FLAT BOTTOM SHIP TANK FOR TRANSPORT OF LIQUEFIED GAS

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Field of Search......... 62/45, 240; 114/74 A; 220/9 LG

References Cited

UNITED STATES PATENTS

2,993,460 7/1961 Dreyer......................... 114/74 A

3,680,323 8/1972 Bognaes et al................. 62/55

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ABSTRACT

A combination of a ship having a hold with a bottom and walls, and a tank, which is circular in horizontal section, for transporting a liquefied gas; said tank having a metal shell having (1) a substantially flat metal bottom (2) a spheroidal section constituting most of the upper part of the tank and (3) a toroidal knuckle portion tangentially joined to the periphery of the metal bottom and tangentially joined to the spheroidal section; load bearing insulation between the ship hold bottom and the tank metal bottom; and a skirt, circular in horizontal section, extending from the tank above the toroidal knuckle portion downwardly to a supporting base in the ship hold.

8 Claims, 5 Drawing Figures
This invention relates to ships used for transporting cryogenic liquefied gases. More particularly, this invention is concerned with improvements in ships for transporting cryogenic liquefied gases and which tanks are separate, independent, structures supported by and anchored to the ship bottom and not necessarily otherwise dependent on the ship hull or hold structure for support.

Many useful gases are available or are produced at geographical locations far removed from the locations where they are used or needed. Although some such gases can be economically transported under pressure in the form of a gas, it is generally more desirable to liquify the gas and transport it in that state because of the increased volume of gas which can be transported in liquid state rather than in the gaseous state.

Some gases can be liquefied at moderate pressures and shipped in tanks capable of maintaining the gas under such pressure to keep it in the liquefied state. Because the pressure needed to liquefy some gases at atmospheric temperature is not unduly great, the pressure vessel required for storage of the so-liquefied gas can be built of a relatively large size economically. Other gases, however, cannot be readily liquefied even at fairly high pressures unless the temperature of the gas is also reduced substantially below atmospheric temperature. Because it is difficult and expensive to construct a pressure vessel capable of storing a cryogenic liquefied gas at high pressure in large volume, it has been found more practical and less expensive to cool the liquefied gas to a temperature at which it can be stored in a tank designed to withstand a minimum internal pressure plus of course the expected dynamic loads due to ship motions. For example, it has been found convenient to store liquefied natural gas, which is essentially methane, at about -260°F. and at about 15 psia or just slightly above atmospheric pressure. Other cryogenic liquefied gases such as hydrogen, helium and ethylene can be similarly stored at about atmospheric pressure following their refrigeration to a temperature below the boiling point of the gas at such pressure.

Tanks for transporting cryogenic liquefied gases at about atmospheric pressure in a ship are of two main types. One type of tank is a membrane tank in which the tank walls and bottom are substantially continuously supported by the ship hull structure. Such a tank relies upon the structure of the ship for the strength and support needed to contain the liquid being stored. Another type of tank is a structurally self-supporting or free-standing vessel or tank which is spaced or separated from the ship hold bottom and walls. Such a vessel or tank does not rely on the strength of the hold walls for necessary reinforcement because it is structurally independent of the ship hold walls insofar as its ability to effectively contain the stored liquid is concerned.

One of the structurally independent types of pressure vessel tanks is spherical. Spherical tanks have been mounted in the ship hold on a metal cylindrical skirt with the tank bottom located above the ship hold bottom. See U.S. Pat. Nos. 3,677,021 and 3,680,323. While such tanks are suitable for liquefied gas transport by ship, they do not occupy as much of the total hold space as would be desired for maximum capacity. The amount of nonusable space between the tank and the ship hold is unduly large and for efficient, more economical transport this space should be reduced and the tank occupy a higher percentage of the hold space. Also, such tanks required all liquid load to go to the perimeter of the tank and to then be redistributed to the ship bottom. This is not efficient or economical. Furthermore, the spherical pressure vessel tank as mounted in a ship hold according to the prior art extends considerably above the ship deck and this causes the center of gravity of the ship to be higher than desired when the tanks are full of a liquefied gas. There is accordingly a need for a ship tank which occupies more of the hold space, is largely free standing and which results in a ship having a lower center of gravity when loaded.

According to the present invention there is provided, in combination, a ship having a hold with a bottom and walls, and a tank, which is circular in horizontal section, positioned in the hold for transporting a liquefied gas. The tank is characterized by a metal shell which has the following three main shell sections or portions: (1) a substantially flat metal bottom, (2) a spheroidal section constituting most of the upper part of the tank, and (3) a toroidal knuckle portion tangentially joined to the periphery of the metal bottom and tangentially joined to the spheroidal section. Located between the ship hold bottom and the tank metal bottom is load bearing insulation upon which the tank bottom rests. A skirt, circular in horizontal section, extends from the tank above the toroidal knuckle portion downwardly to a supporting base in the ship hold.

The described tank of this invention permits most of the hydrostatic load from liquid in the tank to be transferred directly and substantially uniformly through the insulation to the ship hold bottom. Only part of the load must go thru the skirt and be redistributed to the hold bottom. The tank bottom, since it is supported by load bearing insulation, need not be made as thick as the major spheroidal shell portion of the tank which, to meet code and safety requirements, is built to pressure vessel standards. A tank with a thin bottom is a hybrid tank in that the thin bottom is in the nature of a semi-membrane while most if not all of the remaining tank shell is of independent free standing vessel construction which must contain the internal pressure by stress in the shell. The bottom is, however, to some extent in tension when the tank is loaded because of the forces applied against the toroidal knuckle. The internal pressure due to liquid cargo is primarily applied downwardly on the tank bottom and thereby is transferred to the ship hold bottom.

The toroidal knuckle extending upwardly and outwardly in a curved manner from the tank flat bottom is generally at least as thick as the tank bottom. It can be thicker however; for example, it can have a thickness up to or greater than the thickness of the spheroidal shell portion of the tank. It is furthermore considered most suitable for the toroidal knuckle when viewed in vertical cross-section to be tapered from a thin thickness, which can be about the same as the thickness of the tank bottom where it joins the tank flat bottom, to a greater thickness where it joins the spheroidal part of the tank.

That part of the tank shell located upwardly from the toroidal knuckle and extending to the top of the tank
The invention will be described further in conjunction with the attached drawings, in which:

FIG. 1 is a vertical sectional view through the width of a ship containing a conispherical tank with a flat bottom according to the invention;

FIG. 2 is an enlarged view of the lower part of the tank and ship hold shown in FIG. 1;

FIG. 3 is a vertical sectional view through the width of a ship containing a spherical tank with a flat bottom according to the invention;

FIG. 4 is an enlarged view of the lower part of the tank and ship hold shown in FIG. 3; and

FIG. 5 is an enlarged view of the lower part of a tank in a ship hold and illustrates a tank with a tapered toroidal knuckle portion.

So far as is practical, the same or similar elements in the drawings will be identified by the same numbers.

With reference to FIGS. 1 and 2, ship 10 has a hold 11 defined by hold bottom 12 and hold walls 14. Inside of the ship hold is positioned conispherical tank 20.

Tank 20, circular in horizontal section, has a substantially flat relatively thin bottom 21 of metal plate which slidably rests on a layer of support material 22 placed over liquid impermeable flexible membrane 23 supported on top of load bearing insulation 24. Tank bottom 21 is essentially circular. It is joined tangentially at its periphery, such as by welding, to metal toroidal knuckle portion 25 which is joined at its upper peripheral edge, such as by welding, to ring 26. The tank bottom 21 generally can be made thinner than the maximum thickness of the toroidal knuckle portion since the hydrostatic load is applied against the tank bottom and it, in turn, is transferred through the support material 22, which can be balsa wood, and load bearing insulation 24 to the ship hold bottom 12.

A conical section 27 is joined, such as by welding, at its lower edge to ring 26 and at its upper edge to spherical section 28 which completes the tank major structural elements. The conical section 27, the spherical section 28 and the ring 26 together are encompassed within the term "spheroidal-section" as that term is used herein in describing the invention. Equipment well 29 extends inside the tank for its full height and is used for piping, pump and monitoring equipment associated with the tank.

Projecting downwardly from the lower outer edge of ring 26 is conical skirt 30. The lower edge of conical skirt 30 is joined to plate 31 which is bolted to plate 32 supported by upright metal plate 33, thereby forming a bolted transition connection which permits the tank to be secured in position to the ship hold bottom even though the skirt and ship hold bottom are made of dissimilar metals which are not directly weldable. The means used to join the lower edge of the skirt to the ship hold bottom is, however, not a critical part of the invention and other suitable means can be used.

A series of weep holes 34 (FIG. 2) extend through skirt 30 for delivery of escaped liquid to drip accumulating space 35. Insulation 36 is placed over the inner lower portion of conical skirt 30 and the membrane 23 is extended upwardly on the surface of that insulation to angle shield 37.

The external surface of tank 20, and the external surface of conical skirt 30, are covered by insulation 38 and over the insulation is placed spray shield 39. The lower edge of the spray shield 39 terminates in angle gutter 40 which directs accumulated liquid through
The lower part of the insulation 38 on conical skirt 30 is covered with a vapor barrier coating 41, such as of butyl rubber. Weather shield 42 is placed over the entire tank part which extends above the ship deck.

In the described tank 10, vertical loads due to cargo weight and vertical ship acceleration are transmitted to the ship structure primarily through the tank flat bottom 21. Loads resulting from overturning moment, horizontal shear and uplift loadings are transmitted to the ship structure primarily through the skirt 30. The tank bottom is supported by loadbearing insulation 24 having adequate compressive strength to transmit vertical loadings from the tank to the ship structure. The support material 22 functions as a slide pad or means of accommodating differential movement due to thermal displacement of the tank bottom when cycled from atmospheric temperature to a very low temperature, such as -260°F, when used for transporting liquefied natural gas, and back to atmospheric temperature.

Insulation of the conical skirt in the manner previously described leads to development of a uniform thermal gradient through the skirt height, from very cold product temperatures in the skirt upper part to about ambient (i.e. ship hull temperature) or atmospheric temperature in the skirt lower part, which results in thermal stresses within allowable design limits. The skirt base is at approximately ambient temperature so that carbon steel can be used in the ship hold construction.

The tank described with reference to FIGS. 1 and 2 has better utilization of ship hold space than a spherical tank. As a result, such a tank will have less overall height than a spherical tank, permitting a lower center of gravity and lower profile in the ship thereby increasing visibity from the ship deck. Furthermore, by better utilizing the ship hold space there is less residual space which must be inerted. This thereby minimizes the capacity of the inerting system and results in a significant saving in initial cost and operation.

The volume tank of FIGS. 1 and 2 can be increased or decreased by adjusting the length of the conical portion, the conical angle, or the radius of the spherical portion of the conispherical tank. This can have the advantage of permitting an increase in tank volume without changing the ship breadth. A spherical tank can only be adjusted by changing its radius so that a larger tank will require a larger ship breadth.

A further embodiment of the invention is shown in FIGS. 3 and 4. Ship 50, shown in partial lateral cross-section through its width, has a hold 51 defined by a bottom 52 and hold walls 53. Loadbearing insulation 54 is placed on hold bottom 52 and secondary barrier 55 is positioned on top of the insulation. A layer of support material 56 is placed on top of the secondary barrier 55.

Tank flat bottom 57, having a circular periphery, rests on layer 56. The tank bottom 57 is made of thin metal plate. Toroidal knuckle 58 is welded at its lower edge to the peripheral edge of the tank bottom and at its upper edge 59 to spherical section 60. The upper edge of spherical section 60 is welded to metal ring 61. Spherical section 62, which is an approximately hemispherical section, is joined at its lower edge, by welding, to the top edge of ring 61.

Vertically positioned cylindrical metal skirt 63 is joined to ring 61 by welding the upper edge of the skirt to the lower outer edge of the ring. The bottom edge of skirt 63 is joined to plate 64 and it is bolted to plate 65 supported by base plate 66. Base plate 66 is welded to a horizontal ledge in the lower part of the hold. Such a transition joint is not always necessary to join the lower edge of a skirt to the ship hold bottom. A skirt made of 9% nickel could be welded directly to a carbon steel ship hold bottom.

Insulation 67 is positioned over the internal lower portion of skirt 63 and barrier or membrane 55 is extended upwardly over the insulation to angle shield 68. Insulation 69 is located on the external surface of the tank, above ring 61, and on the external surface of the skirt 63. Spray shield 70 covers the insulation on the outside of the tank down to angle gutter 71. Vapor barrier coating 72 is positioned over the outside of the insulation on the external surface of the skirt from below the angle gutter 71 down to the bottom edge of the skirt. Weather shield 73 covers the top of the tank and extends to the hold top or ship deck to protect the hold interior. Equipment well 74 extends for the full height of the tank.

T The tank described with reference to FIGS. 3 and 4 has the same advantages as the tank shown and described in FIGS. 1 and 2.

FIG. 5 illustrates another embodiment of the invention but one which is very similar to the one shown in FIG. 2. The embodiment shown in FIG. 5 however employs a toroidal knuckle 255 which is made of tapered metal plate when viewed in vertical radial section. The bottom peripheral edge 256 has the same thickness as the tank bottom 21 and the upper peripheral edge 257 has the same thickness as spherical section 260 extending between the toroidal knuckle and ring 26. By employing a toroidal knuckle which is tapered as described, or in an equivalent manner, increased flexibility of the metal can be achieved and stresses thus better distributed.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed is:
1. In combination:
   a. a ship having a hold with a bottom and walls;
   b. a tank, which is circular in horizontal section, for transporting a liquefied gas;
   said tank comprising a metal shell having (11) a substantially flat metal bottom (2) a spheroidal section constituting most of the upper part of the tank and (3) a toroidal knuckle portion tangentially joined to the periphery of the metal butt and tangentially joined to the spheroidal section;
   load bearing insulation between the ship hold bottom and the tank metal bottom; and
   a skirt, circular in horizontal section, extending from the tank downwardly to a supporting base in the ship hold.
2. A combination according to claim 1 in which the skirt is conical.
3. A combination according to claim 1 in which the skirt is cylindrical.
4. A combination according to claim 1 in which the tank shell above the skirt is externally insulated, the skirt is insulated externally for its full height and the
7 skirt is insulated internally over at least its lower portion.
5. A combination according to claim 1 in which the toroidal knuckle, in vertical radial section, is tapered and has its thinnest edge joined to the periphery of the tank bottom.
6. A combination according to claim 1 in which a membrane is between the ship hold bottom and the tank bottom.
7. A combination according to claim 1 in which a drip sheet is between the ship hold bottom and the tank bottom.
8. A combination according to claim 7 in which the drip sheet extends upwardly against insulation on the inside of the skirt.

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UNIVERS STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,859,805 Dated January 14, 1975

Inventor(s) Paul Richard Johnson et al.

It is certified that error appears in the above-identified patent
and that said Letters Patent are hereby corrected as shown below:

Column 5, line 41, after "volume" insert "of the";
column 6, lines 23 and 24, delete the "T" at the
beginning of each line; line 35, change "knuckel" to
"knuckle"; line 54, change "periphry" to "periphery"
and change "button" to "bottom".

Signed and sealed this 17th day of March 1975,

(SEAL)
Attest:
RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
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