

[54] UNDERWATER OIL STORAGE TANK AND
METHOD OF SUBMERGING SAME

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abandoned.

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[58] Field of Search..... **61/46, 46.5, .5, 69 R;
114/.5 T, .5 D; 220/18**

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Primary Examiner—W. C. Reynolds

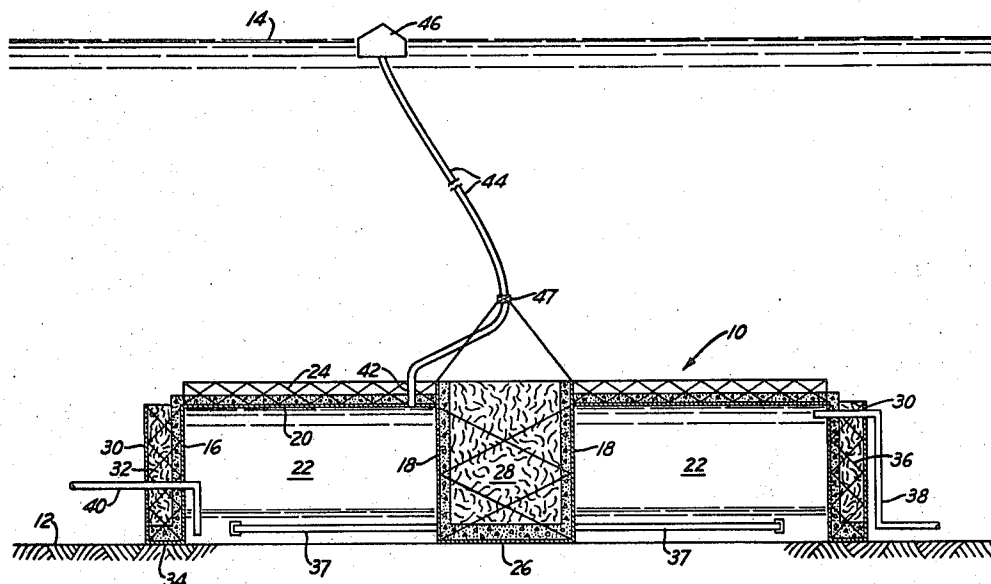
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[57] **ABSTRACT**

A submerged tank for location on the sea bottom has upwardly opening ballast chambers. The ballast chambers have a bottom member that rests directly on the sea bottom. The storage tank is open to the entrance of water into the lower portion of the storage compartment of the tank from the surrounding waters whereby pressure within the tank and in the surrounding water is substantially equal. In a preferred embodiment the tank is of annular shape with a central ballast chamber and an outer ballast chamber surrounding the storage compartment.

The tank is filled with a liquid of lower density than sea water to give it sufficient buoyancy to be floated to the desired site and is sunk at the site by displacement of low density liquid with sea water. After location of the tank on the bottom, the ballast compartments are filled with ballast to secure the tank on the sea bottom.

7 Claims, 4 Drawing Figures



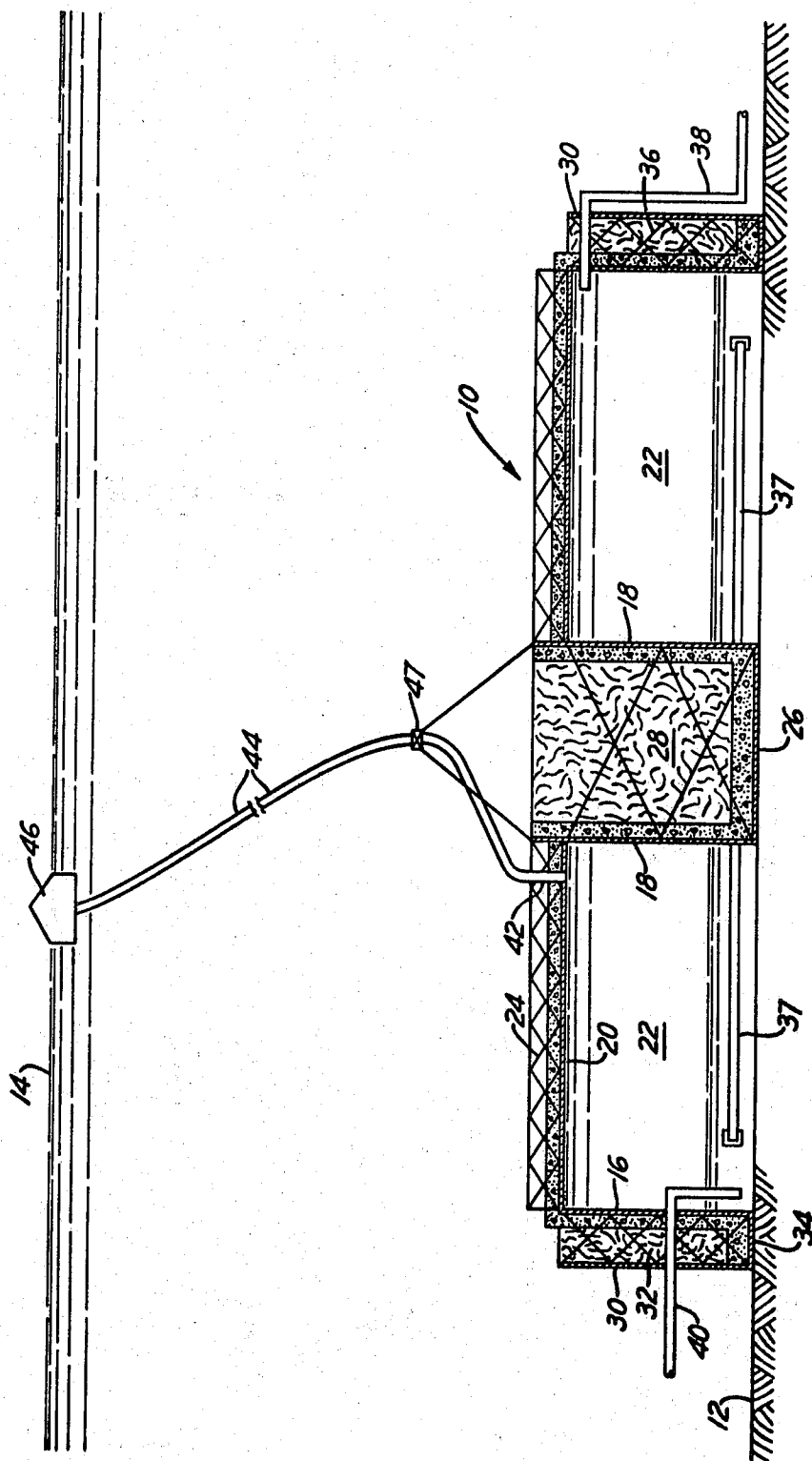
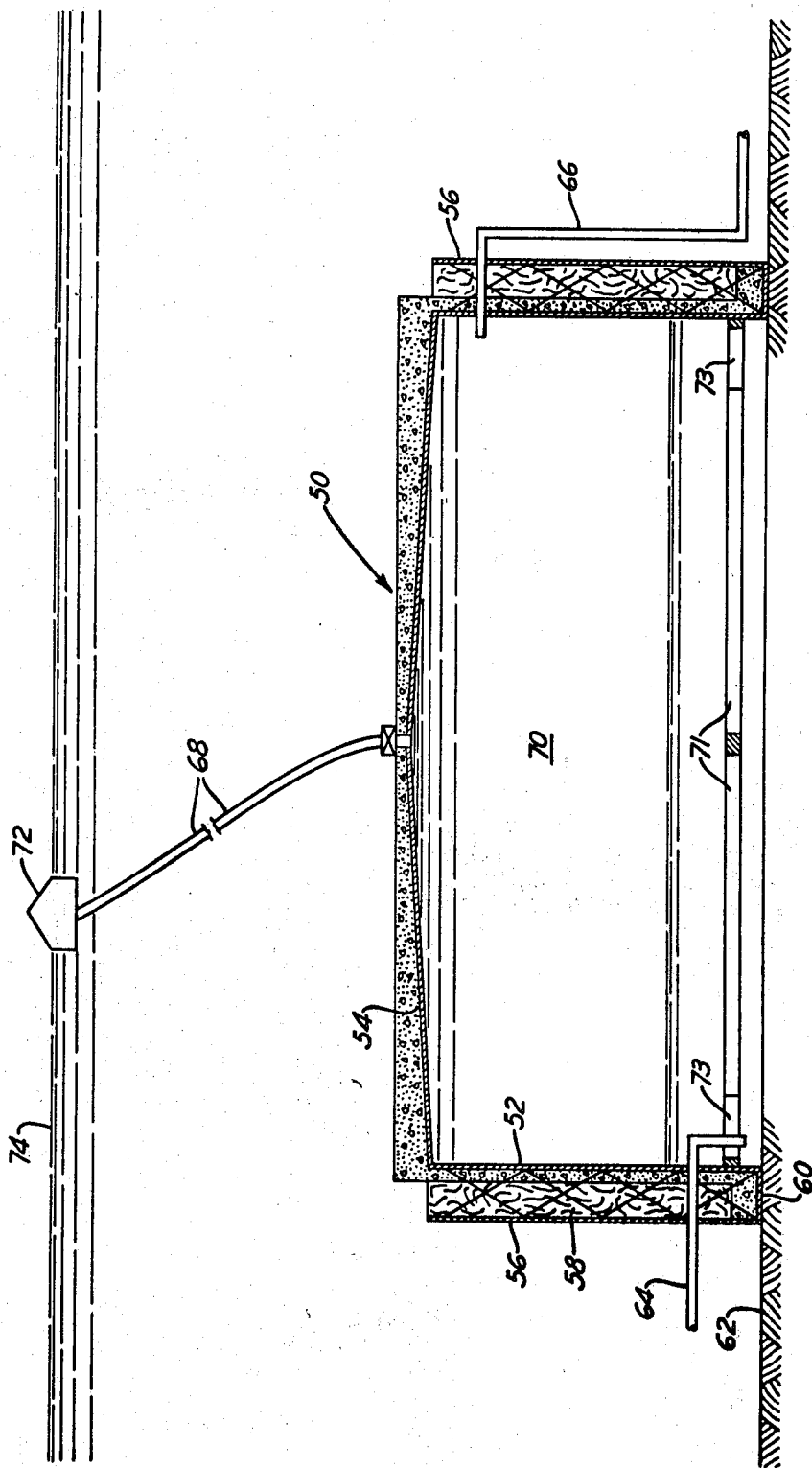
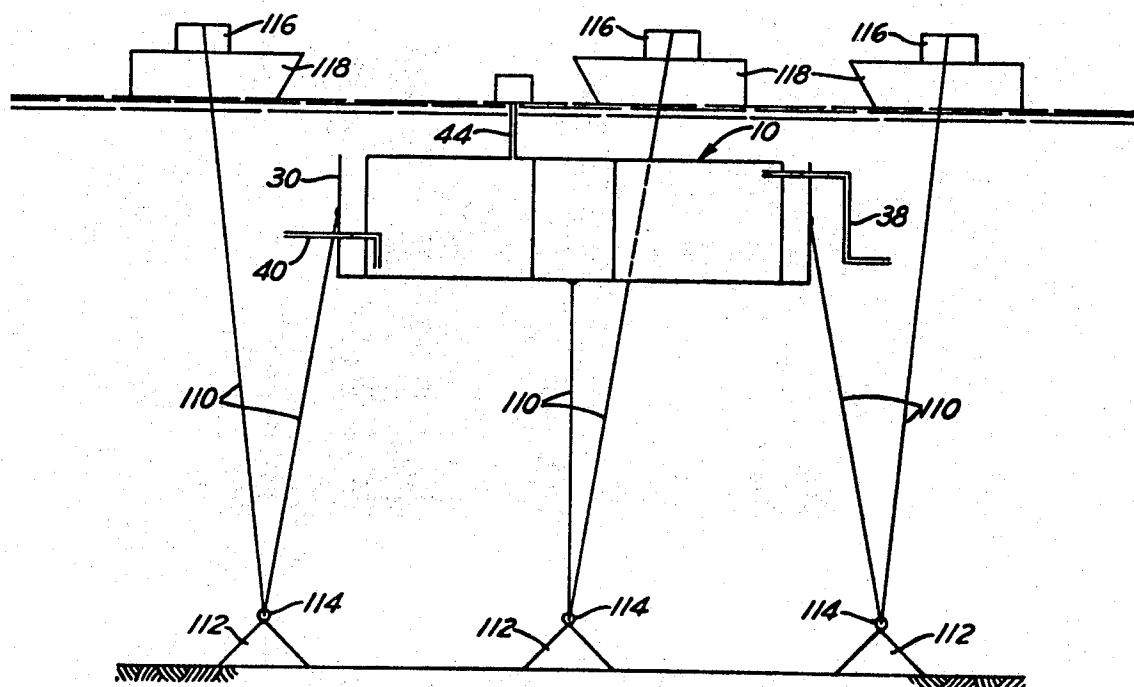
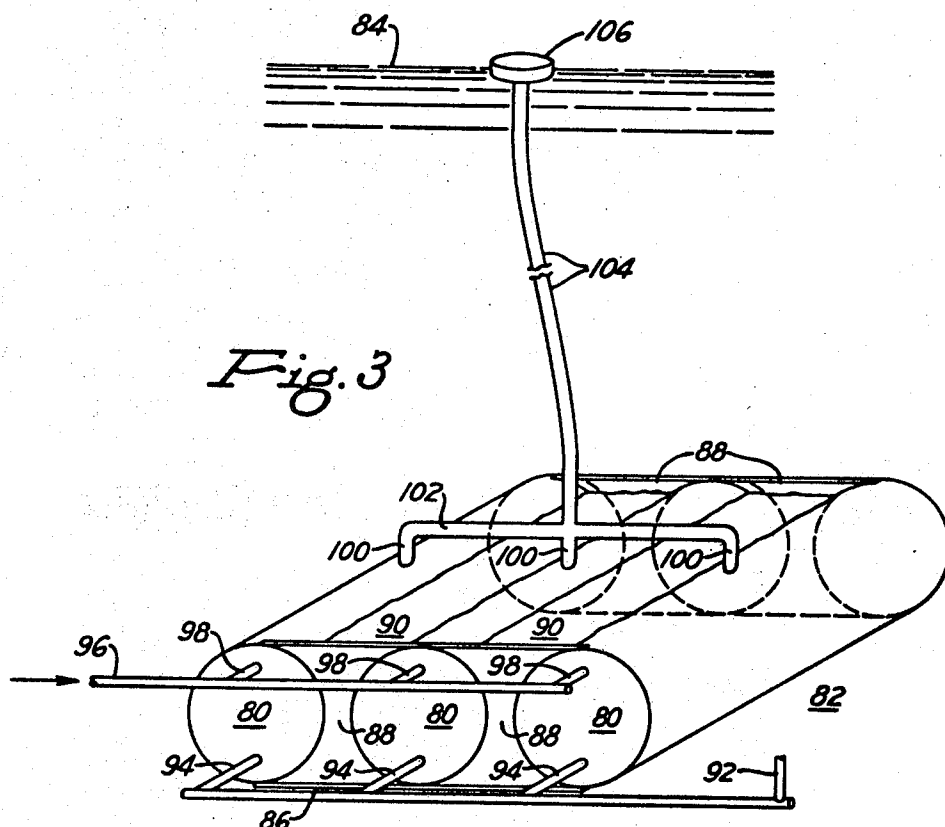


Fig. 1



SHEET 3 OF 3



UNDERWATER OIL STORAGE TANK AND METHOD OF SUBMERGING SAME

This is a continuation of application Ser. No. 152,715, filed June 14, 1971, now abandoned.

This invention relates to the storage of oil and more particularly to a submerged storage tank for offshore locations and a method of lowering the storage tank onto the sea bottom.

A large part of the oil consumed in the world is now produced at offshore wells. It can be expected that the percentage of oil produced from offshore locations will increase in the future because many of the most promising onshore locations have already been thoroughly explored. As offshore exploration and drilling continues, wells will be drilled at increasing distances from the shore and in water of increasing depth. Delivery of oil produced by the wells will, therefore, become more difficult. A pipeline from each production platform to the shore is prohibitively expensive, and production platforms are not large enough for supporting tanks of adequate volume on the production platforms. Moreover as the depth of water in which wells are drilled increases, the cost of production platforms will become excessive and wellhead assemblies will be located close to the sea bottom.

One method of storing oil that has been suggested is in floating storage tanks, which may be of either rigid or flexible construction. Such tanks would be exposed to violent wave action during storms and consequently could cause serious oil spills. The most promising method of handling production for offshore wells in deep water and at substantial distances from shore appears to be to deliver the oil into submerged tanks resting on the sea floor. The tanks will necessarily be of large capacity to permit continued operation of the wells between loadings of tankers which will take the oil from the submerged storage tanks for delivery to onshore sites.

Because most oil is substantially less dense than sea water, difficulty is experienced in holding storage tanks securely on bottom when the tank is filled with oil. One method that has been suggested is to sink the storage vessel onto the bottom and secure the vessel on bottom with piling. Filling the storage tank with oil and then displacing the oil from the tank with sea water causes an alternate upward and downward force on the piling. Continued reversals of the direction of the force on the piling tends to loosen the piling.

It has been suggested that storage tanks for use under water be made of concrete and have sufficient weight as constructed to overcome the buoyant force exerted by oil when the tank is filled with oil. Tanks of large volumetric capacity and heavy enough to overcome the buoyancy resulting from the oil are expensive both to construct and to move and install at the desired location. It is usually necessary to fill such tanks with air to give them sufficient buoyancy to be floated to the offshore site. The increase in density of the air within a tank caused by the increase in pressure as it is sunk causes an increase in the negative buoyancy of the tank unless additional air is introduced into the tank at a controlled rate to compensate for the reduction in unit volume of the air. Such close control of the buoyancy of an air-filled tank is difficult.

This invention resides in an underwater storage tank and a method of anchoring a tank on the sea bottom in which the storage tank has a storage compartment

open at its bottom and upwardly opening confined spaces outside of the storage compartment for receiving ballast after the tank is on the sea bottom. The storage compartment is open to sea water at its lower end to equalize the pressure inside and outside of the storage tank. The storage tank is filled with a liquid having a lower density than sea water to provide a structure with a positive buoyancy that can be floated to the offshore site. Part of the low density liquid is displaced from the storage tank with sea water to sink the structure onto the sea bottom. The upwardly opening confined spaces are then filled with ballast material, preferably sea bottom solids, in an amount adequate to hold the tank securely on bottom when the tank is filled with oil. A delivery line from the upper end of the storage tank extends to the water surface and is supported by a suitable float.

In the drawings:

FIG. 1 is a diagrammatic vertical sectional view of a preferred storage tank of annular shape, constructed in accordance with this invention.

FIG. 2 is a diagrammatic vertical sectional view of a vertical cylindrical storage tank.

FIG. 3 is a perspective view of a bank of horizontal cylindrical tanks utilizing this invention.

FIG. 4 is a diagrammatic view of a tank utilizing this invention being lowered while stabilized by cables from barges.

Referring to FIG. 1, an underwater tank constructed in accordance with this invention and indicated generally by reference numeral 10 is illustrated resting on the sea bottom 12 well below the water surface 14. Storage tank 10 is of vertical annular configuration with a vertical cylindrical outer wall 16 concentrically surrounding a vertical cylindrical inner wall 18. A top 20 extends from the upper end of inner wall 18 to the upper end of outer wall 16 to close the upper end of storage tank 10 and combine with the inner and outer walls to define a storage compartment 22 within the tank. Suitable bracing 24 across the top of the tank aids in supporting top 20.

A circular bottom member 26 secured to the lower end of the inner wall 18 closes the lower end of a centrally located upwardly opening cylindrical bin 22 adapted to receive ballast, as hereinafter described, to aid in holding the storage tank on the sea bottom 12. Encircling and spaced from outer wall 16 is a cylindrical retainer wall 30. The spacing of retainer wall 30 from outer wall 16 will depend on the size of the storage tank 10 and ballast bin 28. For example, in a storage tank having a capacity of approximately 200,000 barrels the diameter of the tank could be 200 feet, the diameter of the bin 28 40 feet, and the height of the tank 40 feet. The space between outer wall 16 and retainer wall 30 would then be 10 feet to provide a ballast chamber 32 between the retainer wall 30 and the outer wall 16 which would overcome the buoyancy of the tank when the tank is filled with oil. The height of retainer wall 30 is preferably the same as storage tank 10; however, the retainer wall 30 can be lower in which event it may be necessary to increase the distance between the retainer wall and the outer wall to provide a ballast bin 32 of sufficient volume. An annular bottom plate 34 extends from the lower end of outer wall 16 to the lower end of retainer wall 30 and is secured to those walls to close the lower end of the ballast chamber 32. It is preferred that suitable bracing 36 be provided be-

tween retainer wall 30 and outer wall 16 to stiffen the storage tank structure. The lower end of the storage compartment 22 is open, but it can be provided with framework indicated by reference numeral 37 to increase the rigidity of the storage tank.

In the storage tank illustrated in FIG. 1 of the drawings, the lower end of ballast chamber 32 and ballast bin 28 have been filled to a depth, for example one foot, with concrete; and the outer wall 16, inner wall 18, and top 20 have been coated with concrete to a thickness, for example, of six inches. The concrete coating reduces the buoyancy of the storage tank, stiffens the structure, and reduces corrosion of the steel walls of the tank.

Storage tank 10 is provided with an oil inlet line 38, preferably opening into the upper part of storage compartment 22. Oil inlet line 38 may be connected directly to wells completed on the sea bottom or may be connected to production facilities supported on a production platform located either above or under the water surface. A sea water exchange line 40 extends through retainer wall 30, ballast chamber 32, and outer wall 16 and opens into the lower part of the storage compartment 22. Sea water exchange line 40 is open to provide equalization of pressure between the inside and outside of the storage tank and allow entry of sea water to displace oil from the storage tank or outflow of sea water as oil is delivered through inlet line 38 into the storage compartment 22.

An oil outlet 42 opens through top 20 and is connected to a flexible oil delivery line 44. A suitable bridle 47 limits movement of delivery line 44. The upper end of delivery line 44 is supported at the water surface 14 by a float 46 and is provided with valves as required for control of the flow of oil delivery from the storage tank 10.

Storage tank 10 is constructed, preferably of light weight steel, at a graving dock. Because there is substantially no pressure differential between the inside and outside of the storage tank at any time during the floating, sinking, or use of the tank, the tank can be constructed of steel approximately 1/4 inch thick. The lower end of the ballast bin 28 and the ballast chamber 32 are partially filled with concrete; and the outer wall 16, inner wall 18, and top 20 are coated with concrete as described above to increase the rigidity and reduce the buoyancy of the tank. The addition of concrete into the lower ends of the ballast compartment 32 and ballast bin 28 and the coating of the outer surfaces with concrete are preferred but are not essential to this invention. Tank 10 is then floated by delivering water into the graving dock. After the tank is lifted from the bottom of the graving dock, an oil, preferably an oil having an API gravity of 30° (density of 7.300 pounds per gallon) or less, is used to displace air from the storage tank and thereby reduce the buoyancy of the tank. In a steel tank of annular shape having a capacity of approximately 200,000 barrels as described hereinbefore, filling the tank with an oil having a gravity of 30° API oil will result in a net buoyancy of about 4,700 tons when the tank is floating in sea water. Filling the lower portion of bin 28 and chamber 32 and coating the walls and roof of the tank adds approximately 3,443 tons of concrete, which have a net weight of about 2,220 tons in sea water, and reduces the net buoyancy to approximately 2,480 tons.

The floating tank is towed to the site and sunk to the desired location by allowing sea water to displace oil from the tank into a barge or tanker to reduce the buoyancy of the tank until it will slowly sink onto the sea bottom. Oil inlet line 38 and delivery line 44 are closed while the tank is towed to the offshore location, and oil inlet line remains closed as the tank is sunk onto the sea bottom. Guide and stability assistance, during lowering, may be obtained by cables from a floating vessel to the tank during the lowering period.

Because the oil is incompressible, there is no effective change in the density of the oil as the tank sinks and hence no change in its negative buoyancy. In contrast, if the tank is filled with air to supply sufficient buoyancy to float the tank to the offshore site, as is required if the tank has sufficient weight as constructed to remain on the bottom when filled with oil, the air is compressed as the tank sinks and the negative buoyancy of the tank rapidly increases. It is then necessary to deliver compressed air into the tank at a controlled rate to prevent the tank's plunging to the bottom. Moreover, open-bottomed tanks filled with air suffer a large and rapid loss of buoyancy if they should tilt and burp while being floated to the site or sunk on bottom.

Although oil has been described as a liquid supplying the buoyancy necessary to float the tank, other liquids can be used. For example, if sea water can be introduced into the graving dock to float the tank, fresh water can be introduced into the storage compartment 22. The difference in density of the fresh water and the sea water will provide sufficient buoyancy to float the tank.

Cable assist may be used in lowering the tank to the sea bottom, depending upon the size and shape of the tank. This may be by pull-down cables from floating vessels through tie down pulleys anchored on the sea bottom. In this case a slight positive buoyancy would be maintained in the tank until it was on or near bottom at which time a negative buoyancy would be attained by change in the oil-water ratio in the tank. The advantage of an unchanging buoyancy of the tank while it is lowered onto the bottom resulting from using a low density liquid to supply the desired buoyancy is also advantageous in the cable assist method of lowering.

Referring to FIG. 4, storage tank 10 is shown diagrammatically with cables 110 attached at intervals around the retainer wall 30. Cables 110 extend downwardly to anchors 112 which can be of the type described in my U.S. Pat. No. 3,431,879. The cables 110 pass through a sheave 114 on the upper end of the anchors and extend upwardly to winches 116 mounted on barges 118. In sinking the storage tank onto the bottom 12, the anchors 112 are lowered from barges 118 by means of cables 110 to rest on the sea bottom 12 around the desired site of the storage tank 10. Anchors 112 are then filled with bottom material if they are of the type disclosed in U.S. Pat. No. 3,431,879. The free ends of the cables are attached to the wall 30 of the tank 10. Oil is displaced from the tank until the tank has a slight positive buoyancy and then the cables 110 are pulled up by the winches 116 on the barges 118 to pull the tank 10 into place on the bottom. Additional oil is taken from the tank to give it a negative buoyancy and ballast is placed in the ballast bins to hold the tank securely on the sea bottom. Divers can be lowered to disconnect cables 110 to allow them and anchors 112

to be recovered or to secure the cables to the anchors if the anchors are to be left in place to further secure the tank against movement by bottom current.

In the apparatus illustrated in FIG. 2 of the drawings, a submerged storage tank, indicated generally by reference numeral 50, differing from storage tank 10 only in the omission of the centrally located ballast bin that is provided in storage tank 10, has a vertical cylindrical outer wall 52 closed at its upper end by conical top 54. A retainer wall 56 encircles the outer wall 52 and is spaced from that wall a distance providing a ballast chamber 58 having a volume that will hold an adequate weight of ballast material to hold the tank on bottom when filled with oil. The lower end of the ballast chamber 58 is closed by a bottom member 60 joining the lower ends of retainer wall 56 and outer wall 52. Bottom member 60 rests on the ocean bottom 62.

Storage tank 50 is provided with a sea water exchange line 64, an oil inlet 66, and an oil delivery line 68 opening into the storage compartment 70 defined by outer walls 52 and top 54. As in the embodiment of the invention illustrated in FIG. 1, there is no bottom closure for the storage compartment 70. Open framework, shown diagrammatically as a plurality of beams 71 extending radially from the center of the tank to a ring 73 secured to the inner surface of wall 52, stiffens the tank. The upper end of oil delivery line 68 is connected to a float 72 at the water surface 74. Submerged tank 50 is illustrated with concrete coating installed similarly to the concrete on storage tank 10. The manner of construction, transportation to the site, and sinking of storage tank 50 at the offshore site is the same for tank 50 as tank 10.

Referring to FIG. 3 of the drawings, a battery of three horizontal cylindrical tanks 80 is shown located on the sea bottom 82, a substantial distance below the water surface 84. Horizontal tanks 80 are arranged with their longitudinal axes parallel and are spaced apart to provide a space between the outer walls of the middle tank and the walls of the outer tanks. A bottom plate 86 closes the lower end of the space between the tanks 80, and end plates 88 close the ends of the spaces between the tanks to provide upwardly opening chambers 90 between the tanks for the reception of ballast material. A sea water exchange line 92 serves as a header with lateral lines 94 opening into the lower part of each of the tanks 80. Similarly, an oil inlet line 96 extends across one end of the tanks and is provided with lateral inlet lines 98 opening into the upper portion of each of tanks 80. Inlet line 96 is connected with wells or other production equipment for delivery of oil into the tanks 80. Oil outlet line 100 opens from the upper portion of each of tanks 80 near the center thereof and is connected through a manifold 102 to an oil delivery line 104. The upper end of oil delivery line 104 is supported on the water surface by a float 106.

As in the other embodiment of this invention, tanks 80 can be constructed and assembled at a graving dock with the bottom plate 86 and end plates 88 secured to the tanks 80 tanks 80 filled with a liquid of lower density than sea water, the graving dock filled with sea water, and the assembled tanks floated from the dock and towed to the offshore site. It will be necessary, of course, to provide suitable closures for oil inlet line 96 and oil delivery line 104 to prevent displacement of oil from the tanks as the tanks are moved to the offshore location. Tanks 80 are sunk onto bottom by opening oil

delivery line 104 to allow sea water to displace the liquid of low density from the tanks until the tanks have a slightly negative buoyancy. After tanks 80 have been sunk onto the sea bottom, the upwardly opening space defined by the walls of tanks 80 and the end plates 88 are filled with suitable ballast material, preferably sea bottom material, in an amount that will hold the tanks securely on the sea bottom even when the tanks are completely filled with oil.

Although this invention has been described for tanks constructed of light weight steel, it is not limited to such material of construction. Similar savings can be made in tanks constructed of concrete. If this invention is employed in the construction of concrete storage tanks for sea bottom sites, it is necessary only to provide concrete thickness adequate to supply the strength required by the storage tank, not of a thickness that will give the tanks sufficient weight to hold them on bottom. Since it is contemplated that the tank will be of open bottom construction, i.e., means are provided for free flow sea water into the lower portion of the tank as the volume of oil storage in the tank is changed, relatively light weight construction is required regardless of whether the tank is constructed of concrete or steel. The installation of ballast adequate to hold the tank on bottom when the tank is filled with oil after the tank has been located on bottom permits a very large reduction in the weight of the storage tank and greatly facilitates its construction and handling in moving to the offshore site.

An advantage of the storage tanks of this invention is that the bottoms of the ballast chambers or ballast bins rest directly on the sea bottom. Such structure is important in further reducing the steel required for the tanks by eliminating the structural supports that would be required if the ballast were placed on surfaces, such as the roof of the storage compartment, spaced above the sea bottom.

As an example of the weight saving of the storage tank structure that is made possible by this invention, assume a vertical annular tank of the type illustrated in FIG. 1 and having 200,000 barrel capacity is constructed having a outer diameter of 200 feet. The weight of 200,000 barrels of 30° API oil is 61,280,000 lbs., and the weight of the same volume of sea water is 71,860,000 lbs.; therefore the oil supplies a buoyant force of approximately 5,300 tons. The weight of the steel structure illustrated in FIG. 1 is about 500 net tons plus 100 tons of bracing, which gives a net buoyancy of the tank when filled with 30° API oil of 4,700 tons. Assuming a 37 percent safety factor to prevent movement of the tank by under water currents, an in-water weight of 7,250 tons would be required. Since the net weight of the steel is 600 tons, ballasting material having a net weight in sea water of 6,650 tons is required. Adding the ballast material before the tank is on bottom makes it necessary to handle a massive structure while floating the tank to the desired location and sinking in onto the sea bottom. Moreover, it would be necessary to use gas to supply the buoyancy required to float the tank to the site.

Coating the sides and top of the tank with 6 inches of concrete and filling the bin 28 and chamber 32 with concrete to a depth of 1 foot would add 3,443 tons of concrete to the steel tank structure. The net weight in sea water of 3,443 tons of concrete would be 2,220 tons. Thus, even after the addition of the concrete, a

storage tank filled with oil would have a buoyancy of 2,470 tons. Filling the remaining space in the bin 28 and chamber 32 with sea bottom material having a net weight of 36 lbs. per cubic foot in sea water would add 5,520 tons to the weight of the structure and provide a negative buoyancy of 2,780 tons which would be more than adequate to insure stability of the storage tank on the bottom.

As an additional example of the weight savings made possible if two horizontal cylindrical tanks 48 feet in diameter and 326 feet long are constructed of concrete to provide 200,000 barrels of capacity, it would be necessary for the tanks to have a wall thickness of 12 inches of concrete with top and bottom slabs 6 inches thick joining it to the tanks to provide a structure with sufficient weight to be stable on bottom when filled with 30° API oil. Utilizing this invention, the horizontal cylindrical tanks could be sunk onto the sea bottom when filled with liquid, only a portion of which is oil, such as a 30° API petroleum oil. The addition of ballast after the tanks are sunk on bottom allows the tanks to have only the wall thickness required to give the tanks the desired strength.

I claim:

1. A submerged storage tank for installation on the sea bottom at offshore locations to store oil having a lower density than sea water comprising a vertical outer wall enclosing a storage compartment, a top member extending across the top of the storage compartment and connected to the outer wall to close the upper end of the storage compartment, said storage compartment being open at its lower end, a retainer wall surrounding the vertical wall and spaced therefrom to cooperate with the vertical wall in defining an upwardly opening ballast chamber between the retainer wall and the outer wall, a bottom member connected to the lower end of the vertical wall and to the retainer wall closing the lower end of the ballast chamber, said bottom member positioned and adapted to rest on the sea bottom when the tank is sunk onto the offshore site, a sea water exchange line extending from outside of the retainer wall into the storage compartment and opening into the lower part of the storage compartment, an oil inlet line opening into the upper part of the storage compartment, and an oil delivery line extending from the top of the storage compartment upwardly to the water surface.

2. Apparatus as set forth in claim 1 in which the tank is of annular shape having a vertical inner wall within the outer wall, said top member extending from the inner wall to the outer wall to leave the space within the vertical inner wall opening upwardly to form a central ballast chamber, and a central bottom member connected to the lower end of the inner wall and extending across the lower end of the central ballast chamber.

3. Apparatus as set forth in claim 2 in which the inner and outer walls are cylindrical and the retainer wall surrounding the outer wall is of substantially the same

height as the outer wall.

4. A submerged storage tank as set forth in claim 1 in which the vertical outer wall, the top member, the retainer wall and the bottom member are constructed of steel and a layer of concrete extends over the upper surface of the bottom member, the outer surface of the vertical outer wall and the top member to increase the rigidity of the structure.

5. In a method of installing a submerged oil storage tank at an offshore location, said tank having upwardly opening ballast compartments outside of the storage compartment, the lower end of the storage compartment being open, the improvement comprising floating the tank on water, filling the storage compartment with oil to provide a buoyancy adequate to float the tank, floating the tank to the desired offshore site, displacing a portion of the oil from the tank with sea water to give the tank a slight negative buoyancy to sink the tank onto the sea bottom, and filling the ballast chambers with ballast material after the tank is on bottom and in an amount adequate to hold the tank on bottom when the tank is filled with oil.

6. In a method of installing a submerged oil storage tank at an offshore location, said tank having upwardly opening ballast compartments outside of the storage compartment, the lower end of the storage compartment being open, the improvement comprising floating the tank on water, filling the storage compartment with oil to provide a buoyancy adequate to float the tank, floating the tank to the desired offshore site, attaching cables at intervals around the periphery of the storage tank and running the cables to barges surrounding the storage tank, displacing oil from the tank with sea water until the tank has a slight negative buoyancy, sinking the tank onto the sea bottom while guiding the tank with the cables to maintain it in a horizontal position, filling the ballast chambers with ballast material after the tank is on bottom, and disconnecting the cables from the tank.

7. In a method of installing a submerged oil storage tank at an offshore location, said tank having upwardly opening ballast compartments outside of the storage compartment, the lower end of the storage compartment being open, the improvement comprising floating the tank on water, filling the storage compartment with oil to provide a buoyancy adequate to float the tank, floating the tank to the desired offshore site, sinking a plurality of anchors onto the sea bottom surrounding the desired site of the tank, running cables from the tank through sheaves on the anchors and to barges surrounding the tank, displacing oil from the tank with sea water until the tank has a slight positive buoyancy, taking up on the cables to pull the storage tank downwardly onto the sea bottom, and filling the ballast chamber with ballast material to anchor the storage tank on bottom.

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