SUNKEN TANK WITH FLOATING COVER FOR LIQUID GAS STORAGE

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ABSTRACT OF THE DISCLOSURE

The present invention has essentially for object a tank for the storage of liquefied gases at low temperature comprising a shallow basin dug beneath the level of the ground, a peripheral bank raised above said ground level for confining said liquefied gas in said basin, heat-insulated fluid-type cover means floating on the free upper surface of said liquefied gas and adapted to follow the displacements of the latter, and sealing means connecting the outer periphery of said cover means to said peripheral bank, wherein said cover and sealing means comprise at least two fluid-tight sheet assemblies having confined therewith a layer of insulating material, said sheet assemblies each consisting of a composite sheet formed of at least a metal sheet applied to at least one face of a plastic film.

The main object of the present invention is to provide a sunken tank, having a floating cover, for the storage of liquefied natural gas or liquefied oil gas at low temperature.

Among the solutions already proposed for designing stores of the sunken or half-sunken type to store liquefied gases at low temperature, the tanks made of ice and intended to form complementing stores, or the tanks made of prestressed concrete without any lining, having an internal heat-insulation made of expanded plastic materials such as polyurethane, are those which seem to be the most advantageous as regards initial expenditure. They are however attended by some inconveniences in that their installation should be especially well-designed where the tank has to be protected against the risk of being upheaved through freezing of the ground if some water-bearing stratum is present there beneath.

The present invention provides a more flexible construction wherein a distortion of the ground, even if rather important, is not liable to have prejudicial effects. The solution provided by the invention has the additional advantage of being more economical than those heretofore proposed for the storage of liquefied gases at low temperature within frozen grounds.

The tanks according to the invention for the storage of liquefied gas at low temperature is characterized in that it comprises a shallow basin covered with a sealed cover or roof, connected to the peripheral bank or rim of said basin by a fluid-tight peripheral connection, said connection including means such as bellows, folds or similar expanding portions allowing movements of the cover, which will follow the surface of the stored liquid from the uppermost plane of the basin into the bottom thereof and conversely.

According to another feature of the invention, the aforesaid cover is of such mass as to float on the free surface of the stored liquefied gas.

According to a particular embodiment of the invention, the basin is of frusto-conical shape, with a wall flaring upwards and the cover or roof includes a disc-shaped center portion having substantially the same diameter as the basin bottom, said center portion being connected to the basin bank by a flexible portion in the shape of a surface of revolution forming part of a toric surface.

According to another embodiment, the cover consists of a disc with concentric peripheral undulations and possibly radial undulations.

Further features of the invention will appear as the following description proceeds.

In the accompanying drawings, given by mere way of illustration:

FIGURE 1 shows in diametral section part of a storage tank according to the invention, including cover means connected to the basin bank by a flexible portion in the shape of a surface of revolution forming part of a toric surface;

FIGURE 2 shows on an enlarged scale a detail of the tank in FIGURE 1;

FIGURE 3 shows on a very large scale the connection of the roof periphery to the basin bank of the tank of FIGURES 1 and 2;

FIGURE 4 is a cross-sectional view of the spacer means provided between the sheets forming the roof of the tank shown in FIGURES 1 and 2;

FIGURE 5 shows in diametral section part of a storage tank according to another embodiment of the invention;

FIGURE 6 is a fragmentary radial sectional view of an undulation of the cover of a tank pertaining to the type shown in FIGURE 5;

FIGURE 7 is a fragmentary radial sectional view of a tank of the same general type as shown in FIGURE 5, according to a modified embodiment.

Referring to the drawings, FIGURE 1 shows a basin 10 filled with liquefied natural gas. The basin 10 consists of a circular excavation which is dug (with a bulldozer or other mechanical means allowing highly economical construction) to a low depth beneath the level 12 of the ground, in loose soils, preferably above the upmost level of the water-bearing stratum, so as to avoid any interference by incoming waters. The bottom 14 of basin 10 is substantially horizontal. To construct the basin bank 16, use is made of the earth or similar materials excavated from the basin, which are banked up above the ground level 12. The bottom 14 of basin 10 may for example lie at 6—10 feet beneath the ground level 12 and the top or crest 18 of bank or rim 16 stands at about 23—33 feet above bottom 14. The rim 16 forms an annular peripheral bank or mound which surrounds completely the basin 10, the diameter of which may range up to several hundred feet.

With a view to avoid the relatively important lateral heat-losses, there is provided a heat-insulating layer 20, e.g. of loose glass, over the external slope of rim 16 and over its top 18, which is preferably horizontal.

As shown in FIGURE 1, the tank 10 is closed at its top by a floating roof or cover which, as illustrated, consists of a disc 22 arranged in the central area of the tank, fluid-tight deformable connecting means being provided between the periphery 24 of disc 22 and the crest 18 surrounding basin 10. These means are shown in more details in FIGURES 2 and 3 and will be described hereinafter.

As shown in FIGURE 2, there is provided between the internal edge 28 of the crest 18 of rim 16 and the periphery 24 of disc 22, a flexible connecting element 26 which, when the basin is filled with liquid wherein the disc 22 is floating, is in the form of a flexible surface of revolution in the shape of half a torus of circular cross-section cut along a diametral plane. The external periphery of the toric connection 26 is in fluid-tight relationship to the rim 16, as will appear hereinafter.
The floating roof consisting of the disc 22 and the toric connection 26 has heat-insulating properties and is flexible. The disc 22 which, as noted before, has substantially the same diameter as the bottom of the basin, is constructed within a said bottom, previously well flattened. It may for example be formed of two sheets 32 and 34, preferably of composite structure, having confined therebetween a finelv divided heat-insulating material such as perlite, or heat-insulating fibers.

There is shown at 36 the insulating layer between the lower sheet 32 and upper sheet 34 and at 38, beads which are evenly distributed between the two sheets to prevent any sinking or shifting of the insulating material and to ensure uniform distribution thereof.

To construct the disc 22, use may be made of composite sheets comprising a fabric and a plastic film bonded to either face of a sheet of aluminum or the like, such sheets being glued together both in end-to-end and in side-by-side relationship to form the sheets 32 and 34. The plastic film is preferably directed to the atmosphere, the fabric being in contact with the insulation 36, as concerns the composite sheet 34, while as concerns the sheet 32, the plastic layer covering the aluminum sheet is exposed to the stored liquid, and the fabric is in contact with the insulation 36.

The beads 38 are preferably made from a composite sheet of the same materials as sheets 32 and 34, which is cut into and glued as to form a cylinder having confined therein finely divided insulating material 40. Preferably, the beads 38 are arranged concentrically with respect to one another, their lower and upper edges being glued to the sheets 32 and 34 respectively. Where a more efficient partitioning is to be provided, then it may be contemplated to arrange further beads in radial positions (not shown).

Moreover, a circular bead is provided at the periphery 24 of disc 22 to form the hinge between said disc 22 and the toric connection 26. The toric connection 26 is, like the beaded roof, in the form of a case made of two composite sheets 46 and 48 including a layer of fabric and a layer of plastic film associated with a metal sheet, said case being filled with perlusive insulating material. To prevent the perlusive insulating (perlite or the like) from gliding along, within the toric connection 26, between the two sheets, use is made of cylindrical beads similar to the beads 38 of disc 22, but much more close to one another.

It has been mentioned above that the insulation in the toric connection 26 might consist of a perlusive product such as perlite. It is also possible and in some cases advantageous to use, instead of perlite or the like, insulating fibers (e.g. mineral wool), to avoid any shifting or local squeezing of the insulator in the steeply inclined portions of the toric surface. FIGURE 2 shows in full line the roof 22 and the toric connection 26 in the positions they normally assume when the tank is filled, and in dash-and-dot lines the various positions they assume as the tank 10 is being emptied.

As clearly apparent from FIGURE 2, the descent of the disc 22 within the tank 10 is attended by a relatively low increase of the radius of curvature of the toric connection 26 which is acted upon by the internal gas pressure, so that said connection may undergo the necessary deformations without risk of being torn off. The sheets 46 and 48 of the toric connection 26 are joined together along their external edge and are extended into a skirt 50, which depends radially from the bottom 44 onto which the enclosing sheets 46 and 48 are glued. The skirt of the band 50 is arranged in a groove or channel 52 provided in the top of rim 16. The channel 52 is defined by substantially vertical concrete walls 53, while its bottom is constituted by the earth which forms the mound and is somewhat porous. The band 50 is fluid-tightly held in the circular channel 52 by means of a frozen water seal. The water may be frozen by circulating liquefied gas at low temperature through tubes (not shown) submerged in channel 52. The ice thus obtained in channel 52 extends into the mound 16.

In this manner, the toric connection 26 may pivot, during the vertical movements of disc 22, about the free upper part of band 50. To ensure the thermal insulation of the hinge, a bead 54 filled with insulating powder or fibers 56 is provided between band 50 and the insulation 20. There may also be provided on the mound 13 around the tank a fence 25 acting as a baffle to protect the tank against the action of the wind.

FIGURE 5 shows a tank for the storage of liquefied gases which is of the same general type as that described with reference to FIGURES 1-4, but differs therefrom by the design of the deformable peripheral portion of its floating roof.

In FIGURE 5, the same reference numerals are assigned to the portions of the store identical with those of the store in FIGURE 1, namely the basin 10, its bottom 14 and its rim 16, heat-insulated at 20.

The roof 60 of the tank shown in FIGURE 5 has concentric undulations 62 allowing the peripheral portion of roof 60 to deflect between its uppermost position (FIGURE 5) and its lowermost position, where it enganges the basin 14 of basin 10. Details schematically shown at 64 are beads similar to the beads 38 of the embodiment of FIGURE 1, adapted to hold the insulation between the two composite sheets (each indicated by a single line in FIGURE 5) properly positioned.

FIGURE 6 is a sectional view, on an enlarged scale, of one undulation of a tank roof of the same type as that shown in FIGURE 5. In FIGURE 6, there is shown at 66 the upper composite sheet and at 68 the lower composite sheet of the roof. Interposed between the upper sheet 66 and lower sheet 68 is a layer 70 of insulating powder and/or fibers. As shown in the drawing, one side of undulation 72 are arranged plates 74 of such rigidity as to ensure that the wave 72 will be formed within the annular gap between the portions stiffened by elements 74, the latter being also in annular array. Some stiffening elements 74 may consist of plates of a certain mass, which act to ballast the roof according to the above defined conditions.

FIGURE 7 shows a modified tank of the type illustrated in FIGURE 5, i.e. including coaxial undulations or waves 80, 82, 84 at the periphery of a roof whereof the circular center portion 86 rests on the surface of the liquid contained in the basin which is defined by the rim designated by the reference 88. The roof comprising the circular portion 86 and the waves 80, 82 and 84 is constructed in the same manner as the tank roofs shown in FIGURES 1 and 5, i.e. it includes two fluid-tight films having confined therebetween a layer of divided, powdered or fibrous insulation. As illustrated in FIGURE 7, the locations where the waves 80, 82 and 84 are to be formed are defined on the lower film of the roof by roll-shaped floaters 81, 83, 85, in concentric annular setting about the central axis of the tank. The roof periphery includes a bead 90 prolonged by a skirt 92 which is of a material identical or similar to that of the upper and lower sheets of the roof and is fluid-tightly embedded in the ice contained in a channel 94 in the top of rim 88.

The dot-and-dash lines in FIGURE 7 show the position assumed by the roof when the tank is but partly filled. The floaters 81, 83 and 85 then assume the positions 81', 83' and 85' respectively, and the waves become 84' which becomes wave 84' being formed thanks to a rigid ring, diagrammatically shown at 96 for the full tank condition and at 96' for the almost empty tank condition. At 98, there is shown a flexible cover arranged above waves 80, 82 and 84. As shown, this cover 98 is inflated (by means of nitrogen or other inert gas, for example). The purpose of this cover 98 is to avoid the accumulation of water between successive
waves or to remove such water which might freeze in winter and prevent normal operation of the waves. In windy weather, the cover 98 is deflated (since the wind has but very little hold on the waves).

The tanks just described are low-pressure tanks (as compared with the conventional tanks). However, should some pressure increase be desired, then the roof may be loaded with a layer of sand or water (not exceeding one inch or so). It should be noted that a blower operated by a responsive regulator is normally used to discharge the evaporated gases from the upper part of the tank. In the case of the store of FIGURE 1 or of that of FIGURE 5, having a diameter of the order of several hundred feet, the roof thickness will be in the range of about 8-16 inches according to the present evaporating conditions.

It will be possible to bring various detail modifications to the tanks described above. The bottom of these tanks may be either left as such after proper flattening, or covered with a thin bed of gravel or concrete for cleanliness purposes, but it may also be contemplated to form therein a bed of ice having a thickness of one or more inch to avoid any direct contact between the stored liquefied gas and the soil.

If the tank bottom has no heat-insulation, then the cold condition will be developed during the filling up with the initial loads of liquefied gas, this being objectionable in that large volumes of gas will be evaporated at low pressure, while if the bottom is heat-insulated, the evaporation caused by the cooling of the ground will spread out in time and the evaporated gases will be recoverable (at least partly).

Where a liquefied gas store already in service is available, it is advantageous to bring beforehand the ground to the cold condition by means by systems of tubes arranged in the bottom 14 of the tank 10, through which cold liquid or gas is run. During this step of bringing the ground to a cold condition, the heat-insulation of the bottom may be effected by means of the heat-insulated roof resting on said bottom. This will spare the cost of any additional insulation, while at the same time minimizing the evaporation at low pressure caused by the step of cooling the ground.

The tanks according to the invention are safe to a very high degree. Since the mound 16 and bottom 14 are frozen to a substantial depth, any risk of accidental discharge of liquefied gas is eliminated. Moreover, the thick layer of incombustible pulverulent insulation lying between the roof sheets, the low volume of gas which is entrapped only beneath the connection and the low pressure of this gas all ensure a much higher degree of safety than in the other sunken or half-sunken tanks or even in the underground tanks, wherein a falling in of the vaults might cause intense vaporization.

Such tanks have also proven advantageous in that they require no foundation, this being highly important since such stores will usually be installed at the sea-side or along rivers, that is in soils of general alluvial character. This suppression of the foundations moreover allows of substantially reducing the time required for the construction.

Of course, the invention is by no way limited to the embodiments described and shown, which are given by mere way of example.

What I claim is:

1. A tank for the storage of liquefied gases at low temperature comprising a shallow basin dug beneath the level of the ground, a peripheral bank raised above said ground level for containing said liquefied gas in said basin, heat-insulated fluid-tight cover means floating on the free upper surface of said liquefied gas and adapted to follow the displacements of the latter, and sealing means connecting the outer periphery of said cover means to said peripheral bank, said cover and sealing means comprising at least two fluid-tight sheet assemblies having confined therebetween a layer of insulating material, said sheet assemblies each consisting of a composite sheet formed of at least a metal sheet applied to at least one face of a plastic film.

2. A tank according to claim 1, wherein said insulating material is in a finely divided state, spacer means being provided between said sheet assemblies.

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