

[54] OFFSHORE LIQUID STORAGE FACILITY

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Related U.S. Application Data

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[51] Int. Cl. F17c 1/02

[58] Field of Search 62/45; 220/13; 9 LG, 26 R; 61/5, 46, 46.5; 114/5 T, 26, 43.5

[56] **References Cited**

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[57]

ABSTRACT

An offshore liquid storage facility includes a receiver tank having an open top and being mountable on the sea floor with its top above sea level, means for maintaining water or other liquid in the receiver tank at a predetermined level above sea level, a liquid storage tank received in the receiver tank and movable telescopically up and down therein, and means for alternately supplying a liquid to the storage tank for storage therein and withdrawing the liquid therefrom, whereby the storage tank is held captive in the receiver tank while water or other liquid may be maintained in the receiver tank at the predetermined level for stabilizing the facility, and variations in buoyancy during liquid withdrawal and supply are accommodated by up and down gravity movement of the storage tank in the liquid maintained in the receiver tank.

11 Claims, 2 Drawing Figures

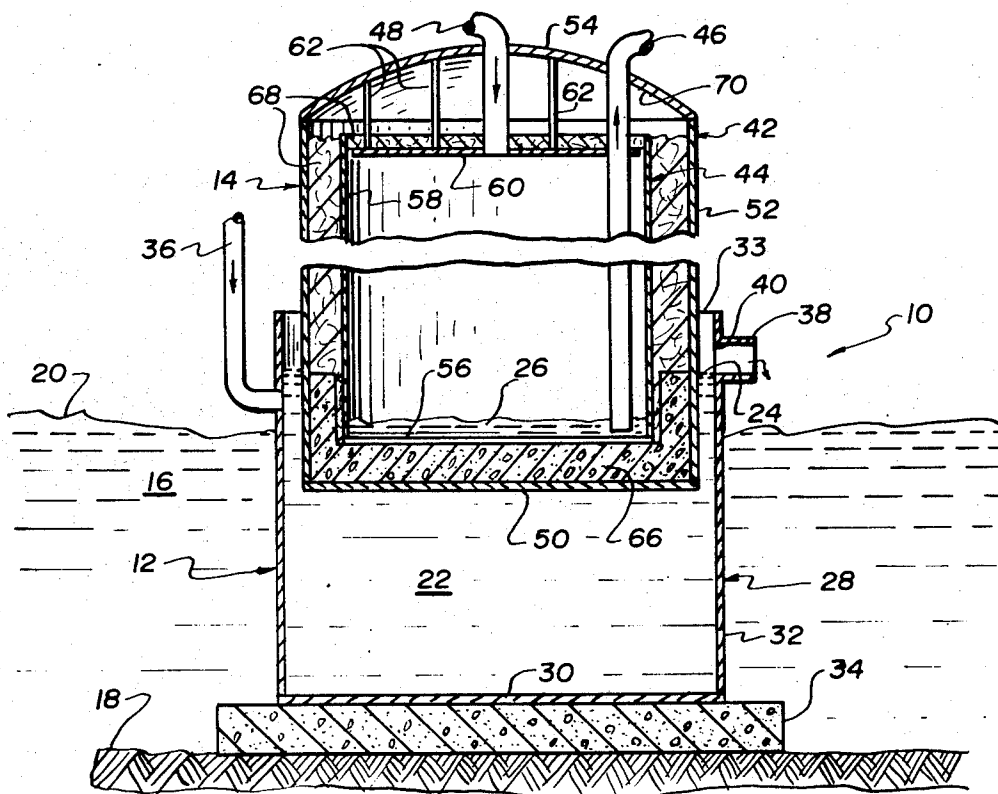


FIG. 1

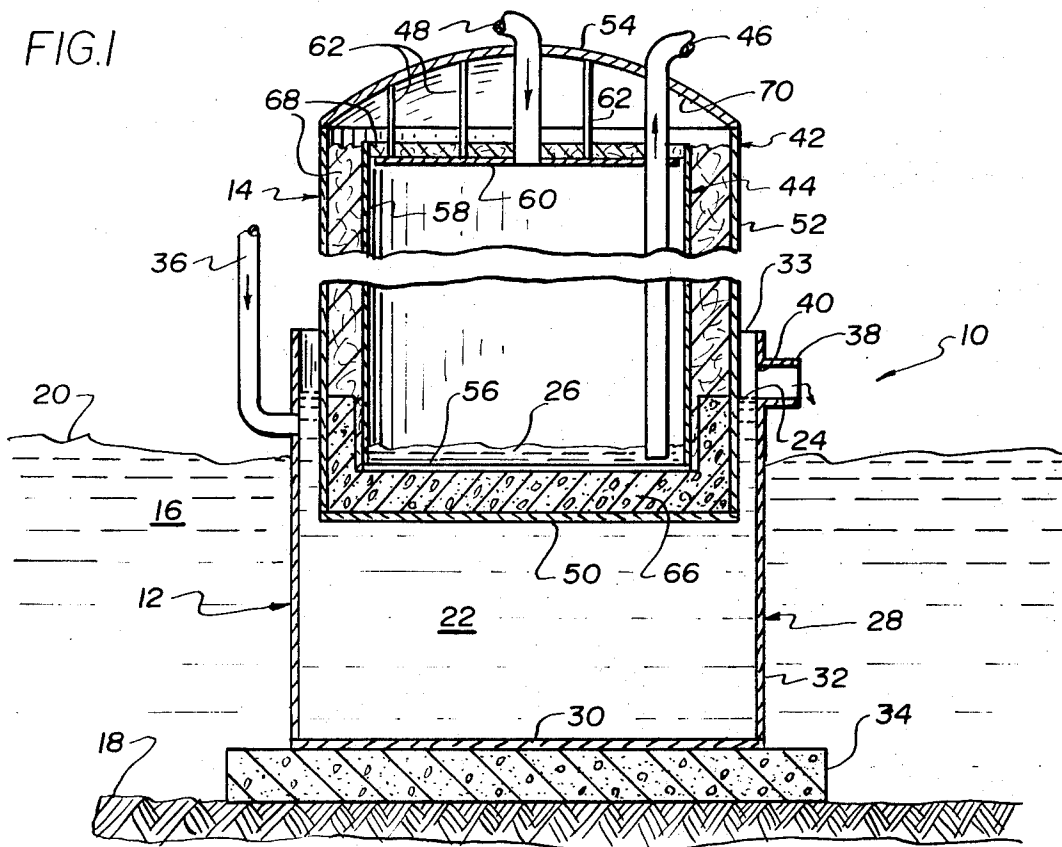
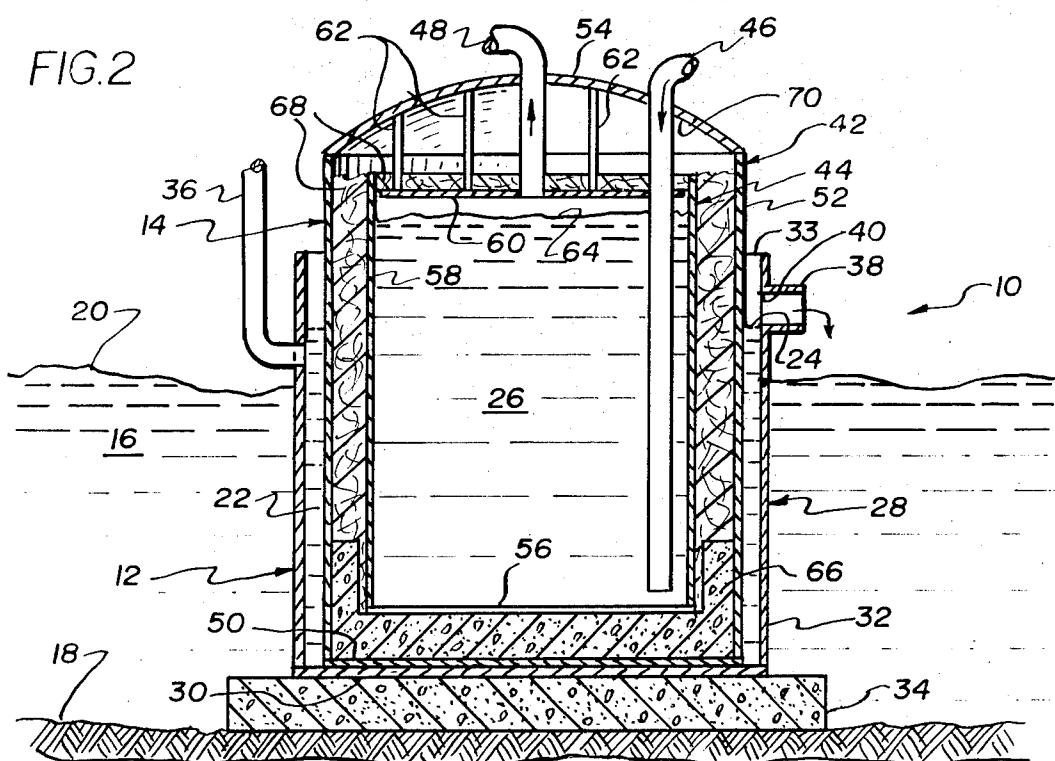


FIG. 2



OFFSHORE LIQUID STORAGE FACILITY

This application is a continuation-in-part of copending application Ser. No. 333,218 filed Feb. 16, 1973 now abandoned.

This invention relates to facilities or installations for offshore storage of liquids, especially for insulated storage of liquids at temperatures above or below ambient temperatures. More particularly, the invention relates to a facility adapted for storing normally solid, liquid or gaseous materials that are maintained in the liquid state during storage. The invention is especially valuable for the storage of liquefied gases.

Offshore storage of liquids which are maintained significantly below or above ambient temperatures poses special problems, inasmuch as the stored liquids must be insulated from the atmosphere and/or sea water, and also or alternatively from structure supporting the storage vessels. Provision must be made for the variations in buoyancy of the storage vessel that occur during a cycle of loading and unloading. At present, suitable facilities for offshore insulated storage are limited to floating vessels or ships, which may be moored or anchored at suitable locations. Relatively sophisticated and expensive structures are required to satisfy the structural and safety requirements for the temperatures and loads involved. Provision must be made for mooring or anchoring the floating storage vessel in various offshore locations and while it is exposed to various weather and water conditions.

With rapidly growing world energy requirements, it will become increasingly necessary to recover gases currently wasted offshore, and to liquefy the gases and store them in offshore facilities. It will thus be highly advantageous to have available suitable offshore facilities for the insulated, refrigerated storage of liquefied natural gas or methane, propane, and butane, which preferably are stored at about their boiling points at approximately atmospheric pressure. Such facilities also may be employed for the low temperature storage of other liquefied gases, such as oxygen, hydrogen, and ethylene. Other materials may be stored in the liquid state, at temperatures ranging from above to below ambient temperatures. The storage facilities may be employed for holding materials near the locations at which they are recovered, or for storing materials delivered from remote points, pending delivery elsewhere or for use at adjacent locations.

An object of the present invention is to provide a new and improved offshore liquid storage facility, in particular, an enclosed and preferably insulated tank-type facility. An accompanying object is to provide a storage facility that overcomes the disadvantages of and provides advantages over prior facilities.

Another object is to provide an offshore storage facility of very stable, permanent or semi-permanent character, which is immersed in a body of water and supported on the floor or bottom of the water body. In particular, it is an object to provide such a facility that resists wind and wave action, and does not significantly move when subjected to the forces thereof.

An additional object is to provide an offshore liquid storage facility that is conveniently installed where needed, and after installation, is readily accessible to production facilities and ships. An accompanying object is to provide such a facility that may be assembled on shore, readily transported to an installation site in a

body of water and there installed, and, if desired, removed subsequently.

A further object is to provide a storage facility of the foregoing character, that is versatile and adaptable to the storage of a number of materials at diverse temperatures, ranging from sub-atmospheric to super-atmospheric temperatures, including normally solid, liquid and gaseous materials stored in the liquid state at a suitable liquefaction temperature, and, preferably, at about atmospheric pressure.

An important specific object of the invention is to provide such a facility for storing normally gaseous materials that are liquid or have boiling points at extremely low temperatures on the order of -100°F and below, which are termed cryogenic liquids. An accompanying object is to provide facilities for storing such liquids at substantially atmospheric pressure and at about their boiling points, with their liquefaction temperatures maintained by suitable refrigeration, preferably, by removing any heat input as heat of vaporization of the stored material.

Another specific object is to provide an offshore liquid storage facility which utilizes a liquid storage tank that may be filled and emptied alternately, while the weight and buoyancy characteristics vary with the stored load, the tank being maintained in a column of liquid such as oil, water or other liquid, and allowed to rise and fall, or float up and down, according to its buoyancy.

A more specific object is to provide for the retention of such a storage tank by mounting it for movement telescopically up and down in a receiver tank, the receiver tank being filled with a liquid such as sea water, oil or other liquid, and supported on the sea floor. An accompanying object is to thereby obviate need for massive guy lines or the like, and accompanying anchoring problems. Another object is to provide for maintaining a head of liquid in the receiver tank, to stabilize the facility on the sea floor, while the storage tank floats in the receiver tank and the liquid surrounding the storage tank provides supplemental insulation for its contents. Although the receiver tank can be more readily filled with sea water, an alternate system could use the receiver tank for the storage of oil or other non-refrigerated product in addition to the low temperature product stored in the receiver tank.

Additional objects include the provision of an offshore liquid storage facility having a relatively simple, basic design, which minimizes the structural material requirements, both quantitatively and qualitatively, to thereby provide economies in manufacture, assembly, transportation, installation and use.

These and other objects, advantages and functions of the invention will be apparent on reference to the specification and to the attached drawings illustrating a preferred embodiment of the invention, wherein like parts are identified by like reference symbols in each of the views, and wherein:

FIG. 1 is a vertical sectional and broken schematic view of an offshore liquid storage facility according to the invention, taken substantially centrally or axially thereof, the view illustrating the facility as installed in a body of water and with the storage tank thereof substantially empty; and

FIG. 2 is a view like FIG. 1, but illustrating the storage tank substantially full.

The invention provides an offshore liquid storage facility which includes a receiver tank having an open top and being mountable in an upright position on the sea floor with its top above sea level, means associated with the receiver tank for maintaining a liquid such as water, oil, or other liquid therein at a predetermined level above sea level, a liquid storage tank in the receiver tank and movable telescopically up and down therein, and means associated with the storage tank for alternately supplying a liquid to be stored thereto and withdrawing the liquid therefrom, whereby the storage tank is held captive in the receiver tank while water or other liquid may be maintained in the receiver tank at the predetermined level for stabilizing the facility, and variations in buoyancy during liquid withdrawal and supply are accommodated by up and down gravity movement of the storage tank in the liquid maintained in the receiver tank. In a preferred structure, an insulated storage tank is employed. More preferably, the tank is insulated sufficiently to enable a cryogenic liquid to be stored therein substantially at its boiling point and under substantially atmospheric pressure. Additional preferred features of the invention are described hereinafter.

Referring to the drawings, a preferred offshore liquid storage facility 10 according to the invention includes a receiver tank 12 having an open top, and an enclosed storage tank 14 received in the receiver tank and movable telescopically up and down therein. The facility 10 is illustrated as it is installed at a suitable location in the sea or other body of water 16.

The receiver tank 12 is mounted in an upright position on the sea floor or bottom 18, and the tank extends upwardly above the sea level 20. A varying quantity of water or other liquid 22 is maintained in the receiver tank 12 at an essentially constant predetermined level 24 above the sea level 20. The storage tank 14 moves by flotation up and down in the liquid 22 within the receiver tank 12. The storage tank 14 is supported at various levels within the receiver tank 12 and projects upwardly therefrom for corresponding distances, depending upon the quantity of liquid 26 stored in the storage tank and the resulting buoyancy of the tank. The storage tank 14 is in its uppermost position when emptied of its storage liquid 26, at which time it floats in the liquid 22 in the receiver tank 12, substantially as illustrated in FIG. 1. The storage tank 14 is in its lowermost position when filled with the storage liquid 26, at which time it may or may not be seated on the bottom of the receiver tank 12. FIG. 2 shows it seated on the bottom of receiver tank 12.

The receiver tank 12 includes a preferably cylindrical vessel or container 28, constructed of a flat circular metal bottom 30 and an upstanding cylindrical metal side wall 32 secured to the bottom 30 around the periphery thereof, preferably by welding. The upper rim 33 of the side wall 32 forms the open top of the receiver tank 12. A ballast slab 34, preferably constructed of concrete, is secured to the bottom 30 of the vessel 28 by any suitable means, not illustrated, and the slab constitutes the base of the receiver tank 12. The slab is seated on the sea floor 18, to support the receiver tank 12 in an upright position. At times, it may be desirable to fix or fasten the slab to the sea floor 18. Thus, for example, piles (not shown) may be driven through suitable openings in the slab and into the sea floor.

The receiver tank 12, and particularly the vessel 28 thereof, is provided with a constant head of water or other liquid 22 therein, at a predetermined level 24 sufficiently above the sea level 20 to maintain stability of the storage facility 10 against the natural forces of wind and waves, which might otherwise tend to shift or overturn the facility. For this purpose, suitable means are provided in association with the receiver tank 12 for maintaining the liquid 22 therein at such predetermined level 24. In the illustrative embodiment, water or other liquid is supplied to the receiver tank vessel 28 through a supply or inlet conduit or pipe 36 connected to the projecting upper portion of the side wall 32. Sea water or other liquid may be pumped through the supply conduit 36 by suitable liquid level-responsive pumping means, not illustrated. An overflow discharge duct or outlet 38 also is provided in the projecting upper portion of the side wall 32. The duct 38 registers with a corresponding opening 40 in the side wall 32, providing for overflow at the desired level 24. The overflow level is determined so as to provide a liquid head in the vessel 28 that is sufficient, together with the weight of the facility 10, to provide stable mounting of the facility under all conditions. The overflow out opening 40 is, of course, controlled to avoid polluting the sea. If oil is the liquid 22, it is not permitted to overflow to the sea but instead it is collected and stored elsewhere. As will be apparent to those skilled in the art, the design of a specific installation will involve, inter alia, an economic balance of the variables, including the dimensions of the side wall 32, the height of the discharge duct 38, and the weight of the ballast slab 34.

The storage tank 14 is of essentially double-walled construction and includes an enclosed outer metal shell 42 and an internal storage compartment 44 spaced therefrom. A liquid flow conduit or pipe 46 extends through the walls of the outer shell 42 and the storage compartment 44, into communication with the interior of the storage compartment, for alternately supplying a liquid to be stored to the compartment and withdrawing the liquid therefrom. A gas flow conduit or pipe 48 extends through the walls of the outer shell 42 and the storage compartment 44, into communication with the interior of the storage compartment, for alternately venting the compartment, and replacing withdrawn liquid with a gas.

The outer shell 42 of the storage tank 14 is generally cylindrical, thus corresponding in shape to the receiver vessel 28, for reciprocal telescopic movement therein. The outer shell 42 includes a flat circular metal bottom wall 50, and an upstanding substantially cylindrical metal side wall 52 secured to the bottom wall 50 around the outer periphery thereof, preferably by welding. The outer shell 42 is completed by a circular metal roof 54 of dome-shaped configuration, which is secured around its periphery to the upper rim of side wall 52, preferably by welding. While the shape of the roof preferably is a spherical segment, it may be constructed in other shapes, such as in the shape of an ellipsoidal segment or it can be conical.

The outer diameter of the side wall 52 of the outer shell 42 is less than the inside diameter of the side wall 32 of the receiver vessel 28, to provide clearance or spacing adequate for free up and down movement of the storage tank 14 in the receiver tank 12, while insuring proper disposition and retention of the storage tank

within the receiver tank. If desired, guide means, such as ring members, not illustrated, may be provided between the shell side wall 52 and the receiver vessel side wall 32, and be mounted on either wall, to assist in guiding the storage tank during its vertical movement, and also, to limit or prevent rotation of the storage tank. The side wall 52 of the outer shell 42 has a height greater than that of the side wall 32 of the receiver vessel 28, so that the storage tank 14 at all times projects upwardly beyond the top of the receiver tank 12 and is accessible at its top.

The storage compartment 44 of the storage tank 14 includes a flat circular metal bottom wall 56, and an upstanding substantially cylindrical metal side wall 58 secured to the bottom wall around its periphery, preferably by welding. The storage compartment is completed by a flat circular metal suspended ceiling 60, which is supported within the side wall 58 a short distance below the upper rim thereof. The ceiling 60 is suspended from the roof 54 of the outer shell 42 by a number of vertical suspension rods 62 distributed over the roof and the ceiling. This structure may correspond to the suspended ceiling structure disclosed in U.S. Pat. No. 3,352,443. The ceiling 60 is suspended above the normal liquid level 64 when the storage compartment is filled with the liquid 26, as illustrated in FIG. 2.

The storage compartment 44 thus is a substantially cylindrical vessel corresponding substantially to the shape of the outer metal shell 42. The outside diameter of the side wall 58 of the compartment is less than the inside diameter of the side wall 52 of the outer shell 42, and the height of the compartment side wall 58 is less than the height of the shell side wall 52, so that the storage compartment 44 is received within and spaced from the walls 50 and 52, and the roof 54 of the outer shell 42.

A layer of ballast 66, such as concrete, which also serves as insulation, and a layer of other suitable insulation 68 are provided around the storage compartment 44, in the space between the compartment and the outer shell 42. The ballast 66 is disposed at the lower end of the storage tank 14, for weighting the bottom thereof. In this manner, proper orientation and adequate submersion of the storage tank 14 are assured, enabling the storage tank to move up and down readily and holding it captive in the receiver tank 12.

The layer of insulation 68 is placed around the side wall 58 and over the ceiling 60 of the storage compartment 44. As disclosed in the aforesaid U.S. Pat. No. 3,352,443, the ceiling 60 is constructed and arranged to permit the passage of vapor from below to above the ceiling and vice versa. A portion of the insulation 68, such as along the edge of the ceiling, is vapor-permeable, so that a vapor-permeable heat barrier is provided. This structure provides for pressure equalization between the interior of the storage compartment 44 and the vapor space 70 remaining between the insulation 68 and the roof 54 of the outer shell 42.

With the foregoing construction of the storage tank 14, the outer shell 42 may be constructed of metals that need only withstand substantially normal or atmospheric temperature changes and the external and internal pressures involved, inasmuch as the shell is substantially insulated from the contents of the storage compartment 44, at other temperatures. On the other hand, the walls 56 and 58, and the ceiling 60 of the storage compartment 44, are constructed of metals

suitable for the intended storage load; in particular, where a cryogenic liquid is to be stored, the bottom wall 56 and the side wall 58 are constructed of metals which retain adequate ductility under the low temperature refrigeration conditions.

The liquid flow conduit 46 extends through the roof 54 of the outer shell 42, through the insulation 68, and through the ceiling 60 of the storage compartment 44, into the storage compartment to a location adjacent to and spaced a short distance above its bottom wall 56. The conduit serves for the supply and withdrawal of the storage liquid 26. For this purpose, it is connected to a pump, not illustrated, in turn connected to a production or supply source, or to delivery facilities, as the storage tank is filled or emptied.

The gas flow conduit 48 extends through the roof 54, the insulation 68, and the ceiling 60, and terminates at the ceiling in communication with the interior of the storage compartment. The gas flow conduit serves for venting the storage compartment as the compartment is filled with liquid, and for replacing withdrawn liquid with a gas, preferably the same type of gas as is stored in the liquid state in the compartment. Alternatively, another gas, such as nitrogen, may serve to replace withdrawn liquid. Structural and economic considerations render it preferable to maintain the interior of the storage compartment at or about atmospheric pressure, i.e., not substantially above or below atmospheric pressure.

When storing a cryogenic liquid 26 in the storage facility 10, the heat transfer from the exterior to the interior of the storage tank 14 is minimized by the insulation around the tank, including the ballast 66 and the insulation 68. Also, insulation is provided by the layer of water or other liquid 22 within the receiver vessel 28 and surrounding the storage tank, as illustrated in FIG. 2, and by the ballast slab 34 of the receiver tank. The insulation thus provided minimizes heat transfer to the interior of the storage compartment 44. The relatively small amount of heat which is transmitted to the liquid 26 preferably is removed or dissipated as heat of vaporization of the liquid, which is maintained at about its boiling point under the substantially atmospheric pressure conditions. The resulting vapor is vented through the gas flow conduit 48. A conventional refrigeration system may be employed for this purpose, for example, such as disclosed in U.S. Pat. No. 3,677,021. The gas flow conduit 48 may be employed as the vapor vent or discharge line in one of the systems disclosed in the patent. The vapor which is formed may be vented to the atmosphere or to a recovery unit. In the preferred practice of the present invention, the storage compartment 44 is maintained at about atmospheric pressure, as described above.

The storage facility 10 may be constructed on shore, the storage tank 14 nested in the receiver tank 12, and the entire assembly floated to an offshore location and submerged as a unit. The facility then becomes a permanent or semipermanent installation. Should it be desired to move the facility at some future time, it may be floated once more and moved to a different location.

The storage facility 10 is anchored firmly in place owing to the weight of the tanks 12 and 14 and the quantities of water or other liquid 22 and storage liquid 26 contained in the tanks. A constant head of water or other liquid is maintained in the receiver tank at the

level 24, which ordinarily will be a substantial distance above the sea level 20, e.g., 20 feet. In this manner, the receiver tank 12 is firmly anchored to maintain its stability against horizontal and overturning forces. Owing to the described construction and arrangement of the tanks 12 and 14, the storage tank 14 is held captive in the receiver tank 12 at all times, floating in the liquid 22 in the receiver tank when empty or partly filled, and possibly, seated on the bottom 30 of the receiver vessel 28 when filled. As the storage tank 14 descends in the receiver tank 12 during a filling operation, the liquid 22 in the receiver tank overflows from the discharge duct 38. As the storage tank rises in the receiver tank during emptying, the liquid level 24 in the receiver tank is maintained constant by supplying sea water or other liquid to the tank through the supply conduit 36.

Liquid to be stored, which may be a cryogenic liquid, is supplied to the storage compartment 44 through the liquid flow conduit 46, until the liquid level 64 is relatively near to and spaced below the ceiling 60, as illustrated in FIG. 2. The gas previously present in the storage compartment is vented through the gas flow conduit 48. Thereafter, quantities of the liquid 26 are boiled off, as a means of absorbing heat input and removing the heat from the vessel, to cool the stored material and maintain it in the liquid state. Other types of materials stored at higher temperatures may require neither refrigeration nor heating, while materials stored at sufficiently high super-atmospheric temperatures may require heating, such as by heating coils or elements, to replace the heat lost from the storage compartment 44.

When it is desired to empty the storage compartment 44 or to remove a portion of the liquid 26 therefrom, the liquid may be pumped from the compartment through the liquid flow conduit 46, so that the tank is left in a condition such as illustrated in FIG. 1. Where the liquid 26 is a cryogenic liquid, such as a liquefied petroleum gas fraction, the removed liquid is replaced with a gas, preferably the same type of material in the gaseous state, introduced through the gas flow conduit 48. Similarly, other liquefied gases may be replaced with the corresponding materials in the gaseous state. In other cases, there may be no need for replacement with a gas, and the storage compartment 44 may be in direct communication with the atmosphere, for venting thereto and replacing withdrawn liquid with air.

The invention thus provides an offshore storage facility which is well suited for the storage of various liquids, and is especially useful for storing liquids at temperatures substantially removed from atmospheric temperatures, notably, cryogenic liquids. The storage facility does away with the prior problems of mooring and anchoring floating storage vessels, and also is simple and economical in structure and operation as compared to such vessels. The invention is very advantageous for the offshore storage of liquefied petroleum gas products, which will become increasingly important as it becomes necessary to recover gases currently wasted offshore and to store liquefied recovered gases at the production site.

While a preferred embodiment of the invention has been illustrated and described, it will be apparent that various changes and modifications may be made therein within the spirit and scope of the invention. It is intended that all such changes and modifications be included within the scope of the appended claims.

What is claimed is:

1. An offshore liquid storage facility which comprises:

a receiver tank having an open top and being mountable in an upright position on the sea floor with its top above sea level,

means associated with said receiver tank for maintaining a liquid therein at a predetermined level above sea level,

a liquid storage tank received in said receiver tank and movable telescopically up and down therein, and

means associated with said storage tank for alternately supplying a liquid to be stored thereto and withdrawing the liquid therefrom,

whereby said storage tank is held captive in said receiver tank while liquid may be maintained in the receiver tank at said predetermined level for stabilizing the facility, and variations in buoyancy during liquid withdrawal and supply are accommodated by up and down gravity movement of the storage tank in the liquid maintained in the receiver tank.

2. A storage facility as defined in claim 1 and wherein said storage tank includes an internal storage compartment, and including means insulating said storage compartment sufficiently to enable a cryogenic liquid to be stored therein substantially at its boiling point and under substantially atmospheric pressure.

3. A storage facility as defined in claim 2 and wherein said storage tank also includes an enclosed outer shell spaced from said storage compartment, and said insulating means comprises a layer of insulation enclosing said storage compartment in the space between the compartment and the other shell.

4. A storage facility as defined in claim 3 and wherein said outer shell and said receiver tank each include an upstanding substantially cylindrical side wall.

5. A storage facility as defined in claim 1 and wherein said receiver tank comprises an upstanding metal side wall and ballast secured to the bottom of the side wall, and said storage tank comprises an enclosed outer metal shell.

6. A storage facility as defined in claim 5 and wherein said storage tank also comprises a storage compartment within and spaced from said outer shell, and a layer of insulation enclosing said storage compartment in the space between the compartment and the outer shell.

7. A storage facility as defined in claim 6 and wherein said outer shell includes a roof, and said storage compartment includes a ceiling suspended from said roof and having said layer of insulation thereon and spaced below the roof to provide a vapor space beneath the roof, said ceiling and insulation layer thereon providing a vapor-permeable heat barrier.

8. A storage facility as defined in claim 6 and wherein said storage tank includes ballast at the bottom thereof and in the space between said storage compartment and said outer shell.

9. An offshore liquid storage facility which comprises:

a receiver tank having an open top and including an upstanding substantially cylindrical metal side wall and ballast secured to the bottom of the side wall for mounting the tank in an upright position on the sea floor with its top above sea level,

means associated with said receiver tank for maintaining a liquid therein at a predetermined level above sea level including conduit means for supplying liquid to the receiver tank and overflow means on said side wall for discharging liquid from the tank, 5

a liquid storage tank received in said receiver tank and movable telescopically up and down therein, said storage tank including an enclosed outer metal shell having an upstanding substantially cylindrical side wall, a storage compartment within and spaced from said outer shell, and a layer of insulation enclosing said storage compartment in the space between the compartment and the outershell, said insulation being sufficient to enable a cryogenic liquid to be stored in the compartment substantially at its boiling point and under substantially atmospheric pressure, 15

liquid flow conduit means communicating with the interior of said storage compartment for alternately supplying a liquid to be stored thereto and withdrawing the liquid therefrom, and 20

gas flow conduit means communicating with the in-

terior of said storage compartment for alternately venting the compartment and replacing withdrawn liquid with a gas,

whereby said storage tank is held captive in said receiver tank while a liquid may be maintained in the receiver tank at said predetermined level for stabilizing the facility, and variations in buoyancy during liquid withdrawal and supply are accommodated by up and down gravity movement of the storage tank in the liquid maintained in the receiver tank.

10. A storage facility as defined in claim 9 and wherein said outer shell includes a roof, and said storage compartment includes a ceiling suspended from said roof and having said layer of insulation thereon and spaced below the roof to provide a vapor space beneath the roof, said ceiling and insulation layer thereon providing a vapor permeable heat barrier.

11. A storage facility as defined in claim 10 and wherein said storage tank includes ballast at the bottom thereof and in the space between said storage compartment and said outer shell.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,828,565 Dated August 13, 1974

Inventor(s) John Stanton McCabe

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

Column 6, line 43, "tte" should be --the--; Column 8, line 35, "other" should be --outer--.

Signed and sealed this 22nd day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents