the transverse cofferdams 159 by means of a key 120 engaging a corresponding keyway shown generally at 122. Accordingly, because slidable relative motion between the key and keyway is permissible, it will be readily apparent from FIGS. 3 and 4 that the vessel 110 may contract or expand in width, length, and height relative to the hull as its dimensions vary due to the introduction of a low temperature cargo therein. The exterior of the outer skin 114 is insulated with any suitable foam type insulation system shown schematically in the figures at 116.

Referring to the internal structure of the tank, it may be readily seen from FIG. 4 how the internal thereof is divided up into four generally rectangular chambers. Each of these rectangular or quadrant chambers is sim-ilar in configuration and for this reason only one has been illustrated in detail. The tank 110 is divided longitudinally by a main center line bulkhead 124 which is substantially impervious except for a vent or pressure equalization aperture 126 at a top portion thereof (FIG. 3). This impervious longitudinal bulkhead 124 there-fore is effective to prevent sloshing of the LNG material
from side to side within the tank. Tank 110 also includes a main transverse bulkhead 128 which includes a plurality of apertures 139 to permit limited flow of liquid fore and aft between adjacent compartments on either side of the longitudinal bulkhead 124. Each of the bulkheads 124 and 128 are stiffened and rigidified by a plurality of structural members or webs 132 as may best be seen in FIGS. 3 and 4. In each of the four chambers within the tank 110 a plurality of both longitudinal and transverse webs 136 are employed to further rigidify and structurally reinforce the structure of each tank. The webs 136 each include a pair of upper trunk cutout portions 138 and main cutout portions designated 140 to permit relatively free passage of the liquid within the tank between the web sections. Each of the webs 136 includes a flange portion 142 about the periphery of the respective apertures 140. Extending horizontally across each of the four semi-separated chambers or quadrants of the tank 110 are a pair of deck or plate sections designated 144. These plate sections 144 define a substantially flat plane adding further structural rigidity to the tank structure. These plate sections may be defined by circular apertures 146 and semi-circular apertures 148 along the longitudinal edges of each plate adjacent the longitudinal bulkhead 124 and inner skin 112 of the tank. These apertures serve to lighten the plate as well as permit relatively free transfer of liquid between respective levels of the tank and provide for adequate drainage thereof. The tank 110 includes at its bottom a pair of cargo pumps designated 152 which are shown schematically on either side of the bulkhead 124. The left hand pump is effective to discharge fluid from the left hand side of tank 110 through a discharge conduit represented schematically by the dotted line 154. The upper end of the lines 154 exit through a hatch or dome (not shown) penetrating the upper portion of the tank in the area of the tank. The exterior of the tank 110 is generally surrounded by a relatively large void space between the insulation 116 and the inner hull 104 of the ship. However, a plurality of anti-floation blocks 156 are provided between the underside of the deck and the upper surface of the tank to prevent undue movement of the tank 110 in a vertical direction relative to the hull structure. These anti-floation blocks 156 are required to prevent undue upward movement of the tank 110 should liquid seep into the bottom of the tank. The blocks 156 may also be removed so that should inspection of the underside of the tank 110 be required, the entire tank may be temporarily raised within the hold to transfer the relatively large void space normally occurring on the top of the tank to below the tank so that an underside inspection may be made.

Thus, it will be seen how the space of internal bulkheads, webs, stiffening plates and deck plates within the interior of the LNG tank in combination with the plurality of vertical and horizontal T-shaped stiffeners 118 in between the inner and outer skin of the tank present an effective and common structural cage to which the primary and secondary protective barriers 141, 142, 144, and 146 respectively are attached. This structural arrangement provides optimum rigidity and maximum safety with least cost in this highly specialized and extreme environment of cryogenic temperature at which the container of the invention is required to operate.

It should be understood that the specific structures herein illustrated and described are representative only, as certain changes may be made therein without departing from the clear teachings of the disclosure. For instance, while the invention finds particular utility as a ship board cryogenic container, those skilled in the art will readily appreciate that it may be employed to equal advantage for the safe land-based storage of cryogenic materials. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention.

What is claimed is:

1. In a combination, a tanker having a cargo hold of predetermined shape and insulated from the surrounding atmospheric conditions, and an insulated container for liquefied gases maintained at atmospheric pressure and cryogenic temperature mounted within said hold, said container including:
   (a) a primary tank substantially similar in shape to said hold,
   (b) a large secondary tank substantially similar in shape to said hold and surrounding said primary tank,
   (c) thermally conductive rigid structural means for maintaining said primary tank in fixed, spaced relation within said secondary tank and for reducing the thermal gradient between said primary and secondary tanks when said liquefied gases are initially loaded into said container and during transportation of said gases in said tanker,
   (d) said tanks providing primary and secondary liquid-tight barriers for retaining cryogenic liquefied gas cargo at atmospheric pressure, and
   (e) foam insulation means applied externally and secured about said secondary tank in an enveloping relation therewith, said insulation means constituting substantially the sole insulation means of said container.

2. The combination of claim 1 including means for supporting said container within said hold for expansion and contraction as a unit relative thereto.

3. The system of claim 2 in which:
   (a) said primary tank and secondary tank are fabricated from material having high strength properties at low temperatures characteristic of stainless steel and aluminum.

4. The system of claim 2 in which:
   (a) said insulation is permeable and of insufficient strength to withstand the hydrostatic and thermal stresses induced by liquified gases at atmospheric pressures.

5. The system of claim 2 in which:
   (a) said container for storing and/or transporting liquefied gases at atmospheric pressures and cryogenic temperature comprising:
      (a) a self-supporting primary tank,
      (b) a self-supporting secondary tank substantially similar in shape to but larger than said primary tank, and
      (c) a plurality of thermally conductive rigid structural elements extending between said tanks for maintaining the walls thereof in said fixed spaced relation and for reducing the thermal gradient therebetween when said container is initially loaded and subsequently filled with said liquefied gases,
   (d) said tanks forming a cargo container including primary and secondary liquid-tight barriers for liquid cargo,
   (e) means supporting the bottom wall of the secondary tank spaced above a supporting surface, and
   (f) foam insulation secured about and enveloping the secondary tank, said insulation constituting substantially the sole insulation about said container.

6. The container of claim 6 is further characterized by:
   (a) said container being positioned in the hold of a ship, and
   (b) the insulated container being so proportioned with respect to the hold as to provide an access space between the exterior of said insulated container and the interior of the hold.
8. The combination of claim 5 including an inert gas in the space between the primary and secondary tanks and wherein said structural means contain a plurality of apertures.

9. The combination of claim 1 including a longitudinal bulkhead within said container dividing said container in substantially liquid isolated port and starboard portions, a transverse bulkhead dividing each of said port and starboard portions into fore and aft portions, and separate submerged pump means located in each of said port and starboard portions for pumping liquefied gases from said container.

10. The combination of claim 9 including cooperative key and keyway means between the exterior of said container and the interior of said cargo hold to permit relative movement therebetween due to thermally induced changes in the dimensions of said container.

11. The combination of claim 10 wherein the container is supported within said hold by a plurality of substantially parallel wooden beams, said beams having a vertical grain orientation to provide maximum compressive load carrying capacity and being composed of balsa wood for optimum thermal insulation efficiency.

12. In combination, a tanker having a cargo hold of predetermined shape and a container for liquefied gases maintained at atmospheric pressure and cryogenic temperature mounted within said hold, said container including, an internal longitudinal bulkhead dividing said container in substantially liquid isolated port and starboard portions, a transverse bulkhead dividing each of said port and starboard portions into fore and aft portions, a plurality of apertured webs extending from side to side of said container, a primary tank substantially similar in shape to said hold and secured to the periphery of said webs and periphery of each said bulkhead, a plurality of stiffening structural members secured to the exterior of said primary tank for rigidifying said tank, and a larger secondary tank substantially similar in shape to said primary tank secured to said structural members in spaced relation to said primary tank, said structural members in combination with each said bulkhead and said webs providing a common structural cage for said primary and secondary tanks, and insulation means secured to the outer surface of said secondary tank.

13. The combination of claim 12 including cooperative key and keyway means between the exterior of said container and the interior of said cargo hold to permit relative movement therebetween due to thermally induced changes in the dimensions of said container.

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