

Feb. 25, 1969

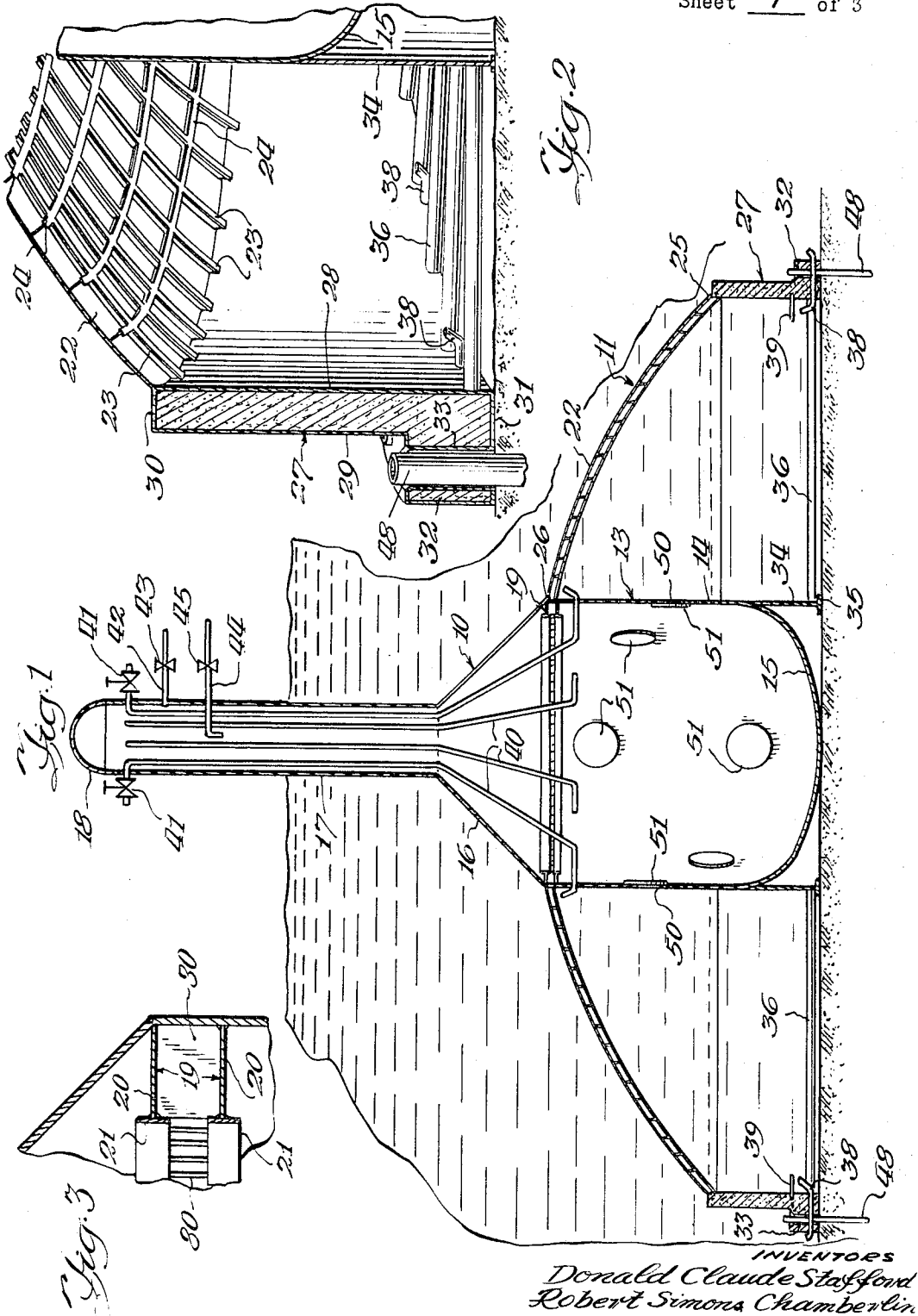
D. C. STAFFORD ET AL

3,429,128

OFFSHORE STORAGE STRUCTURE

Filed April 21, 1967

Sheet 1 of 3



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Fig. 4

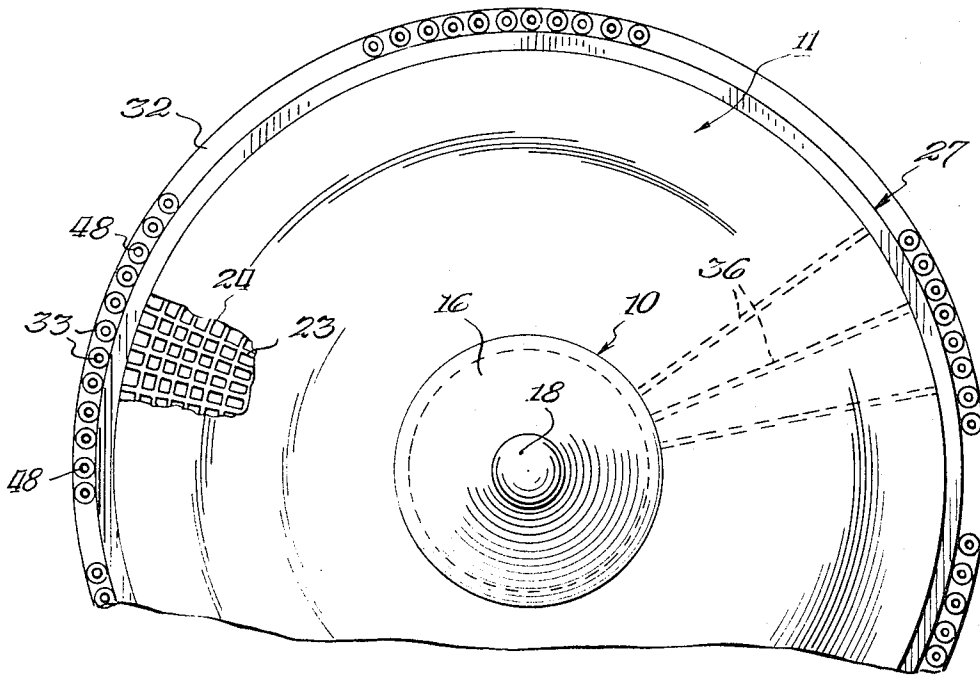


Fig. 6

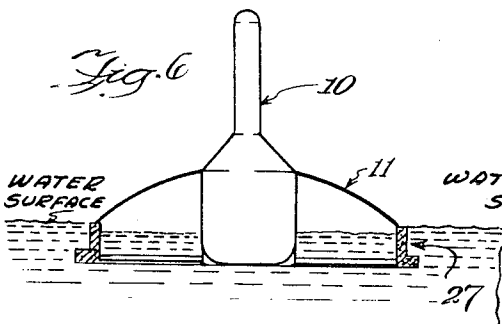


Fig. 5

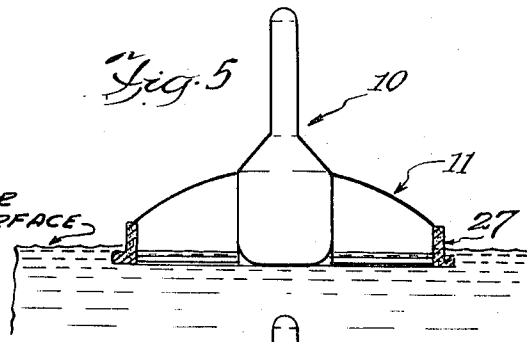


Fig. 8

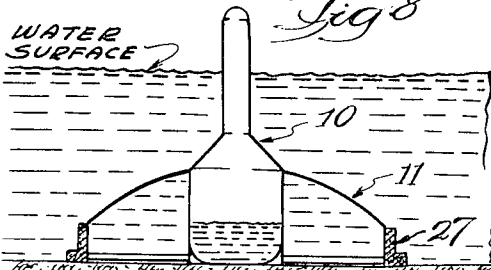
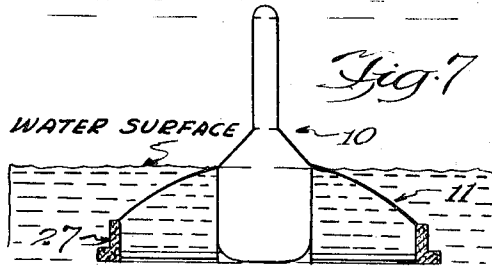


Fig. 7



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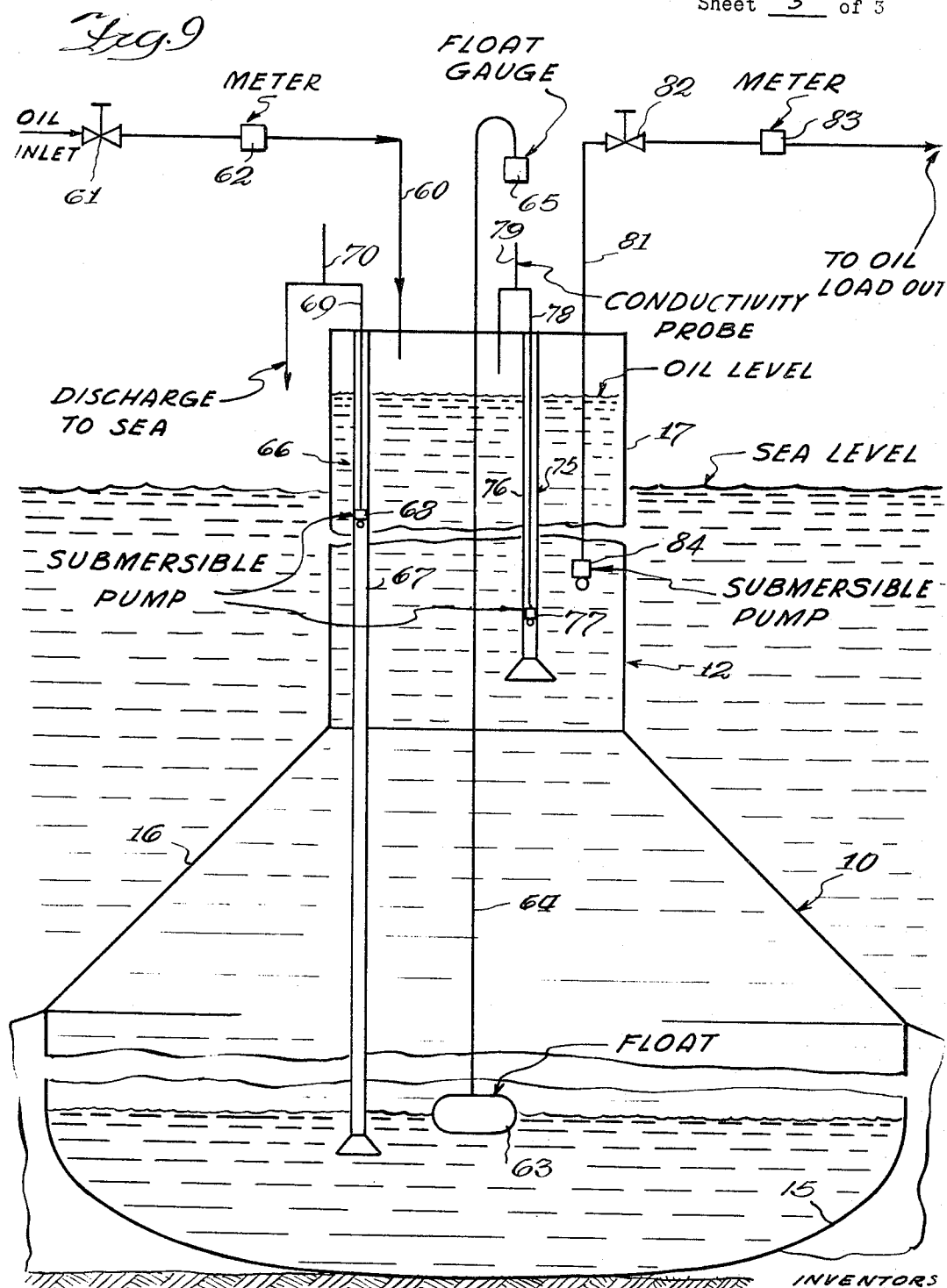
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3,429,128

OFFSHORE STORAGE STRUCTURE

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14 Claims

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ABSTRACT OF THE DISCLOSURE

Provided is an offshore liquid storage tank which rests submerged supported on the floor of a body of water. The tank is comprised of two vessels, both of which contribute to floating buoyancy and to controlled submergence of the tank at a desired site.

This invention relates to tanks for storing liquids. More particularly, this invention is concerned with an underwater offshore liquid storage tank which can be floated to a site and submerged. Although other liquids may be stored which have specific gravities less than the specific gravity of water, the tank is particularly useful for storing oil and liquid hydrocarbon products derived therefrom.

Large amounts of oil are obtained from offshore wells many miles from the nearest shoreline. The location of such wells makes it impracticable to pipe the oil directly to storage tanks on shore. Although the oil can be piped directly from the well to a waiting oil tanker, this approach is not generally economical because of the time needed to pump enough oil from the well to fill the tanker. In many instances it has been recognized that the most practical means of handling the oil is to store it in a tank in the vicinity of the wells and to later transfer it to a tanker when the supply is large enough.

Because of the water depths encountered in offshore oil production, surface and underwater currents and storm conditions, the provision of storage tanks at the site has presented many engineering problems. To be economically useful, such tanks must be of large volume, such as of 100,000 barrel capacity and upwards. The large size of the tanks, and the problems which would be involved in building them offshore, has so far made it essential that they be built completely, or in major components, on land and transported to the offshore site for positioning or erection. Transporting the tanks to the site has usually required floating them with all the problems of buoyancy and stability plus structural integrity that this involves. Upon arriving at the site, the tanks are lowered until they are supported by or rest upon the floor or bed of the body of water. As buoyancy is decreased, floating stability varies continuously, with capsizing a constant threat. Experience has shown a definite need for offshore oil storage tanks which can be floated to the site with stable buoyancy and then submerged sufficiently to be supported by the floor of the body of water while maintaining control of the tank against unstable dangerous listing or tilting and with full control of the rate of descent.

There is accordingly provided by this invention an underwater offshore liquid storage tank, floatable to a site for positioning on the floor of a body of water, of such design and shape as to possess unusually stable buoyancy during floating and when being lowered to the bottom. The structure also permits construction of tanks in graduated sizes according to the capacity considered most suitable for a particular location. Strength against underwater turbulence and pressure is also a feature of the tank structure provided by this invention.

The underwater offshore liquid storage tank of this

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invention has a roofed shell enclosing a volume therebelow and an opening in or near the bottom by means of which water can move in or out from beneath the shell. By this is meant that the entire bottom of the shell can be open, or it can be partially open or closed, or fully closed except for an opening in or near the bottom through which water can move in or out of the shell. The roofed shell can be of any suitable shape which will define a volume therebelow. In horizontal section, it can be circular or polygonal or combinations of straight and arced segments. The shell can have any suitable shape, such as obtained by rotating a line about a vertical axis to obtain a conical, spherical or elliptical shape, or it can be pyramidal or some similar shape. However, the peripheral edge of the roofed shell advisably lies in a horizontal plane.

The periphery of the roofed shell is advisably heavily ballasted to a height to provide a substantial righting moment against significant tipping of the tank when the ballast is at least partly above water level. The ballast causes the center of gravity of the tank to be well below the metacentric height of the tank and thus gives excellent stability at minimum draft.

Means are also provided to remove air from the roofed shell and supply the same with liquid in submerging the tank.

Joined to the roof shell, and forming part of the tank, is at least one hollow vessel of such size that the buoyancy of that vessel will statically float the roofed shell above the floor of a body of water partly or fully submerged even with all air removed from beneath the roofed shell.

The hollow vessel advisably includes a standpipe which communicates with the hollow vessel and extends to above the level of the body of water when the tank is supported by the floor of the body of water. The standpipe, when empty of liquid, provides a substantial source of positive buoyancy to the tank when the roofed shell and major part of the hollow vessel are submerged.

Means are also provided to supply liquid to the hollow vessel to submerge the tank.

The tank, in the specific embodiment described hereinafter, when floating with minimum draft, has its center of gravity above the center of buoyancy, and the metacenter above the center of gravity. The tank maintains this relationship of inherent stability against capsizing during submerging until submerging of the tank and lowering of the ballasted periphery of the roofed shell causes the center of gravity of the tank to be below the center of buoyancy thus further providing an inherent stable condition against tilting as submerging continues. In other words, until the center of gravity moves below the center of buoyancy during submerging of the tank, the value GM in the formula

$$GM=KB+BM-KG$$

must be a positive value for stability, where

GM is the distance from the center of gravity to the metacenter,

KB is the distance from the bottom of the tank to the center of buoyancy,

BM is the distance from the center of buoyancy to the metacenter, and

KG is the distance from the bottom of the tank to the center of gravity.

In the tank of this invention GM is always a positive value until the center of gravity is below the center of buoyancy and stability exists because of that relationship.

The displaced volume of the hollow vessel is advisably such that it supports a significant part of the entire tank prior to and during the transfer of the center of buoyancy

from below to above the center of gravity. This generally requires that the bottom of the hollow vessel be located about in line with the bottom of the roofed shell and that the bottom of the hollow vessel displace a large enough volume of water to give the needed buoyancy. The invention will now be described further with reference to the attached drawings in which:

FIGURE 1 is a vertical section through the axis of an oil storage tank of this invention resting submerged on the bottom of a body of water;

FIGURE 2 is an isometric view, partially in section, showing the interior structure of the roofed shell and the peripheral wall;

FIGURE 3 is a sectional view showing the stiffener rings where the roofed shell joins the central vessel or buoyancy maintaining bottle;

FIGURE 4 is a top plan view of the tank of FIGURE 1; FIGURE 5 shows the tank floating at the site where it is to be positioned;

FIGURE 6 shows the tank after being partially submerged;

FIGURE 7 shows the tank after being further submerged but with only air in the central vessel;

FIGURE 8 shows the tank after being fully submerged and before being put in operation; and

FIGURE 9 shows apparatus which can be used in association with the tank for filling with, and emptying the tank of, oil.

With reference to FIGURE 1, the underwater oil tank as shown in this embodiment of the invention has an enclosed hollow first vessel 10 to which is connected roofed shell 11 which comprises in essence a second vessel. Vessel 10 is herein sometimes referred to as a bottle because of its shape, having a necked portion or standpipe 17 of smaller size than the main body 13.

Vessel 10, as shown in FIGURE 1, has a vertical circular cylindrical shell 14 with a concave bottom shell 15 joined thereto. To the top of shell 14 is connected a conical sectional shell 16. Vessel 10 includes standpipe 17 which joins shell 16 and terminates in a temporary cap 18. Standpipe 17 provides buoyancy during submergence and, once the tank is on the bottom, it may be removed if the tank is to be operated fully submerged. Standpipe 17 can be of such height as desired but usually will extend sufficiently high above sea level when the tank is on the floor of a body of water to cause hydrostatic pressure of oil therein to force water out of the tank. No standpipe 17 need be used if the tank is to be operated fully submerged with no extension above water and oil fed thereto under a positive pressure adequate to displace water therefrom. Thus after submergence, standpipe 17 can be removed and a suitable cover applied.

Shell 11, forming the second vessel of the tank, radiates axially outwardly and downwardly from vessel 10. The upper edge of shell 11 is joined securely to vessel 10, and as shown in FIGURE 1, about where conical section 16 joins cylindrical shell 14. Because of the forces concentrated at this joint, large internal stiffener rings 19 are positioned at the joint inside vessel 10. The rings 19, as shown in FIGURE 3, comprise horizontal elements 20 having vertical terminal flanges 21. Vertical plates 80 are welded between elements 19 to stiffen them and form a unitary structure.

For a 500,000 barrel overall storage tank, vessel 10 can have an 80 ft. diameter for shell 14, and standpipe 17 can be 20 ft. in diameter. The body of vessel 10, excluding standpipe 17, can have a height of about 100 ft. The major volume of vessel 10 is clearly below shell 11.

Roofed shell 11, constituting the second vessel of the tank, can be of such shape as desired but for resistance to water currents when submerged, it is advisably a convex spherical segment. In the tank as illustrated, it can be a spherical segment having a 180 ft. radius. Even though a spherical segment has inherent strength because of its shape, it is considered advisable to support the plates 22

by arcuate ribs 23, as shown in FIGURE 2, which radiate axially from the junction 26 of roofed shell 11 with vessel 10 to the outer edge 25 of the plates 22 used in roofed shell 11, and by circular ribs 24.

The peripheral portion of roofed shell 11 is heavily ballasted by vertical circular concrete wall 27 having a metal shell 28 on the inside and a metal shell 29 on the outside as shown in FIGURE 2. The top of the wall 27 is covered by metal plate 30 and the bottom is covered by plate 31. The weight of wall 27 is necessarily sufficient to lower the center of gravity substantially and provide a metacentric height well above the center of gravity. Wall 27 has a flange 32 at the bottom which projects laterally outwardly. Flange 32 is made of concrete and is covered by metal plates. A plurality of large metal tubular sleeves 33 are positioned in flange 32 and extend completely therethrough. The upper portion of sleeves 33 are flared outwardly for guiding piles into the sleeves when the tank is to be anchored to the floor of a body of water.

The overall height of wall 27 can be about 30 ft. for a 500,000 barrel tank and the spherical segment of roofed shell 11 can be about 45 ft. high. Also, wall 27 can have a diameter of about 250 ft.

Depending from roofed shell or vessel 13 is cylindrical skirt 34 with footing plate 35 at the lower end thereof. To strengthen wall 27 against lateral movement, a plurality of tubes 36 are positioned to extend radially from skirt 34 to the inside of wall 27. The tubes 36 are equally spaced radially around skirt 34.

Running through the bottom of wall 27 is a plurality of horizontal tubes 38 having both ends upturned so as to project above the floor of a body of water when the tank rests thereon. Vortex plates 39 are placed above the inner ends of tubes 38 to suppress vortex formation as water enters and leaves the tank by means of these tubes.

The bottom of roofed shell or vessel 11 can be completely open to the water, partially covered or completely covered. Since there is generally no advantage in covering the tank bottom, it is usually left completely open to minimize cost. Thus, if the bottom is fully closed, water can move in and out through tubes 38 in the same way as if fully or partially open. However, if the bottom 11 is fully or partially open, water can move in and out from beneath roofed shell 11 through the open bottom and openings like tubes 38 are generally not needed.

About six to eight vent lines 40 are provided to communicate with the uppermost part beneath shell 11 so as to remove air therefrom when submerging the tank. Vent lines 40 extend upwardly in standpipe 17 and out near the top thereof where valves 41 are provided to control air flow. Although vent lines 40 project through vessel 10, appropriate joints are used so as to prevent leakage of air or water from roofed shell or vessel 11 into vessel 10.

Air line 42, controlled by valve 43, may be used to pressurize vessel 10 and water supply line 44, controlled by valve 45, can be used to supply water to vessel 10 to effect controlled submergence.

Because of its size, the storage tank is most suitably built on shore in a graving dock, then floated and towed to the desired site for submerging. FIGURE 5 is illustrative of the shallow draft which the tank will have when floating. Buoyancy is achieved by air trapped below shell 11 and by vessel or bottle 10. Vessel 10 must be able to withstand external water pressure during submergence. Vessel 10 can be built with walls inherently strong enough to resist the pressures involved or it can be built with thinner walls and the interior pressurized with air to counter the external pressures to which it is subjected during submerging. When floating, valves 41 must be closed and valves 43 and 45 are also closed if vessel 10 must be pressurized to equalize external water pressure.

The tank when floating as shown in FIGURE 5 has marked stability against uncontrolled tilting because (1)

the weight of concrete wall 27 and its distance from the tank axis provide a high and effective coupling moment against uncontrolled tilting and (2) the buoyancy of enclosed vessel 10. Although the center of gravity is above the center of buoyancy when the tank is floating with minimum draft, the tank is in a stable condition because the metacenter is above the center of gravity.

To lower the tank, air is removed from vessel 11 by vent lines 40. The removal of air lets the tank sink. As it sinks to the position shown in FIGURE 6, the center of buoyancy moves upwardly until, when the top of wall 27 is at about water level, it is just below the center of gravity but the metacenter is still above the center of gravity. At this point tilting of about 10° to 15° can be expected but without loss of stability. As more air is removed from below roofed shell or vessel 11, the tank sinks more but with ever increasing stability and the tank becomes progressively level again. During this phase of submergence, the center of gravity moves from above to below the center of buoyancy and stability is thus maintained. When all air is removed from below roofed shell or vessel 11, as shown in FIGURE 7, vessel 11 will be essentially below water level. At this point, the tank, exclusive of standpipe 17, is at approximately neutral buoyancy. If it were not for the buoyancy provided by the standpipe, the tank would be essentially weightless in the water and could drift submerged up and down with water currents.

The addition of weight to a body at neutral buoyancy will give it negative buoyancy and cause it to sink, but at an uncontrolled rate. To obtain controlled lowering of a body in water, the body must have positive buoyancy, either inherent in its structure or supplied by other means such as derrick barges or similar equipment, at least until the body touches the floor of the body of water. Once on the floor, negative buoyancy is needed to keep the body in position.

The tank as shown in FIGURE 7 is mostly submerged but floats because, while it is in a state of balanced buoyancy, i.e. the weight of the tank equals the weight of the water it displaces, the tank still possesses potential positive buoyancy, by means of standpipe 17, which must be overcome to lower the tank further.

To submerge the tank lower than the position obtained by removing all air from below roofed shell or vessel 11, as shown in FIGURE 7, water is supplied to vessel 10, advisably at a constant rate. For controlled submergence, water is pumped into vessel 10 by line 44. If advisable, air can be vented by line 42 to maintain any desired pressure in vessel 10. The addition of water to vessel 10 progressively reduces the positive buoyancy of the tank induced by standpipe 17 and causes the tank to sink at a controlled rate until it rests on the bottom of the body of water. As the tank sinks, the center of buoyancy continuously moves higher above the center of gravity because of the buoyancy continually supplied by standpipe 17 as it is lowered. The tank thus is always in a stable condition during submergence. After the tank rests on the floor of the body of water, it is advisable, to make the tank negatively buoyant, to continue adding water to vessel 10 until it is filled to near or above water level to balance internal and external pressures thereon.

After the tank is supported on the bottom, piles 48 can be slid through sleeves 33 and driven into the floor of the body of water. Grout applied between the piles and sleeves will hold them securely in place. The number of piles used depends on water conditions and forces. The main purpose of the piles is to secure the tank against lateral and vertical wave forces and, secondary, buoyancy caused by oil in the tank. The buoyancy of the oil, however, usually is adequately overcome by the weight of the tank even when full of oil. The tank need not rest on the floor of the body of water in total contact therewith since under some circumstances it can be advisable to position

the tank on the side of a mound or hill in the floor of the body of water and support it raised therefrom by means of piles. The tank when so raised above the floor and even having an open bottom for roofed shell 11 will effectively store oil.

After the tank has been secured to the floor, cap 18 is removed. Ports or other openings can be provided in vessel 10 below its juncture 26 with roofed shell 22 to permit interflow of oil and water between vessels 10 and 11. As shown in FIGURE 1, a plurality of ports 50, covered by plates 51, are provided. Plates 51 are advisably removed after the tank is supported on the floor of the body of water thus permitting water and oil to flow to and fro by gravity between vessel 10 and vessel 11. However, no communication between vessels 10 and 11 need be provided by ports 50 if the tank is to be used to store two different liquids, such as jet fuel in vessel 10 and bunker fuel in roofed shell 11.

In operation with ports 50 open, the tank is full of water or oil, or some of each, at all times. Initially the tank contains water. As oil is produced from wells, it is fed into standpipe 17 which extends considerably above water level. The hydrostatic head of oil forces water out the bottom of the tank and through lines 38. This continues so long as oil is pumped into the tank. As oil is removed from the tank, water flows into the tank by means of the open bottom and lines 38. The oil-water interface in each of vessels 10 and 11 is maintained essentially the same because of ports 50 which permit free liquid flow between the vessels.

Although various known systems can be used to regulate filling and emptying the tank, FIGURE 9 shows representative apparatus which can be used. Oil can be pumped into the tank by line 60 having control valve 61 and volume meter 62. The location of the oil-water interface can be measured by means of float 63 which is submersible in the oil and which will remain afloat in water. The weight of tape 64 supporting float 63 can be counterbalanced by a negator motor. The position of the float is shown on float gauge 65.

A control 66 is provided to prevent overfilling of the tank with oil. This low water control consists of a pipe 67 running from the top of standpipe 17 to a point close to the bottom of vessel 10. Pipe 67 is normally full of water. A small submersible pump 68 is placed in the pipe and it continuously pumps water through line 69 to the body of water. When the oil-water interface goes below the bottom end of pipe 67, oil will rise in the pipe and be pumped out line 69. Conductivity probe 70 senses the presence of oil and sets off an alarm or illuminates a light. This indicates the tank is full of oil.

Also provided is a high water alarm 75. Pipe 76 extends from the top of standpipe 17 to a point somewhat below water level. Pump 77 of the submersible type is placed in pipe 76 and by means of line 78 pumps oil and empties it back into tube or standpipe 17. Pump 77 is interconnected to operate only when pump 84 is emptying oil from the tank. Conductivity probe 79 senses the change from oil to water flow through line 78 and sounds an alarm or turns off pump 84.

Pump 84 is used to empty the tank by pumping oil out through line 81. Valve 82 and volume meter 83 are placed in line 81 for control purposes.

The system as described with reference to FIGURE 9 can be used solely to fill and empty vessel 10 when ports 50 are closed, i.e. when vessel 10 does not have communicating openings for liquid to travel to vessel 11. However, with such an arrangement, means are needed to transfer water in and out of vessel 10 as oil is removed or added thereto. One way of effecting such water transfer would be to extend one or more of pipes 38 to communicate with the inside bottom area of vessel 10. Of course, if vessel 10 is built strong enough it need not be full of a liquid at all times to balance the pressure from liquid in roofed shell 11. In this case, only a liquid

such as oil need be put in or removed from vessel 10. A different liquid can be stored in vessel 11 by pumping it in thereto under pressure and for this purpose lines 40 could, for example, be used. Of course, other suitable piping could be used, and the arrangement of the same is well within the skill of the art.

It is also within the subject invention to compartmentalize roofed shell 11, such as by vertical walls therein, to permit storing of two or more liquids therein or for such other purposes as desired.

Although the embodiment of the invention as shown in the drawings has a single central vessel or buoyancy bottle 10, two or more enclosed vessels can be used to stabilize the tank and give controlled descent during submergence. The use of two or more vessels or bottles 10 permits them to be constructed of smaller size than when only one is used since the buoyancy obtained will be the additive volume of the enclosed vessels. The combined buoyancy of such vessels must be adequate, however, to support the roofed shell 11 in at least a partially floatable position above the floor of the body of water so that it can be lowered subsequently at a controlled rate by regulated reduction in buoyancy. The tank of this invention thus basically employs two separate structures, both of which are used to float it and to effect controlled submergence of the tank. Although the bottle 10 is shown as a single vessel, two or more vessels which give the needed buoyancy can be used; however, they must not only supply the needed buoyancy but must be so positioned and of such size as to give continual stability while the tank is towed floating or being lowered to the floor of the body of water. This requires that the metacenter be above the center of gravity of the tank at all times.

The tank of this invention and the stability achieved prior to total submergence of walls 27 can be likened to an outrigger canoe with the lower part of vessel 10 being imagined as the canoe and walls 27 as the outriggers. As the walls move in and out of the water, they overcome excessive tilting in the same way as do outriggers on a canoe. Obviously, as in a canoe there must be a balanced relationship between the canoe displacement and that of the outriggers for stability so there must be a balanced relationship between the buoyancy of hollow vessel 10 and the water displacement of walls 27.

If desired, after the tank is secured to the bottom of the body of water, an operating platform or mooring dock can be built on the top of the tubular standpipe 17.

Moving the tank to a new location can be effected by separating the tank from the piles and reversing the submerging procedure.

Various changes and modifications of the invention can be made and, to the extent that such variations incorporate the spirit of this invention, they are intended to be included within the scope of the appended claims.

What is claimed is:

1. An underwater offshore liquid storage tank floatable to a site for positioning on the floor of a body of water comprising:

a convex roofed shell enclosing a volume therebelow, said convex roofed shell being open at the bottom and having a circular vertical ballast wall at its peripheral edge to provide a substantial righting moment against significant tipping of the tank while the wall is at least partly above water level,

means to remove air from the convex roofed shell and supply the same with water in submerging the tank,

a hollow vessel having a vertically positioned cylindrical body circular in horizontal section with a concave bottom and a generally convex top, and a vertical standpipe communicating with the interior of the vessel through the convex top and extending upwardly therefrom to above the water surface when

the tank is supported by the floor of the body of water,

said convex roofed shell being concentrically joined to the exterior upper part of the hollow vessel,

bracing means extending from the lower part of the hollow vessel to the lower part of the wall of the convex roofed shell, and

means to supply water to the hollow vessel in submerging the tank,

said hollow vessel being of such size that the buoyancy of the vessel will statically float the roofed shell above the floor of the body of water partly or fully submerged at least with all air removed from beneath the roofed shell.

2. An underwater offshore liquid storage tank floatable to a site for positioning on the floor of a body of water comprising:

a hollow first vessel having a vertical tube communicating with the top interior of the vessel and extending upwardly therefrom to above the water surface when the tank is on the floor of the body of water, and

a second vessel comprising a roofed shell concentrically joined to the exterior upper part of the first vessel and projecting radially outwardly and downwardly therefrom and terminating in a circular periphery the lower edge of which is in about the same horizontal plane as, or a short distance below, the bottom of the first vessel and in equispaced distance from the first vessel, said roofed shell having an opening about at its bottom to the body of water and said first vessel being of such size that the buoyancy of the vessel will statically float the roofed shell above the floor of the body of water partially or fully submerged at least with all air removed from beneath the roofed shell.

3. An underwater offshore liquid storage tank according to claim 2 in which the roofed shell of the second vessel has a depending vertical wall about its circular periphery and the bottom of the wall is adapted to be supported by the floor of the body of water.

4. An underwater offshore liquid storage tank according to claim 2 in which the first vessel has a vertically positioned cylindrical body circular in horizontal section, a dished bottom and a generally convex top from which the vertical tube projects upwardly, and the roofed shell of the second vessel is axially joined to the cylindrical body.

5. An underwater offshore liquid storage tank according to claim 2 in which the wall bottom has means for securing the same to piles driven into the floor of the body of water to secure the tank against lateral and vertical movement.

6. An underwater offshore liquid storage tank floatable to a site for positioning on the floor of a body of water comprising:

a hollow first vessel having a vertically positioned cylindrical body circular in horizontal section with a dished bottom and a generally convex top, and a vertical standpipe communicating with the interior of the vessel through the convex top and extending upwardly therefrom to above the water surface when the tank is supported by the floor of the body of water, and

a second vessel comprising a roofed shell concentrically joined to the exterior upper part of the first vessel and projecting radially outwardly and downwardly therefrom and terminating in a vertical circular peripheral wall, the bottom edge of which wall is adapted to be supported by the floor of the body of water, said second vessel being open at the bottom to the body of water and said first vessel being of such size that the buoyancy of the vessel will statically float the roofed shell above the floor of the body of water partially or fully submerged at least

with all air removed from beneath the roofed shell.

7. An underwater offshore liquid storage tank according to claim 6 having bracing means extending from the lower part of the first vessel to the lower part of the wall of the roofed shell of the second vessel.

8. An underwater offshore liquid storage tank according to claim 6 having ports in the first vessel below the roofed shell of the second vessel which ports when open permit interchange of liquids therebetween.

9. An underwater offshore liquid storage tank floatable to a site for positioning on the floor of a body of water comprising:

a roofed shell enclosing a volume therebelow, said roofed shell having its periphery heavily ballasted to a height to provide a substantial righting moment against significant tipping of the tank while the ballast is at least partly above water level, means to remove air from the space beneath the roofed shell and supply the space with liquid in submerging the tank,

at least one hollow vessel joined to the roofed shell, at least a part of the volume of said hollow vessel being positioned below the roofed shell and of such size that the buoyancy of the vessel will statically float the roofed shell above the floor of the body of water partly or fully submerged at least with all air removed from the space beneath the roofed shell, a standpipe communicating with the hollow vessel and extending to above the level of the body of water when the tank is supported by the floor of the body of water, said standpipe when empty of liquid providing a substantial source of buoyancy to the tank when the roofed shell and major part of the hollow vessel are submerged, and

means to supply liquid to the hollow vessel in submerging the tank,

said tank when floating with minimum draft on the water surface having its center of gravity above the center of buoyancy, and the metacenter above the center of gravity and being capable of maintaining this relationship of inherent stability against capsizing during submerging until submerging of the tank and lowering of the roofed shell below the water surface causes the center of buoyancy of the tank to be above the center of gravity thus providing an inherently stable vertical condition as submerging continues.

10. An underwater offshore liquid storage tank floatable with inherent stability against uncontrolled tipping to a site for positioning on the floor of a body of water comprising:

a roofed shell enclosing a volume therebelow, said shell having means to remove air therefrom and means to transport water to the volume below the roofed shell,

at least one hollow vessel joined to the roofed shell, the hollow vessel defining a volume separated from the volume defined by the roofed shell thereby permitting independent control of the amount of air or liquid in each of said volumes during flotation and submergence of the tank,

the hollow vessel being of such size that the buoyancy of the vessel will statically float the roofed shell above the floor of the body of water partially or fully submerged at least with all air removed from beneath the roofed shell, and

means to supply liquid to the hollow vessel in submerging the tank,

said tank when floating with minimum draft having its metacenter above its center of gravity.

11. A tank according to claim 10 in which the roofed shell has a circular vertical wall at its peripheral edge.

12. A tank according to claim 10 in which the roofed shell has a peripheral edge with means to anchor the roofed shell to the floor of a body of water.

13. A tank according to claim 10 having a standpipe which is part of the hollow vessel and extends to above the level of the body of water when the tank is supported on the floor of the body of water.

14. A tank according to claim 10 in which the major volume of the hollow vessel is below the roofed shell.

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JACOB SHAPIRO, *Primary Examiner.*

U.S. Cl. X.R.

114—5; 220—1, 13