Sept. 16, 1969 B. C. GERWICK, JR., ET AL **3,467,118**

SUBMERGED OIL STORAGE FACILITY AND METHOD

Filed Jan. 26, 1967 2 Sheets-Sheet 1

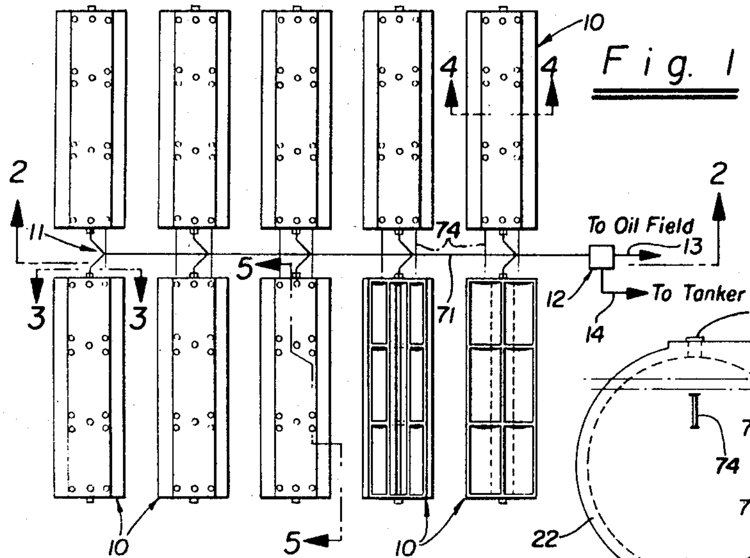

Fig. 1

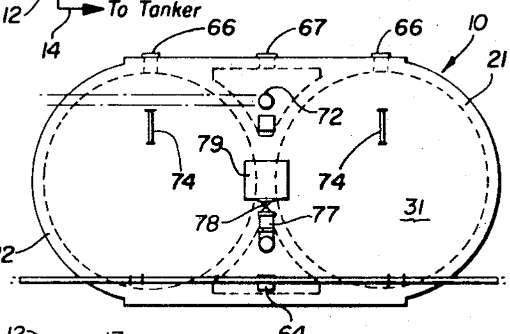

Fig. 3

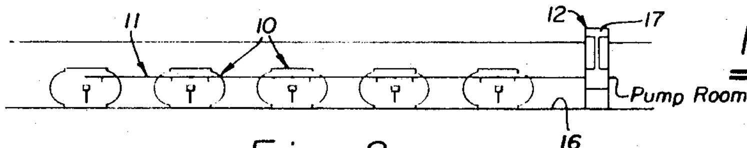

Fig. 2

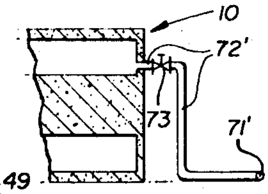

Fig. 7

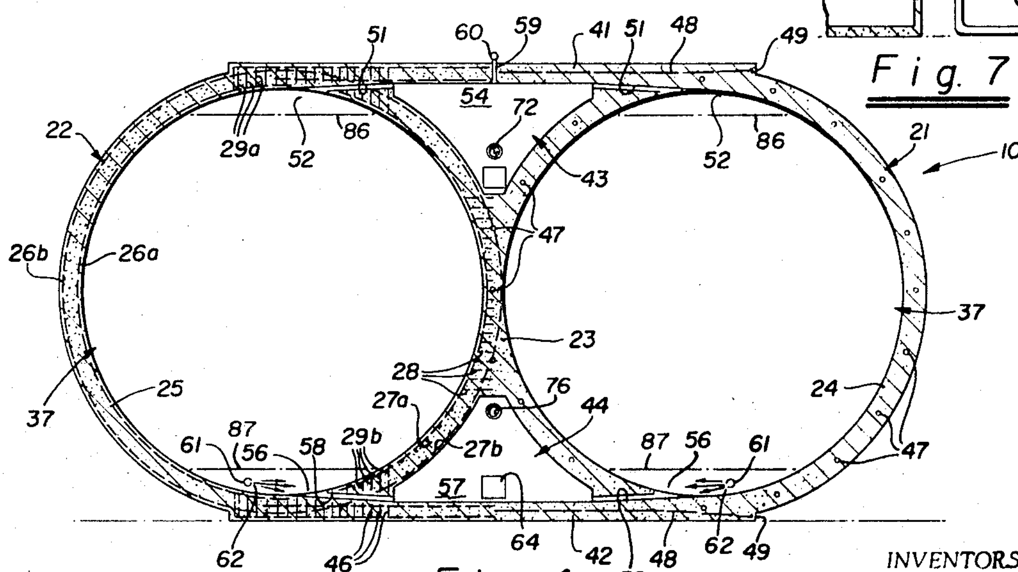

Fig. 4

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SUBMERGED OIL STORAGE FACILITY AND METHOD

Filed Jan. 26, 1967 2 Sheets-Sheet 2

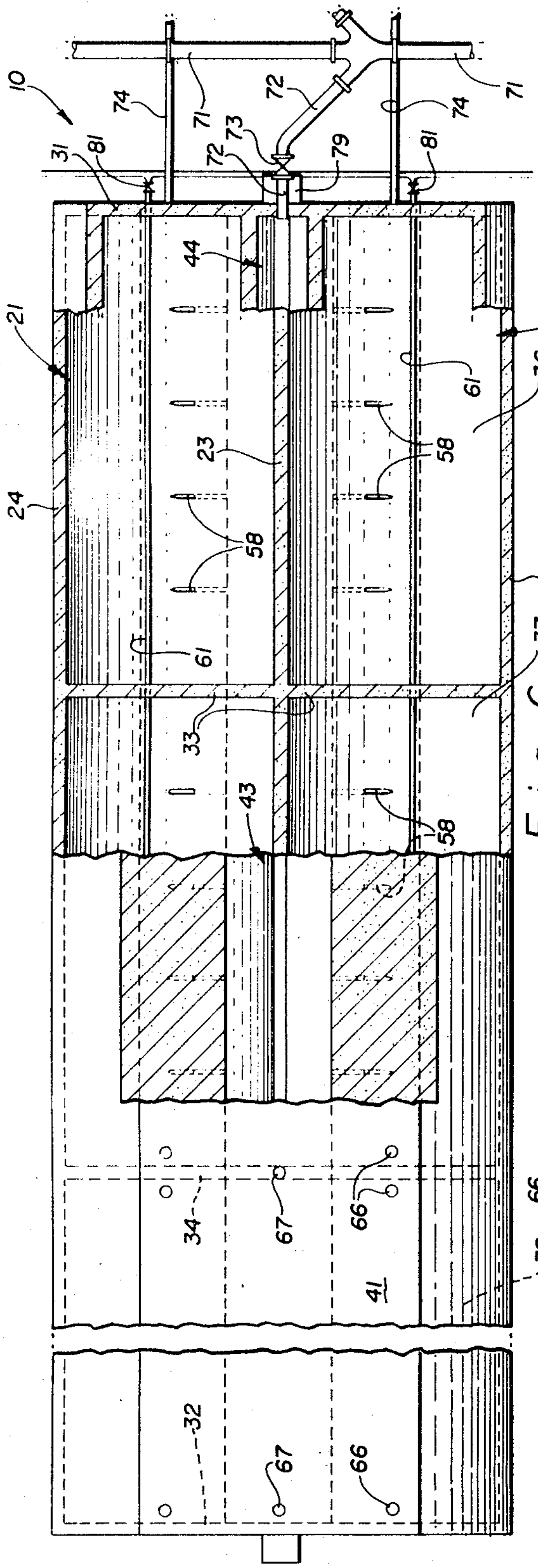

Fig. 6

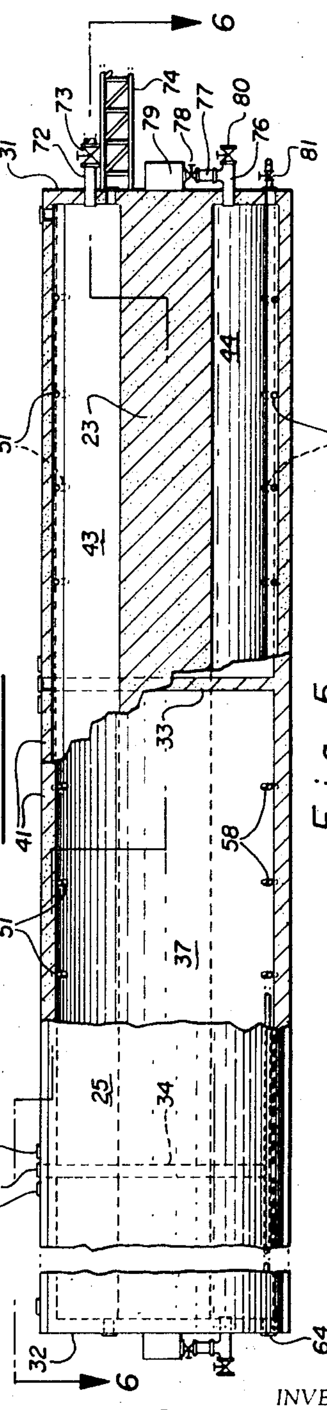

Fig. 5

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SUBMERGED OIL STORAGE FACILITY AND METHOD

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ABSTRACT OF THE DISCLOSURE

A concrete submergible unit consisting of a pair of side by side identical cylindrical shells having a common structural wall joining them and enclosed at their ends to form tanks, together with upper and lower planar external walls cooperating with the cylindrical shells to form upper and lower distribution chambers communicating with the tanks through passages in the shells. Reinforcing and prestressing plans are given as well as piping interconnections.

This invention relates to the storage of oil at sites covered by deep water and, more particularly, to a submerged storage facility for temporarily storing petroleum oil derived from off-shore oil wells.

In off-shore petroleum oil mining operations there is a need for intermediate storage 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 removal to the refinery. Heretofore, facilities proposed for this purpose have been unsatisfactory because of complexity of construction and inability to resist damage in rough weather. Furthermore, such facilities have been criticized as unduly difficult to maintain and as permitting appreciable contamination of the stored oil with sea water and the components therein. There is therefore a need for new and improved commercially feasible oil storage facilities of the type described.

In general, one object of the present invention is to provide a satisfactorily operable submerged facility and method for storing oil or other liquid having a different density and being immiscible with water which will overcome the above limitations and disadvantages and which can be easily and successfully maintained under all sea and weather conditions.

Another object of the invention is to provide a submerged oil storage facility and method in which an enclosed chamber is filled with liquid maintained at the hydrostatic head corresponding to the depth at which the facility is submerged and to which oil can be added and removed without disturbing an oil-water interface established within the chamber.

Another object of the present invention is to provide a storage facility and method of the character described which can receive oil at high velocity from a well, and transmit the same to storage without intermixing or contamination of the oil with components of the water phase.

Another object of the invention is to provide a storage facility of the above character which can be towed on the surface of a body of water and submerged at a desired location and which presents a structural configuration capable of bearing heavy loads so that it is little affected by rough weather, and also capable of resting on an uneven sea bottom without leveling, dredging or other preparation of the same.

Another object of the invention is to provide a storage facility of the above character which has interior storage chambers which are accessible and easy to clean,

particularly as respects sludge, slit and like particulate matter that accumulates therein.

Another object of the invention is to provide a storage facility of the above character in which gases evolved from the stored liquid are passed out of the facility and not accumulated and in which there is a low dead storage volume.

Another object of the invention is to provide a storage facility which achieves the above objects using a unitary structure which provides excellent strength at moderate cost.

Another object of the invention is to provide a storage facility of the above character which can be refloated and recovered from the sea bottom for removal and use elsewhere.

These and other objects of the invention will appear from the following description, taken in conjunction with the accompanying drawings.

Referring to the drawings:

FIGURE 1 is a plan view of an underwater storage facility constructed according to the invention with certain portions thereof shown in section.

FIGURE 2 is a sectional view of the storage facility shown in FIGURE 1 taken along the lines **2—2.**

FIGURE 3 is end view of a single tank unit within the storage facility of FIGURE 1 taken along the lines **3—3.**

FIGURE 4 is a transverse cross-sectional view of a single tank unit of the storage facility of FIGURE 1 taken along the lines **4—4**, the left half showing the reinforcement details, and the right half showing the prestressing details.

FIGURE 5 is an elevational view in section, partially broken away, of one of the 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 of the invention 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 constructed according to the invention 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 **18.**

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

Referring to FIGURES 3 through 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 **26***a, b* interconnected by longitudinally extending strands **27***a, b.* Radially extending strands **28** serve to tie together the circumferential strands **26***a*, *b* from each of the walls **24**, **25** in the common wall **23**. Radially extending strands **29***a*, *b* tie other elements of the structure together as hereinafter described.

Transversely extending base 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 bulkhead **33**, **34** which are also constructed as a unit with the remainder of the structure. Walls **33**, **34** are of a sufficient number of adequately support the midregions of the tank and form within each shell vertically uninterrupted 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 **46** extends transversely of the walls **41**, **42** and is interconnected with reinforcing **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**. Each of the plurality 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 wall 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 unit. 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 a such suitable valve means consists of a pressure relief valve connected in series with the 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. An example of such a pressure relief valve is that sold by Varec, Inc. of Gardena, Calif., Series No. 4800.

All interior surfaces of the unit are coated with an impervious coating seal such as an epoxy paint.

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 base 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 a distribution chamber **43** through wall **41**. Furthermore, chamber **43** is provided with gates at each end thereof in base 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 piping **76** having a branch **77** therein connected through valve **78** to a filter **79**. 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 within a facility constructed according to the invention.

Piping: Pipe **71**—40 inches; pipe **72**—30 inches; pipe **76**—24 inches.

Storage Tank: Overall length—325 feet; length per section **36**, **37**, **38**—105 feet; interior diameter of chamber—48 feet; exterior wall thickness—2½ feet; ducts **51** and **58**—9 inches in diameter. For these dimensions effective storage limit of the tank is 42 feet; bulkhead thickness of bulkheads **33**, **34**—30 inches.

The organization and operation of a storage facility constructed according to the invention 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 unit possesses numerous advantages over other structures. By using the cylinder as a structural shape the unit is strong in resisting bending loads and in resisting transverse loads in true compression so that it can be conveniently made of concrete. Moreover, the strength of the unit permits it to be positioned and used on an uneven sea bottom without having it break-up. It also is sufficiently strong that the unit can be refloated and recovered from the sea bottom for placement elsewhere.

After the desired number of tanks has been submerged to form the desired capacity of the facility, 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 are 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 out of the primary storage chambers **36, 37, 38**. The displaced water is simultaneously forced out through lower ducts **58** and discharged through 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 unit 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 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 method and facility for the under water storage of oil which is especially effective in maintaining the oil uncontaminated while nevertheless using the water at the pressure of submergence to maintain the facility full. In this way, the strength requirements of the facility are substantially reduced as well as the cost of manufacturing it. Moreover, the facility operates to transform a high flow, high velocity stream to a high flow, low velocity stream so that the oil, water, and interface therebetween are left relatively undisturbed as oil is added or removed from the facility.

Many modifications and adaptations of the invention will occur to those skilled in the art to which this invention pertains. For example, referring especially to FIGURE 7, there is shown 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 lateral piping **72′** can be made flexible as by using flexible armored rubber flexible hose or of a series of rigid pipes interconnected with flexible dredging sleeves. As shown, the intake-discharge line **71′** can be laid directly on the sea bottom and the trusses **74** eliminated.

We claim:

1. In a large volume facility for storing oil or other liquid having a density different from and immiscible with water under a body of water, such oil being received from an oil supply line, a storage tank comprising means forming a primary chamber for storing liquid, said chamber being relatively large and vertically uninterrupted, means forming a first distribution chamber connected to said oil supply line, means forming a first plurality of flow ducts for connecting the first distribution chamber to the uppermost region of said primary chamber, said ducts having a sufficiently large combined flow cross section to facilitate a high volume low velocity transfer of oil to and from said first distribution chamber, means forming a second distribution chamber connected to the body of water, means forming a second plurality of flow ducts connecting said second distribution chamber to the bottom of said primary storage chamber, said last named ducts having combined flow cross section comparable to said flow cross section of said first plurality of ducts so that, when said primary chamber is filled with oil and water, the low velocity movement of oil and water through said ducts leaves a substantially undisturbed interface maintained therebetween as said oil and water are pumped in and out of said primary chamber and said interface is shifted.

2. A facility as in claim **1** wherein said flow ducts have a combined flow cross section significantly larger than the flow cross section of said supply line.

3. A facility as in claim **1** wherein said facility comprises a plurality of said oil tanks and means including valve means for selectively connecting said tanks to said oil line.

4. In a large volume facility for storing oil or other liquid having a density different from and immiscible with water under a body of water, such oil being received from an oil supply line, a storage tank comprising means forming a primary chamber for storing liquid, said chamber being relatively large and vertically uninterrupted between upper and lower inner boundaries, means forming an upper distribution chamber connected to said oil supply line and having an upper inner boundary, means forming a first plurality of flow ducts for connecting the upper distribution chamber to the uppermost region of said primary chamber, said ducts having a large combined flow cross section to facilitate a high volume low velocity transfer of oil to and from said upper distribution chamber, means forming a lower distribution chamber connected to the body of water and having a lower inner boundary, means forming a second plurality of flow ducts connecting said lower distribution chamber to the bottom of said primary storage chamber, said last named ducts having combined flow cross section comparable to said flow cross section of said first plurality of ducts so that, when said primary chamber is filled with oil and water, a substantially undisturbed interface is maintained therebetween as oil and water are pumped in and out of said primary chamber, said facility being so constructed and arranged that the upper boundary of the primary chamber is lower than the upper innerboundary of the upper distribution chamber and the flow ducts therebetween gradually rise from said primary chamber to the upper chamber so that gas evolved within the primary storage chambers 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.

5. In a large volume facility for storing oil or other liquid having a density different from and immiscible with water under a body of water, such oil being received from an oil supply line, a storage tank comprising means forming a primary chamber for storing liquid, said chamber being relatively large and vertically uninterrupted between upper and lower inner boundaries, means forming an upper distribution chamber connected to said oil supply line and having an upper inner boundary, means forming a first plurality of flow ducts for connecting the upper distribution chamber to the uppermost region of said primary chamber, said ducts having a large combined flow cross section to facilitate a high volume low velocity transfer of oil to and from said upper distribution chamber, means forming a lower distribution chamber connected to the body of water and having a lower inner boundary, means forming a second plurality of flow ducts connecting said lower distribution chamber to the bottom of said primary storage chamber, said last named ducts having combined flow cross section comparable to said flow cross section of said first plurality of ducts so that, when said primary chamber is filled with oil and water, a substantially undisturbed interface is maintained therebetween as oil and water are pumped in and out of said primary chamber, said facility being so constructed and arranged that the lower boundary of the primary storage chamber is higher than the lower boundary of the lower distribution chamber and the flow ducts therebetween gradually descend to the lower chamber so that matter which settles to the bottom of the primary chamber is easily washed out through such ducts.

6. In an underwater storage facility for storing oil received from a supply line, a storage tank, said tank 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 each said shells, upper and lower planar tangent walls joined to the outside surfaces of said cylinders to form upper and lower distribution chambers having generally triangular cross section, a plurality of entrance ducts connecting said distribution chambers with the primary storage chambers within said cylindrical shells, base walls closing the ends of said shells, the volume within said shells defining large and vertically uninterrupted primary storage chamber means and valve means selectively connecting the upper distribution chamber to a source of oil, the combined total flow area of said entrance ducts being significantly larger than the flow cross section of said source of oil.

7. A facility as in claim **6** further including 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 coupling said tendons to said walls to prestress the same.

8. A facility as in claim **5** further including a pipe extending longitudinally along the lower region of each of said primary storage chambers and on that side away from said ducts, said pipe including means for directing streams of water across the lowermost region of said chambers and toward said lower entrance ducts.

9. In a submerged facility for storing a liquid, such as oil, having a different density from and immiscible with water, the liquid being received from a high velocity supply line, a storage tank unit, said tank unit comprising a pair of side-by-side right circular cylindrical shells lying

outside each other, base walls closing the ends of said shells, means joining said shells together so that they are contiguous along a line lying longitudinally along each shell, the volume within said shells being relatively large and vertically uninterrupted, means forming an upper distribution chamber connected to said liquid supply line, said upper distribution chamber lying along the upper region between said shells, a plurality of ducts connecting said upper distribution chamber with the upper regions within said shells, means forming a lower distribution chamber connected to said body of water, said lower distribution chamber lying along the lower region between said side-by-side shells, a plurality of ducts connecting said lower distribution chamber with the lower regions within said shells, said ducts having a combined flow area significantly larger than the flow area of said liquid supply line so that the velocity of flow of liquid entering and leaving said storage facility is reduced to a value such that the interface of liquid in water within the facility remains substantially undisturbed as the relative proportions of liquid and water are varied.

10. A facility as in claim **9** including a plurality of such tank units, together with piping and valving for selectively interconnecting said units to said supply line.

References Cited

UNITED STATES PATENTS

194,847	9/1877	Shaw	222—395
636,076	10/1899	Smith	222—395
916,130	3/1909	Evans	222—395
1,710,006	4/1929	Peter	137—256 XR
2,503,792	4/1950	Brandon	220—5
2,747,774	5/1956	Breitenbach	222—395
2,748,739	6/1956	Monti et al.	222—395 XR
3,019,948	2/1962	Huska	222—395
3,189,224	6/1965	Meyers	222—395 XR
3,208,696	9/1965	Kastan.	

FOREIGN PATENTS

487,593	12/1953	Italy.

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137—256; 220—5; 222—395