March 22, 1966 A. D. KORIN ET AL 3,241,703

LIQUEFIED GAS STORAGE TANK

Filed Oct. 18, 1963

FIG. 1

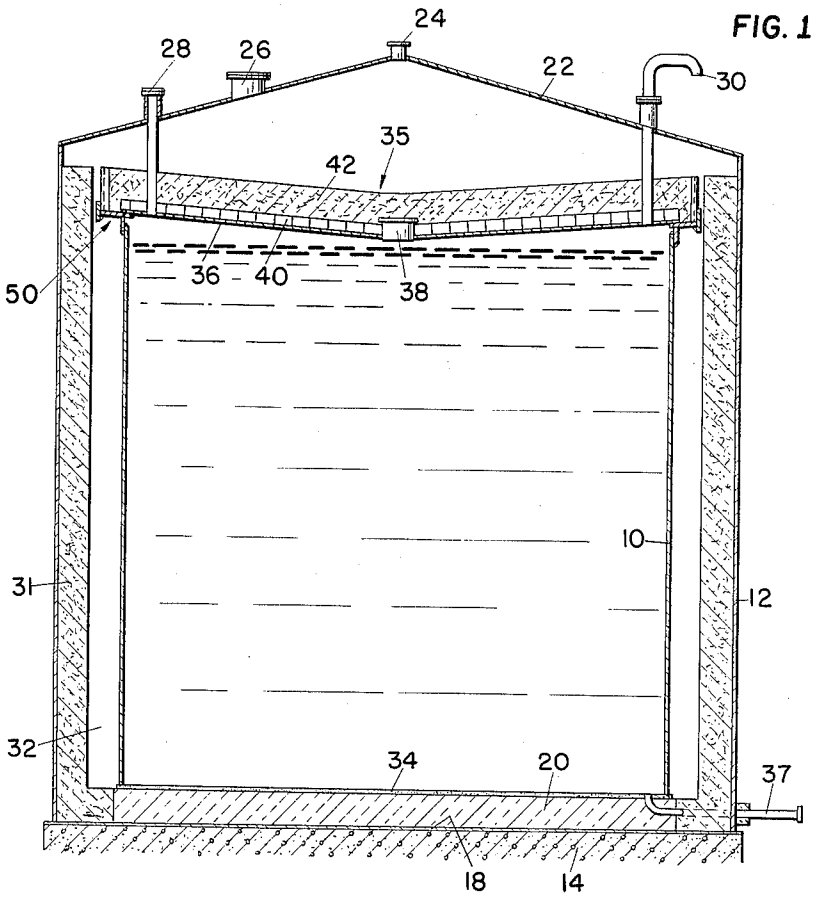
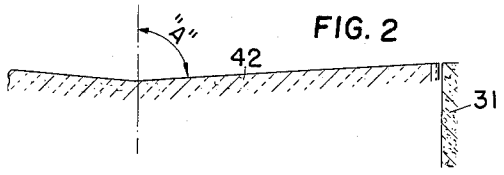


FIG. 2



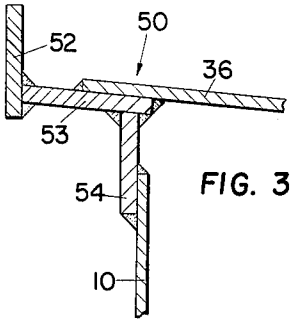


FIG. 3

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United States Patent Office 3,241,703 Patented Mar. 22, 1966

3,241,703

LIQUEFIED GAS STORAGE TANK

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Filed Oct. 18, 1963, Ser. No. 317,279
4 Claims. (Cl. 220—9)

This invention relates to improvements in a storage tank primarily adapted for storing liquefied natural gas and similar liquefied gaseous materials at temperatures below about —40° F. and as low as —424° F. so that the liquids can be stored at substantially atmospheric pressure. It is an improvement on our co-pending application, Serial No. 83,076, filed Jan. 16, 1961, and now abandoned and refiled as Serial No. 313,142 on Sept. 27, 1963, and now issued as Patent Number 3,225,955, dated Dec. 28, 1965.

As described in the above application, the mechanical design of suitable tanks for storage of liquefied gases has proved to be extremely difficult due to the necessity of assuring adequate strength, maximum use of the metal, simplified construction, and especially to provide a tank which has a relatively low heat infiltration. It is also necessary to provide a high factor of safety and to permit substantially 100% inspection and provide for possible repair. This is in addition to the need to accommodate repeated variations in size due to expansion and contraction under the various temperature changes as during filling and discharge.

A feature of the foregoing invention was the provision in a double tank assembly, of an improved lightweight insulated cover for the inner liquid containing tank, such cover being preloaded to withstand the effect of any small gas pressure above the stored liquid resulting from heat leak which causes vaporization of part of the liquid. With storage tanks of this type, which are often from 30 to 100 feet or more in diameter, it was found most economical to provide a relatively light gauge metal for the cover and then to support the cover with numerous base-mounted internal columns. The overall roof was directly supported from this cover and suitable seals were provided to prevent gas losses when such gases were of the noxious type.

Our present invention particularly concerns the design and construction of a liquid containing tank and cover for low temperature and for cryogenic service wherein expensive metals or alloys are required and wherein the cover is of the preloaded type.

The principal object of our invention is to further simplify the construction and reduce the cost of land tankage for the storage of liquefied gases under low temperature conditions below —40° F. or cryogenic service at much lower temperatures.

More specifically, the objectives of our invention are attained by providing a tank the cover of which is secured to the tank in a gas proof manner and in which the cover is preloaded against internal tank pressure, and of a simplified shape in the nature of an inverted dished head or cone whereby the minimum of material is required.

Further objects and advantages of our invention will appear from the following description of a preferred form of embodiment thereof taken in connection with the attached drawings in which:

FIG. 1 is a substantially central vertical cross section through the tank.

FIG. 2 is a detailed schematic cross section through the upper part of the tank.

FIG. 3 is an enlarged vertical cross sectional detail showing the compression ring construction at the junction of the cover and the side wall of the liquid containing tank.

As more particularly shown in FIG. 1, the liquefied

gas storage tank includes an inner shell or main liquid receiving tank **10**, which is preferably mounted in an outer shell or safety and shielding and insulating tank **12**, both of which are supported from a foundation generally indicated at **14**.

Conveniently, the outer tank **12**, which may be of carbon steel, is built on a suitable carbon steel base plate **18** carried by the foundation **14**. Insulation **20** such as foam glass, balsa wood or similar material is laid on the base **18**.

The outer tank **12** is conveniently provided with a suitable roof **22** which has the usual pitch and is self-supporting from the wall of the outer tank. The roof is usually provided with a pressure-vacuum safety valve connection **24** and manhole **26**. The inner face of the side wall of this outer tank **12** has suitable insulation **31** and preferably this is spaced from outside of the side wall of the inner tank **10** to such an extent that an inspector may enter the space **32** therebetween for inspection and repair of the inner tank wall and insulation on the outer tank.

The inner tank has a suitable base **34** which is appropriately mounted on the insulation **20** and the side wall **10** is conveniently welded to the base in a customary manner. Generally, the base and side wall of the inner tank are of aluminum or nickel steel as distinguished from the use of carbon steel or similar materials for the outer tank **12** to withstand the very low temperatures of the liquefied materials. A suitable fill and discharge conduit **37** is taken from the base of the inner tank. The cover **35**, hereinafter described in greater detail, is provided with a nozzle for a liquid level indicator **28**, a vent conduit **30** and a manhole **38**. It will be appreciated that with liquid oxygen tanks the vent conduit **30** may discharge to the atmosphere whereas with liquid methane, or other noxious materials, it will be connected to a suitable condenser.

The principal feature of our present invention concerns the cover **35** for the inner tank, such cover being a composite structure including an aluminum plate **36** which, as shown in FIG. 3, is seal welded to the wall **10** and preloaded with material such as brick, sand, or concrete **40**. Loading is normally in the range of 10 to 150 pounds per square foot but may be as much as 750 pounds per square foot to resist any positive internal pressure. Above this loading are mounted suitable layers of insulation **42**, the entire mass being supported by the inner tank side wall **10** and being free for movement upwardly and downwardly with respect to the outer tank wall **12**.

A supplemental or pre-loading of from 10 to 750 pounds per square foot thus assures a gas pressure safety factor of from 0.07 to 5 pounds per square inch in addition to any pressure that the cover itself would sustain. This is especially significant with aluminum or light gauge alloy materials customarily used.

It has been found by us that the shape of this cover is a matter of significant cost in the construction of the entire tank and it has been possible by a critical study to reduce the total cost of a tank 34 feet in diameter by nearly 16%.

As more particularly shown in FIG. 2, the cover plate **36** is of dished or conical type having an angle A between the side of the cone and its axis or one half of the apex angle of the cone of less than 90 degrees and usually in the range of 89 degrees to not less than 60 degrees. Preferably the range should be between about 75 and 85 degrees which will vary slightly with tank diameter.

By forming the cover of inverted conical shape with the plate in tension, it is possible to reduce the thickness of the plate by a substantial amount and still have it directly supported by the inner tank wall. It is thus possible to eliminate columns and to materially reduce the cost of alternative constructions using typical ellipsoidal covers.

While the degree of the angle A could be reduced below 60 degrees, it is found that a cone of such sharp angle projects too deeply into the tank and thus limits the liquid volume in the tank as it is undesirable for the cover to come in contact with the liquid.

With the dished or conical cover, it is structurally desirable that the upper edge of the inner tank **10** be reinforced as by a compression ring generally indicated at **50** as more particularly shown in FIG. 3. This is shown as a Z shaped element including a cylindrical vertically extended band **52**, a substantially horizontally extending annular web **53** and an annular section **54** which together engage the cover **36** and the tank wall **10**. This compression ring thus uniformly distributes and resists the transverse as well as vertical stresses of the cover into the tank wall. The compression ring may be H shaped to develop the required moment of inertia for larger diameter tanks.

For very low temperature storage as for liquid oxygen or liquefied natural gas, the multiple tank unit shown in FIG. 1 is preferred. The tank wall **10** is insulated against heat leak by the outer tank **12** and the insulation **31** as well as the insulating space **32**. Such a construction also has the advantage of safety in that a leak in the inner tank can be controlled by the outer tank. However, there are many instances when only a single tank is justified and in such case the wall of tank **10** may be suitably insulated as in the usual manner. The advantage of the cover shape is equally as important.

While we have shown and described preferred forms of embodiment of our invention, we are aware that modifications may be made thereto and we desire a broad interpretation of our invention within the scope and spirit of the description herein and of the claims appended hereinafter.

We claim:

1. A heat insulated storage tank for storing liquefied gas at temperatures below —40° F. and at substantially atmospheric pressure, having a base adapted to be foundation mounted and having a side wall extending above said base and forming a chamber of substantially circular cross section therewith, and a cover for said tank, said cover being supported by and sealed with respect to the side wall to form a closed pressure tight tank, said cover being of inverted dished or conical shape having its apex projecting into the closed chamber, one half of the apex angle of said cone being between 60 and 89 degrees, said cover having counterweights therein to establish a preloading in the range of 10 to 150 pounds per square foot to resist a pressure build-up within the tank sufficient to discharge vapors released from the liquefied gas, and a compression ring on the said wall of the tank adjacent the top of the side wall with a portion integrated wth the cover and a portion integrated with the side wall and having an annular portion, said compression ring resisting and distributing transverse and vertical stresses of said cover to said side wall.

2. A heat insulated storage tank as claimed in claim **1** wherein one half the apex angle of the cone is between 75 and 85 degrees.

3. A heat insulated storage tank as claimed in claim **1** having means to insulate said tank, said means including a surrounding tank having insulation on the inner surfaces thereof.

4. A heat insulated tank assembly for storing liquefied gas at temperatures below —40° F. comprising an inner tank and an outer tank, the outer tank having a foundation mounted base and a side wall extending above said base, insulation on the base of said outer tank and on the internal face of said side wall of said outer tank, the inner tank having a base supported by the base of the outer tank and having an upstanding wall spaced from the side wall of the outer tank, said internal tank having a preloaded cover, said cover being supported by the wall of said internal tank, said outer tank having a roof, means to support said roof, means to seal the roof with respect to the side wall of the outer tank, the cover of said inner tank being an inverted dished head or cone with one half of its apex angle being between 60 and 89 degrees and a compression ring on the upstanding wall of the inner tank adjacent the top thereof with a portion integrated with the cover and a portion integrated with the upstanding wall and having an annular portion, said compression ring resisting and distributing transverse and vertical stresses of said cover to the upstanding wall.

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