

PATENT SPECIFICATION

(11) 1 232 097

DRAWINGS ATTACHED

1 232 097

- (21) Application No. 38908/68 (22) Filed 14 Aug. 1968
 (45) Complete Specification published 19 May 1971
 (51) International Classification E 02 d 29/00
 (52) Index at acceptance
 E1H 10X4
 (72) Inventors BEN CLIFFORD GERWICK
 CARL YATES FARRELL



(54) IMPROVEMENTS IN OR RELATING TO THE
 SUBAQUEOUS STORAGE OF A LIQUID SUCH AS OIL

(71) We, J. H. POMEROY & CO. INC.,
 a Corporation organized and existing under
 the laws of the State of Washington, United
 States of America, of 755 Sansome Street,
 5 San Francisco, State of California, United
 States of America, do hereby declare the
 invention, for which we pray that a patent
 may be granted to us, and the method by
 which it is to be performed, to be particu-
 10 larly described in and by the following
 statement:

This invention relates to a subaqueous
 storage tank, or tank assembly for liquid
 which has a density less than that of water.
 15 In off-shore petroleum oil mining oper-
 ations there is a need for intermediate stor-
 age facilities for accumulating oil at the site
 of the wells as it is recovered. Later, the oil
 can be transferred to a tank or vessel for
 20 removal to the refinery. Heretofore, facili-
 ties proposed for this purpose have been un-
 satisfactory because of complexity of con-
 struction and inability to resist damage in
 rough weather. Furthermore, such facilities
 25 have been criticised as unduly difficult to
 maintain and as permitting appreciable con-
 tamination of the stored oil with sea water
 and the compounds therein. There is there-
 fore a need for new and improved com-
 30 mercially feasible oil storage facilities.

According to the present invention there
 is provided a subaqueous storage tank for
 storing a liquid which has a density lower
 than that of water and which liquid is im-
 35 miscible with water, said storage tank com-
 prising a primary chamber for storing the
 liquid, said chamber being vertically un-
 interrupted, a first distribution chamber
 with means for connection to a liquid flow
 40 line, a first plurality of flow ducts connect-
 ing the first distribution chamber to the
 uppermost region of said primary chamber,
 a second distribution chamber with means
 for communicating with the body of water
 45 in which the tank is immersed, and a second

plurality of flow ducts connecting said sec-
 ond distribution chamber to the bottom of
 said primary chamber, so that, while the
 tank is in use, whenever said liquid enters
 of leaves the primary chamber through the 50
 first plurality of flow ducts an equal, or at
 least substantially equal, volume of water
 correspondingly leaves or enters the prim-
 ary chamber through the second plurality
 of flow ducts, the total flow cross-section of 55
 the first plurality of flow ducts and that of
 the second plurality of flow ducts being
 such that while the liquid is entering or leav-
 ing the primary chamber as aforesaid the
 velocity of flow of liquid and water in the 60
 respective ducts is sufficiently low to main-
 tain a substantially undisturbed interface
 between the liquid and the water within the
 primary chamber.

The liquid to be stored may be petroleum 65
 oil and the body of water may be the sea.

According to the present invention there
 is further provided a large volume storage
 tank assembly comprising at least one stor-
 age tank as previously described. 70

The invention will now be described by
 way of example with reference to the accom-
 panying drawings in which:

Figure 1 is a plan view of an underwater
 large volume storage assembly with certain 75
 portions thereof shown in section.

Figure 2 is a sectional view of the stor-
 age facility shown in Figure 1 taken along
 the lines 2-2.

Figure 3 is end view of a single tank with- 80
 in the storage facility of Figure 1 taken
 along the lines 3-3.

Figure 4 is a transverse cross-sectional
 view of a single tank of the storage assembly
 of FIGURE 1 taken along the lines 4-4, 85
 the left half showing the reinforcement de-
 tails, and the right half showing the pre-
 stressing details.

FIGURE 5 is an elevational view in sec-
 tion, partially broken away, of one of the 90

[Price 25p]

tanks shown in FIGURE 1 taken along the lines 5-5.

FIGURE 6 is a plan view in section, partially broken away, of the tank taken along the lines 6-6 of FIGURE 5.

FIGURE 7 is an elevational view in section, partially broken away showing a modified form of piping interconnection to the tank.

Referring to FIGURES 1 and 2, there is shown an oil storage facility and consisting of a plurality of underwater tanks 10 interconnected through suitable piping 11 to a pumping and control station 12. Pumping station 12 is connected to an oil field through a supply line 13 and to moored tankers (not shown) through piping 14 and is fitted out with suitable pumps for moving oil to and from tanks 10. As shown, the tanks 10 are submerged so that they rest on the floor 16 below the body of water while the pumping station extends upwardly and is provided with a control room 17 above the water line.

Each of tanks 10 is identical, and, as shown in FIGURE 4, is also symmetrical about a center plane either vertically or horizontally dividing the tank into halves. Thus, in the following description only the half portion of the tank on one side of the vertical plane aforesaid will be completely described, since the other side is the same in character and function.

Referring to FIGURES 3 to 6, the tank 10 of the invention is shown in detail and consists of a pair of side by side cylindrical shells 21, 22 arranged external to each other and joined together along an elongate region lying at the tangent plane between and common to each of the shells. Cylindrical shells 21, 22 are formed of circularly cylindrical lateral walls 24, 25 of concrete having a substantial thickness and intersecting each other to form a common wall 23. Each of walls 24, 25 is reinforced by circumferentially wrapped inner and outer circular or helical strands 26a, 27b interconnected by longitudinally extending strands 27a, 27b. Radially extending strands 28 serve to tie together the circumferential strands 26a, 26b from each of the walls 24, 25 in the common wall 23. Radially extending strands 29a, 29b tie other elements of the structure together as hereinafter described.

Transversely extending end walls 31 and 32 close the ends of the cylindrical shells and are connected therewith to form a unitary structure. Each of the cylindrical shells 24, 25 is subdivided by a transversely extending circular bulkheads 33, 34 which are also constructed as a unit with the remainder of the structure. Walls 33, 34 are of a sufficient number to adequately support the midregions of the tank and form within each shell chambers 36, 37, 38 which serve as primary chambers for storing oil.

Upper and lower planar tangent walls 41, 42 are joined to the outside surfaces of such lateral walls 24, 25 to form upper and lower distribution chambers 43, 44 having substantially triangular cross section, as shown. Distribution chambers 43, 44 extend the entire length of the tank and are therefore neither vertically nor horizontally interrupted. Suitable reinforcing strands 46 extends transversely of the walls 41, 42 and is interconnected with reinforcing strands 29, hereinbefore mentioned, to provide unity of structure between the walls 41, 42 and lateral walls 24, 25.

Walls 24, 25, 41, 42 are appropriately prestressed. Thus, longitudinal post-tensioning tendons 47 extend the length of the lateral walls 24, 25, and, transversely extending post-tensioning tendons 48 extend across walls 41, 42 and are anchored into a suitable means 49 affixed at their lateral boundaries.

A plurality of ducts 51 connect the upper distribution chamber 43 with each of the storage chambers 36, 37, 38 which are connected by a second plurality of ducts 58 to the lower distribution chamber 44. The plurality of ducts 51 have a combined flow cross section significantly larger than the flow cross section of the oil line connected to the distribution chamber as will be hereinafter described. As shown, particularly in FIGURE 4, the uppermost region 52 of primary storage chamber 37 is located at a height slightly below the uppermost region 54 of the distribution chamber 43. The distribution ducts 51 pass through the lateral walls and connect regions 52 and 54 such that the duct continuously rises from region 52 to region 54.

Likewise, the lowermost regions 56 of chambers 36, 37, 38 lie slightly above the lowermost region 57 of the lower distribution chamber 44. Thus, ducts 58 pass through the cylindrical lateral walls and continuously descend from region 56 to region 57. The slope of ducts 51 and 58 is approximately 12 degrees.

Ducts 51 permit gas evolved within primary storage chambers 36, 37, 38 to rise and pass through such ducts into region 54. A gas escape duct 59 is formed through wall 41 and passes from the region 54 to the exterior of the storage tank. This duct is fitted with a suitable valve means 60 for permitting gas to escape from the distribution chamber while retaining the liquid oil therein. An example of such suitable valve means consists of a pressure relief valve connected in series with a check valve so that when the liquid level falls below a predetermined level the check valve opens and the differential pressure across the relief valve causes the latter to open and permit release of the evolved gases.

All interior surfaces of the tank are coated with an impervious coating such as an epoxy resin.

Ducts 58 permit exchange of fluid between chambers 36, 37, 38 and distribution chamber 44 and also permit particulate matter and silt which settles to the bottom of the primary storage chambers to be easily washed out. To facilitate washing out such settled materials, there is provided a longitudinally extending pipe 61 along region 56. Pipe 61 extends the full length of the tank and passes through bulkheads 33, 34 and end wall 31. Pipe 61 is provided with a plurality of holes 62 spaced therealong which are arranged to direct streams of water, supplied through the pipe, toward the lower entrance ducts 58 and through the region 56 to thereby flush out region 56. In this manner, settled material is swept into ducts 58 and region 57 from which it can be removed through a gate 64 located at each end of the distribution chamber 44 adjacent region 57. Gate 64 is sufficiently large to permit sludge removal from the chamber. The upper wall 41 is provided with a series of manholes and covers 66 therein for permitting access to any of chambers 36, 37, 38 and another series of manholes 67 for entering the distribution chamber 43 through wall 41. Furthermore, chamber 43

is provided with gates at each end thereof in end walls 31, 32 for permitting removal of accumulated deposits and sludge therein.

As shown in FIGURE 1, a plurality of the above-described tanks are positioned in a row such that their ends 31 face in a common direction, which preferably is more or less aligned with the direction of prevailing currents of the body of water in which they are located. Each of the storage tanks is connected to a large diameter intake-discharge line 71 by a somewhat smaller diameter pipe 72 through a valve 73. As shown, particularly in FIGURES 5 and 6, the piping system 11 is supported by trusses 74 secured to and extending between opposed tanks 10. The pipe 71 is supported at the midspan of truss 74.

The lower distribution chamber is connected to water inlet pipes 76 each having a branch 77 therein connected through valve 78 to a water filter 79 and to water outlet pipes 80. Each of pipes 61 pass through wall 31 and is connected through a suitable valve 81 to a water feed line under high pressure for the purposes hereinbefore described.

To illustrate the practice of the invention, the following are indicated as typical dimensions for the components used for each tank assembly:

PIPING:

Pipe 71 - 40 inches; pipe 72 - 30 inches; pipe 76 - 24 inches.

STORAGE TANK:

Overall length — 325 feet; length per chamber 36, 37, 38 — 105 feet; interior diameter of each primary chamber — 48 feet; exterior wall thickness — 2-1/2 feet; ducts 51 and 58 — 9 inches in diameter. For these dimensions the effective storage limit of the tank is 42 feet i.e. the distance between lines 86 and 87; bulkhead thickness of bulkheads 33, 34 — 30 inches.

The organization and operation of a tank assembly will now be described. Each of the storage tanks 10 of the invention is conveniently constructed in a suitable dry dock facility and subsequently floated and towed to the site. It is found that the configuration in which they are formed is exceedingly convenient in rendering the tank stable under tow, even in rough waters. At the site of the underwater storage facility, the tanks are positioned by suitable mooring lines or other means and are then submerged by being flooded with water. In this connection, the use of a plurality (at least two) of side by side right circular cylindrical shells joined together to form a tank possesses numerous advantages over other tanks. By using the cylinder as a structural shape the tank is strong in resisting bending loads and in resisting transverse loads in true com-

pression so that it can be conveniently made of concrete. Moreover, the strength of the tank permits it to be positioned and used on an uneven sea bottom without having it break-up. It also is sufficiently strong that the tank can be refloated and recovered from the sea bottom for placement elsewhere.

After the desired number of tanks has been submerged to form the capacity of the assembly, the tanks are connected through piping 72 to the line 71 and to pumping station 12. Each of the valves controlling the opening and closing of the various lines are the remote type and are operatively connected to suitable controls in control station 12. Thus, to fill one of tanks 10 with oil, the valves 73, 78 of that tank selectively opened so that oil is pumped into upper distribution chamber 43 and through ducts 51 in sufficient volume and pressure to displace

the water of the primary storage chambers 36, 37, 38. This displaced water is simultaneously forced out through lower ducts 58 and discharged through the water outlet pipes 80 attached to the distribution chamber 44. In so doing, an oil-above-water interface is created within the primary storage chambers 36, 37, 38, the liquid oil and water therein maintaining the chambers flow of liquid at approximately the pressure of the hydrostatic head at the level to which the tank is submerged. The upper distribution chamber 43 consequently receives high velocity oil from the oil lines 71, 72 and reduces the velocity of movement of such oil because of the higher flow cross section of the combined ducts 51. When the flow is reversed, ducts 58 serve the same purpose, i.e., permit high volume low velocity flow between the distribution chamber and the storage chamber. Thus, liquid entering the chambers 36, 37, 38 from the distribution chambers 43, 44 enters smoothly as a smoothly flowing stream without causing turbulence or intermixing of the oil and water with consequent contamination of the oil with components from the water phase. A like action occurs between the lower distribution chamber 44 due to the combined higher flow cross section of the lower ducts 58 compared to water inlet pipe 76. The effective storage limits of the tank are indicated by the broken lines 86 at the top and 87 at the bottom within the storage unit. In operation, as it is received from the field, oil is added to that in storage, causing the interface to drop from the upper mark 86 to the lower mark 87. In discharge, the oil is pumped out to tankers while permitting sea water to displace the same until the interface rises to mark 86. If desired, the difference in hydrostatic head of oil and water at the depth of submergence can be used as the driving force to discharge oil from the tank.

Thus, there has been provided a new and improved storage tank for the under water storage of petroleum oil which is especially effective in maintaining the petroleum oil uncontaminated while nevertheless using the water at the pressure of submergence to maintain the tank assembly full. In this way, the strength requirements of the assembly are substantially reduced as well as the cost of manufacturing it. Moreover, the assembly operates to transform a high flow, high velocity stream to a high flow, low velocity stream so that the petroleum oil, water, and interface therebetween are left relatively undisturbed as petroleum oil is added or removed from the assembly.

There is shown in Figure 7 a modified form of piping interconnection for use with the tank of the invention. Thus, where the tanks are to be positioned where they are

out of alignment or may get out of alignment, or for convenience of installation, the piping 72' can be made flexible as by using flexible armored rubber flexible hose or of a series of rigid pipes interconnected with flexible sleeves. As shown, the intake-discharge line 71' can be laid directly on the sea bottom and the trusses 74 eliminated.

WHAT WE CLAIM IS:—

1. A subaqueous storage tank for storing a liquid which has a density lower than that of water and which liquid is immiscible with water, said storage tank comprising a primary chamber for storing the liquid, said chamber being vertically uninterrupted, a first distribution chamber with means for connection to a liquid flow line, a first plurality of flow ducts connecting the first distribution chamber to the uppermost region of said primary chamber, a second distribution chamber with means for communicating with the body of water in which the tank is immersed, and a second plurality of flow ducts connecting said second distribution chamber to the bottom of said primary chamber, so that, while the tank is in use, whenever said liquid enters or leaves the primary chamber through the first plurality of flow ducts an equal, or at least substantially equal, volume of water correspondingly leaves or enters the primary chamber through the second plurality of flow ducts, the total flow cross-section of the first plurality of flow ducts and that of the second plurality of flow ducts being such that while the liquid is entering or leaving the primary chamber as aforesaid the velocity of flow of liquid and water in the respective ducts is sufficiently low to maintain a substantially undisturbed interface between the liquid and the water within the primary chamber.

2. A tank as claimed in claim 1, wherein the upper inner boundary of the primary chamber is lower than the upper inner boundary of the upper distribution chamber and the flow ducts therebetween are arranged so that gas evolved within the primary chamber rises and passes through such ducts to accumulate in an upper region of the upper distribution chamber, and further including gas release means connected into said upper distribution chamber for releasing accumulated gas therefrom.

3. A tank as claimed in claim 2, wherein further the lower inner boundary of the primary chamber is higher than the lower inner boundary of the lower distribution chamber and the flow ducts therebetween are arranged so that any solid matter which settles to the bottom of the primary chamber can be easily washed out through such ducts.

4. A tank as claimed in any of the preceding claims wherein the first and second

the water of the primary storage chambers 36, 37, 38. This displaced water is simultaneously forced out through lower ducts 58 and discharged through the water outlet pipes 80 attached to the distribution chamber 44. In so doing, an oil-above-water interface is created within the primary storage chambers 36, 37, 38, the liquid oil and water therein maintaining the chambers flow of liquid at approximately the pressure of the hydrostatic head at the level to which the tank is submerged. The upper distribution chamber 43 consequently receives high velocity oil from the oil lines 71, 72 and reduces the velocity of movement of such oil because of the higher flow cross section of the combined ducts 51. When the flow is reversed, ducts 58 serve the same purpose, i.e., permit high volume low velocity flow between the distribution chamber and the storage chamber. Thus, liquid entering the chambers 36, 37, 38 from the distribution chambers 43, 44 enters smoothly as a smoothly flowing stream without causing turbulence or intermixing of the oil and water with consequent contamination of the oil with components from the water phase. A like action occurs between the lower distribution chamber 44 due to the combined higher flow cross section of the lower ducts 58 compared to water inlet pipe 76. The effective storage limits of the tank are indicated by the broken lines 86 at the top and 87 at the bottom within the storage unit. In operation, as it is received from the field, oil is added to that in storage, causing the interface to drop from the upper mark 86 to the lower mark 87. In discharge, the oil is pumped out to tankers while permitting sea water to displace the same until the interface rises to mark 86. If desired, the difference in hydrostatic head of oil and water at the depth of submergence can be used as the driving force to discharge oil from the tank.

Thus, there has been provided a new and improved storage tank for the under water storage of petroleum oil which is especially effective in maintaining the petroleum oil uncontaminated while nevertheless using the water at the pressure of submergence to maintain the tank assembly full. In this way, the strength requirements of the assembly are substantially reduced as well as the cost of manufacturing it. Moreover, the assembly operates to transform a high flow, high velocity stream to a high flow, low velocity stream so that the petroleum oil, water, and interface therebetween are left relatively undisturbed as petroleum oil is added or removed from the assembly.

There is shown in Figure 7 a modified form of piping interconnection for use with the tank of the invention. Thus, where the tanks are to be positioned where they are

out of alignment or may get out of alignment, or for convenience of installation, the piping 72' can be made flexible as by using flexible armored rubber flexible hose or of a series of rigid pipes interconnected with flexible sleeves. As shown, the intake-discharge line 71' can be laid directly on the sea bottom and the trusses 74 eliminated.

WHAT WE CLAIM IS:—

1. A subaqueous storage tank for storing a liquid which has a density lower than that of water and which liquid is immiscible with water, said storage tank comprising a primary chamber for storing the liquid, said chamber being vertically uninterrupted, a first distribution chamber with means for connection to a liquid flow line, a first plurality of flow ducts connecting the first distribution chamber to the uppermost region of said primary chamber, a second distribution chamber with means for communicating with the body of water in which the tank is immersed, and a second plurality of flow ducts connecting said second distribution chamber to the bottom of said primary chamber, so that, while the tank is in use, whenever said liquid enters or leaves the primary chamber through the first plurality of flow ducts an equal, or at least substantially equal, volume of water correspondingly leaves or enters the primary chamber through the second plurality of flow ducts, the total flow cross-section of the first plurality of flow ducts and that of the second plurality of flow ducts being such that while the liquid is entering or leaving the primary chamber as aforesaid the velocity of flow of liquid and water in the respective ducts is sufficiently low to maintain a substantially undisturbed interface between the liquid and the water within the primary chamber.

2. A tank as claimed in claim 1, wherein the upper inner boundary of the primary chamber is lower than the upper inner boundary of the upper distribution chamber and the flow ducts therebetween are arranged so that gas evolved within the primary chamber rises and passes through such ducts to accumulate in an upper region of the upper distribution chamber, and further including gas release means connected into said upper distribution chamber for releasing accumulated gas therefrom.

3. A tank as claimed in claim 2, wherein further the lower inner boundary of the primary chamber is higher than the lower inner boundary of the lower distribution chamber and the flow ducts therebetween are arranged so that any solid matter which settles to the bottom of the primary chamber can be easily washed out through such ducts.

4. A tank as claimed in any of the preceding claims wherein the first and second



plurality of flow ducts both have a combined flow cross section significantly larger than the flow cross section of said flow line.

- 5 A storage tank as claimed in any of the preceding claims comprising a pair of side by side cylindrical shells lying outside of each other and joined together along a linear region at a tangent plane lying between and common to said shells, upper and lower planar tangent walls joined to the outside surfaces of said shells to form the first and second distribution chambers having generally triangular cross section, walls closing the ends of said shells, the volume within each of said shells defining the vertically uninterrupted primary chamber and valve means selectively connecting the upper distribution chamber to the liquid flow line.

6. A storage tank as claimed in claim 5 further comprising a plurality of tendons running lengthwise in the walls of said cylindrical shells, means coupling the tendons to the ends of such walls for prestressing the same, and further including a plurality of tendons running transversely at spaced positions along the upper and lower tangent walls and means for coupling said tendons to said walls to prestress the same.

7. A storage tank as claimed in claim 6 further comprising a pipe extending longitudinally along the lower region of said primary chamber, said pipe including means for directing streams of water across the lowermost region of said chambers and toward said lower entrance ducts.

8. A large volume storage tank assembly comprising at least one storage tank as claimed in any of the preceding claims.

9. A large volume storage tank assembly as claimed in claim 8 wherein there is provided a plurality of tanks and means for selectively connecting said tanks to the liquid supply.

10. A storage tank substantially as hereinbefore described with reference to and as illustrated in Figures 3 to 7 of the accompanying drawings.

11. A large volume storage tank assembly substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

J. H. POMEROY & CO. INC.,
Per: BOULT, WADE & TENNANT,
112 Hatton Garden, London, E.C.1.
Chartered Patent Agents.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1971
Published at the Patent Office, 25 Southampton Buildings, London WC2A 1AY from which copies may be obtained.

