

Aug. 25, 1964

C. E. YOUNG

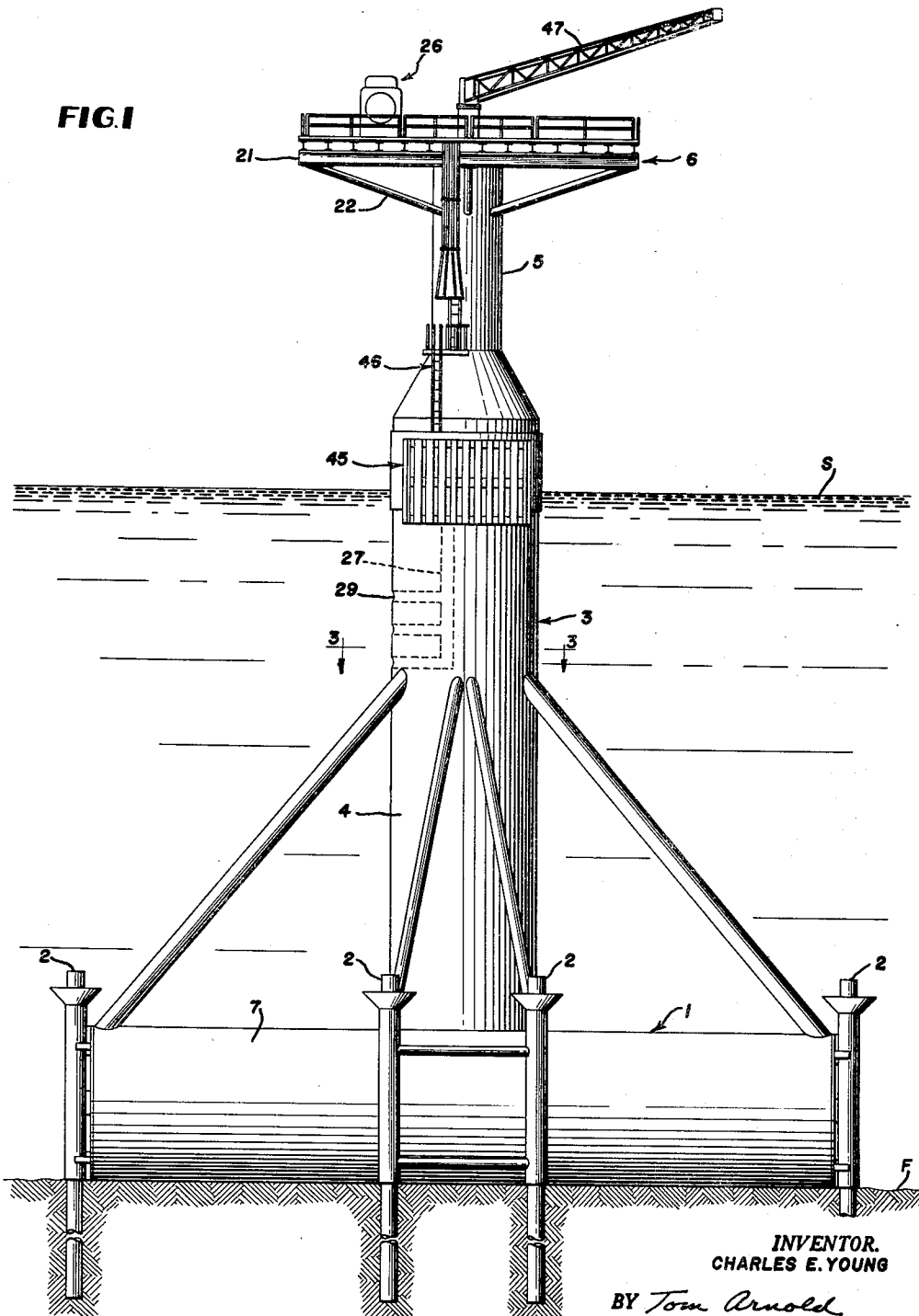
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UNDERWATER STORAGE APPARATUS

Filed March 14, 1960

4 Sheets-Sheet 1

FIG. 1



INVENTOR.
CHARLES E. YOUNG

BY *Tom Arnold*
D. C. Boylance
ATTORNEYS

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C. E. YOUNG

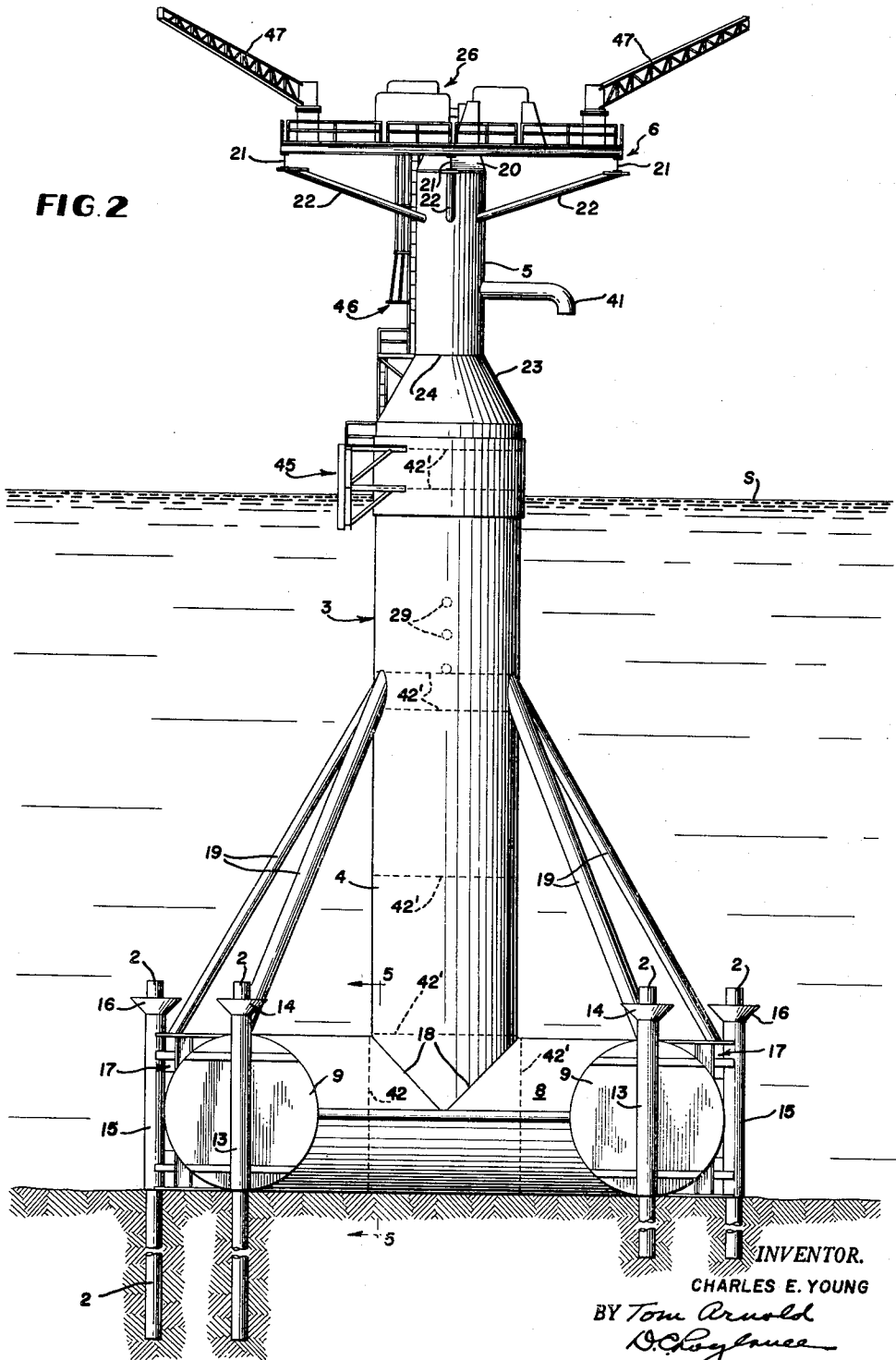
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UNDERWATER STORAGE APPARATUS

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FIG. 2



C. E. YOUNG

UNDERWATER STORAGE APPARATUS

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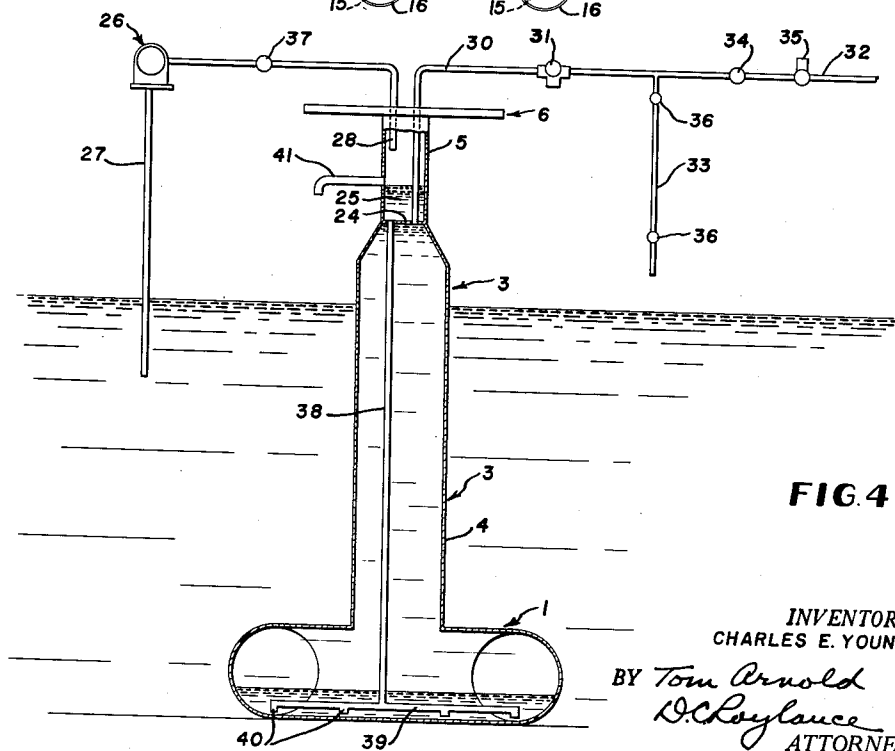


FIG.4

INVENTOR.
CHARLES E. YOUNG

BY *Tom Arnold*
D. Choylance
ATTORNEYS

Aug. 25, 1964

C. E. YOUNG

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UNDERWATER STORAGE APPARATUS

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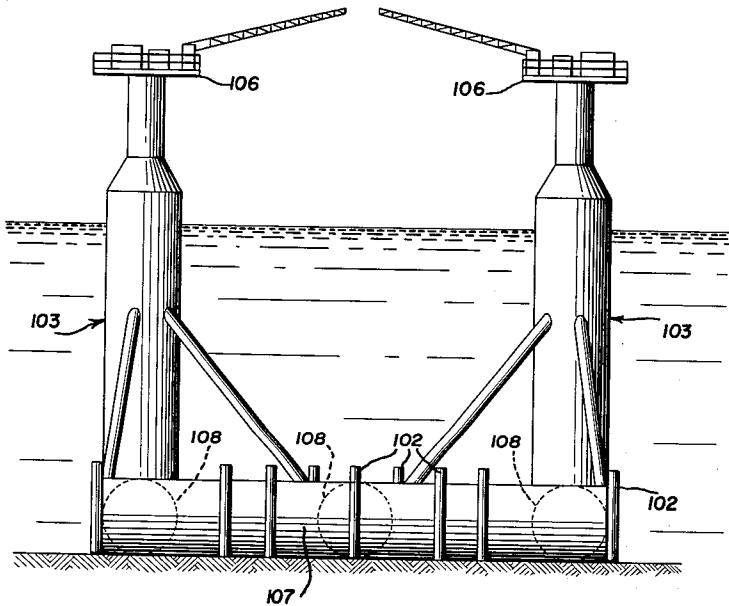


FIG. 7

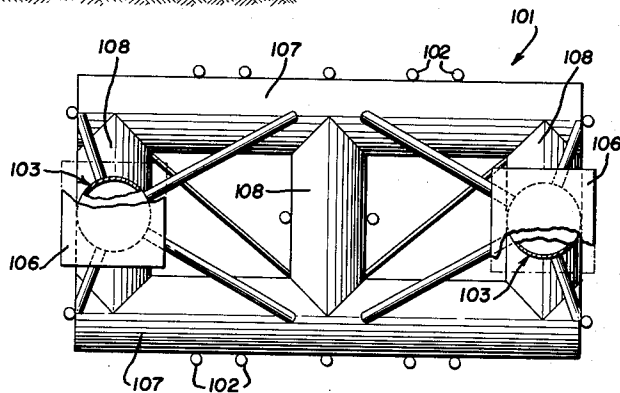


FIG. 6

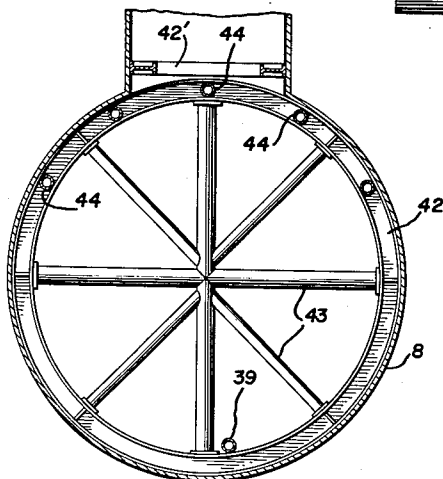


FIG. 5

INVENTOR.
CHARLES E. YOUNG

BY *Tom Arnold*
D. Choylance

ATTORNEYS

UNDERWATER STORAGE APPARATUS

Charles E. Young, New Orleans, La., assignor, by direct and mesne assignments, of fifty percent each to Phillips Petroleum Co., Bartlesville, Okla., a corporation of Delaware, and J. Ray McDermott & Co., Inc., Houston, Tex., a corporation of Delaware

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10 Claims. (Cl. 61-46)

This invention relates to the storage of fluids and more particularly to improved apparatus for storing, under a body of water, water-immiscible liquids which are lighter than water, the invention finding particular application in submerged off-shore storage of oil.

In recent years, there has been a marked increase in the off-shore production of oil, that is, from wells drilled through the floor of the ocean or of a lake, and a concurrent increased demand for adequate oil storage facilities has resulted. While various types of floating or above-water tank systems have been employed, it seems to be accepted in the trade that underwater or submerged storage facilities would be more satisfactory. The main advantage contemplated for underwater storage, as compared to orthodox storage, is economy. Above-water storage facilities, at the site of the off-shore well, require a supporting platform, a basic structure which is itself extremely expensive. Thus, the cost of a production platform without tankage approximates half a million dollars, a base figure to which the cost of the tanks and related apparatus would be added. Costs of off-shore above-water storage facilities, constructed new, are currently estimated above \$50/barrel of capacity. On the other hand, the cost of submerged facilities, disposed at the floor of the body of water, is projected, by those in the industry, at about half of the usual cost for above-water tankage.

Despite the fact that the desirability of underwater storage is accepted by those in the trade, no commercial installation of submerged storage facilities for off-shore oil production has as yet been made.

One reason for failure of the industry, as yet, to undertake construction of an underwater storage facility off-shore is the fact that the storage tanks, being submerged at substantial depths, up to 150 feet or more, will be subjected to great external forces under normal weather conditions and must withstand far greater external pressures during heavy weather, particularly under hurricane conditions, because of the fact that waves, traveling over the area in which the tanks are submerged, will temporarily increase the water depth by as much as fifty feet. Such externally applied pressures present the most serious problems in the design of hollow vessels. The design of a practical underwater storage facility also presents other problems, particularly in securing the structure to the floor of the body of water and in providing for positive and dependable discharge of the stored liquid.

A general object of the present invention is to devise an underwater storage apparatus which is practical for use in off-shore storage of oil and which provides satisfactory solutions for those problems which heretofore have prevented actual construction and installation of such an apparatus.

Another object is to provide an underwater storage apparatus comprising submerged tank means and including means for introducing water thereto to displace stored liquid, the apparatus being so constructed that pressures are applied internally to the submerged tank means, such internal pressures being greater than those applied externally to the tank means by the body of water in which the apparatus is installed.

A further object is to devise novel means, in such an apparatus, for establishing a predetermined hydrostatic head and applying the same to accomplish both discharge of stored liquid and internal pressurizing of the submerged storage tank means. In this connection, a still further object is to provide means for automatically limiting such hydrostatic head.

Yet another object is to provide an apparatus of the type described which, when installed, is secured rigidly to the floor of the ocean or other body of water, the manner of installation being such that mounting of the apparatus is substantially independent of the nature and grade of the floor of the body of water.

Another object is to provide an improved apparatus of the type described characterized by great resistance to forces applied to the apparatus by waves, high winds, etc. In this connection, the apparatus is easily constructed in accordance with the invention to withstand the effects of a maximum hurricane.

A further object is to devise such an apparatus which can be completed on shore, floated and towed to the installation site, the apparatus being stable when floated. It is also an object of the invention to construct the apparatus in a fashion such that it can be installed with relative ease by use of a floating crane.

A still further object is to provide a relatively economical underwater storage apparatus including a work platform disposed above the surface of the water, support for the platform being provided by portions of the storage tank means in such manner that the necessity for the usual platform-supporting structure is eliminated.

In order that the manner in which these and other objects are attained, in accordance with the invention, can be understood in detail, reference is had to the accompanying drawings, which form a part of this specification, and wherein:

FIGS. 1 and 2 are side elevational views of an underwater storage apparatus constructed in accordance with one embodiment of the invention;

FIG. 3 is a view partly in horizontal section on line 3-3 of FIG. 1 and partly in top plan elevation;

FIG. 4 is a diagrammatic illustration of the embodiment of the invention seen in FIGS. 1-3, illustrating the interior arrangement of the apparatus and the manner in which liquids are handled therein;

FIG. 5 is a fragmentary transverse vertical sectional view taken on line 5-5 of FIG. 2;

FIG. 6 is a simplified top plan elevational view of apparatus constructed in accordance with another embodiment of the invention; and

FIG. 7 is a side elevational view of the apparatus of FIG. 6.

Referring now to the drawings in detail, and first to FIGS. 1-5 thereof, it will be seen that the embodiment of the invention here illustrated is an apparatus for underwater storage of oil in an off-shore location. The apparatus comprises a horizontally extending base tank structure indicated generally at 1 and rigidly secured to the floor F of the ocean or other body of water by piles 2 in a manner hereinafter described in detail. Mounted on base tank structure 1 is an upright tank structure indicated generally at 3, the upright tank structure including a cylindrical portion 4, which is of larger diameter and is mainly submerged and a smaller top portion 5 disposed in its entirety at a substantial distance above the mean surface level S of the ocean or other body of water. Centered with respect to and securely mounted on top portion 5 of the upright tank structure is a horizontally extending work platform or deck indicated generally at 6.

As best understood from FIGS. 2 and 3, the base tank structure 1 comprises a pair of elongated cylindrical tank

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portions 7 spaced apart and extending horizontally in parallel relation, the two tank portions 7 being connected, at their midpoints, by a cross tank portion 8 which is in the form of an elongated cylinder, tank portions 7 and 8 all having the same diameter. Tank portions 7 being parallel, and tank portion 8 being joined to the midpoints of portion 7 and being at right angles to those tank portions, it will be understood that the three tank portions define an H, as seen in FIG. 3, with the plane of the H extending horizontally. As will be clear from FIG. 2, tank portions 7 are enclosed at each end by closure plates 9. The ends of tank portion 8 are welded at 10 to the corresponding tank portion 7, along lines defining the right angle intersection between two identical cylinders, and the tank portions 7 are provided with lateral openings aligned with tank portion 8, so that the interiors of all three tank portions 7 and 8 are in mutual communication. These tank portions being constructed in completely fluid-tight relation, it will be seen that they combine to form a horizontally extending hollow base tank structure of substantial capacity.

Horizontally extending tubular cross braces 11 extend between and rigidly interconnecting the corresponding ends of the two tank portions 7. To increase rigidity of the structure, additional tubular diagonal braces 12 are provided, as seen in FIG. 3. Centered on each end of each tank portion 7 and rigidly secured thereto is a vertically extending tubular pile guide or skirt 13, FIGS. 1 and 2, each guide 13 having an upwardly and outwardly flaring top portion 14. Across each tank portion 7 from cross tank portion 8 are provided two centrally disposed, spaced tubular vertically extending pile guides or skirts 15, each having an upwardly and outwardly flared top portion 16, the guides 15 each being rigidly attached to the side wall of the corresponding tank portion 7, as by the rigidly welded bracing indicated generally at 17, FIG. 2. From FIG. 3, it will be noted that the pile guides are arranged in pairs opposed along straight lines which extend through the geometric center of the H defined by tank portions 7 and 8. Each guide 13, 15 accommodates a different one of the piles 2, the piles extend for a substantial distance below the guides into the solid formation of the flow of the ocean or other body of water and each pile is grouted to its surrounding guide member.

As best seen in FIG. 2, the lower portion 4 of upright tank structure 3 intersects cross tank portion 8 of the base tank structure at the center thereof, portion 4 of the upright tank structure having the same diameter as does tank portion 8 and the two cylinders being joined rigidly together by welding along lines 18, FIG. 2. Tank portion 8 is provided with an upwardly facing opening directed toward the interior of the upright tank structure 3, so that the interiors of the base tank structure and the upright tank structure are in communication. In addition to being supported by its welded connection to the base structure, upright tank structure 3 is provided with a plurality of tubular brace members 19 each connected at one end to a point on the side of the upright tank structure which is below the mean surface level S of the body of water and at the other end to the base tank structure at its upper end and at its lower end. Thus, as seen in FIG. 3, four of the brace members 19 extend downwardly and outwardly each to a different end of the parallel tank portions 7, while four others of the brace members 19 slant downwardly and outwardly to framing 17, each brace member 19 terminating at its lower end immediately adjacent to a different one of the pile guides.

Platform 6 can be of any suitable construction providing a rigid horizontal work surface of substantial extent. In this embodiment, the platform is shown as having a square plan shape, the center of the platform being attached, by any suitable base structure 20, FIG. 2, to the top of portion 5 of the upright tank structure

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3. Platform 6 is shown as including three rigidifying I-beams 21 and suitable braces 22 extend between the I-beams and top portion 5 of the upright tank structure.

Portions 4 and 5 of the upright tank structure are connected by an intermediate tubular portion 23 of frusto-conical form, the arrangement being such that the junction between portions 5 and 23 is spaced a substantial distance above the mean surface level S. As will be clear from FIG. 4, a transverse bulkhead 24 extends across the interior of upright tank structure 3 at the junction between portions 5 and 23. Bulkhead 24 is so constructed and attached to the walls of tank structure 3 as to be effective to define the interior of the upright tank structure into separate chambers, one extending in uninterrupted fashion downwardly to communicate directly with the interior of the base tank structure and the other, indicated at 25, extending upwardly to platform 6. Platform 6 carries suitable pump means employed to take water from the ocean or other body of water in which the base tank structure is submerged and supply the water so taken to the chamber 25. Thus, in the present embodiment, the invention employs a diesel engine powered turbine pump indicated generally at 26, the pump having an intake 27, FIG. 4, extending into the ocean or other body of water and an outlet 28 extending into the space in portion 5 of the upright tank structure above bulkhead 24. While suitable inlet conduiting can be mounted in various fashions, it is advantageous to extend the same downwardly within upright tank structure 3, as will be clear from FIG. 1, the intake conduiting extending through bulkhead 24, via a sealed joint, and terminating at its lower end in at least one laterally projecting portion communicating with the exterior of the upright tank structure via an inlet opening 29, the opening 29 being located well below the mean surface level S.

To provide for supply of oil to the interior of the tank structure, and for discharge of the oil, the apparatus includes a duct or pipe 30, FIG. 4, extending downwardly through platform 6, through the interior of top portion 5 of the upright tank structure and projecting through bulkhead 24, so as to open into the space within tank structure 3 below bulkhead 24, the lower end of duct 30 being sealed in fluid-tight fashion to bulkhead 24 in any conventional fashion. A suitable flow meter 31 is connected in duct 30 and, on the outboard side of the flow meter, duct 30 is connected to an oil supply line 32 and an oil unloading line 33. The supply line 32 is provided with a manually-operated shut-off valve 34 and an automatic shut-off valve 35, the two valves being in series and the automatic valve being controlled in response to the level of stored oil within the tank structure in any suitable fashion. Unloading line 33 is provided with suitable valving, as indicated at 36. A suitable control valve 37 is connected between the pump 26 and the outlet end of discharge conduit 28.

Still referring to FIG. 4, chamber 25 communicates with the lower portion of the interior of base tank structure 1 via a vertical conduit 38, the upper end of which extends through bulkhead 24 and is sealed thereto. Conduit 38 extends downwardly through the interior of portion 5 of upright tank 3, terminates adjacent the bottom wall of cross tank portion 8 of the base tank structure 1 and is there connected to a horizontally extending water discharge manifold 39. The manifold 39 extends for substantially the full length of cross tank 8 and is provided with a plurality of downwardly opening outlets 40 spaced uniformly along the length of the manifold.

From FIG. 4, it will be noted that no upper closure member, other than such closure means as may be employed to mount platform 6, is employed to define the top of chamber 25. Rather, portion 5 of the upright tank structure is provided with a laterally extending overflow pipe 41 projecting from the upright tank structure, and communicating with the interior thereof, at a predetermined point spaced above the bulkhead 24.

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From the foregoing, it will be apparent that both the base structure 1 and that portion of the upright tank structure 3 below bulkhead 24 define oil storage space. That portion of the interior of top portion 5 of the upright tank structure between bulkhead 24 and discharge pipe 41 constitutes a separate chamber, to which water from the body of water can be supplied by the pump means 26 and which chamber is in communication directly with the lower portion of the interior of the base tank structure. It will also be noted that the base and upright tank structures combine to rigidly support all portions of the apparatus located above water, particularly including the work platform 6 and the equipment and facilities mounted thereon. It is accordingly necessary that the apparatus be so mounted on the floor of the ocean or other body of water, and be so constructed, that the entire apparatus constitutes a rigid assembly.

In this connection, it will be understood that the various tanks are of heavy construction and are adequately reinforced to provide the necessary rigidity. Thus, for example, FIG. 5 shows in detail a typical arrangement for stiffening the horizontally extending tanks and for rigidifying the tank structures in those areas where two tank portions are joined together. Here, a circular stiffening ring 42, having the transverse cross-sectional shape of an I, is welded or otherwise rigidly attached to the inner surface of the cylindrical tank wall, the ring 42 lying in a plane at right angles to the longitudinal axis of tank portion 8 and being disposed at one side of the juncture between tank portion 8 and the bottom of the upright tank structure. Within the ring, a plurality of generally radially extending rigid tubular braces 43 are provided, welded together at the center of tank portion 8 and welded to ring 42 at their outer ends. Limber holes (not shown) can be provided in the main web of ring 42, when and as required. Similar stiffening rings are provided at spaced points along the tank structures, as indicated at 42'.

Where two such stiffening rings are provided one on each side of a juncture between two tank portions, the two rings are connected together by a plurality of rigid tubular members 44, FIGS. 3 and 5, which extend axially of the tank portion containing the two stiffening rings. In each such case, the members 44 are spaced arcuately across the opening between the two joined tank portions. Thus, in the case illustrated in FIG. 5, members 44 are spaced across the opening in cross tank portion 8 at the juncture between that tank portion and the upright tank structure. It will thus be seen that the combination of two stiffening rings 42 and the members 44 constitutes means for rigidifying tank portion 8 in the area of the opening therein which provides communication with upright tank structure 3.

In order that the structural members can be simply fabricated, yet made adequately rigid, flat wall members such as the end plates 9 and the bulkhead 24 are fabricated of heavy plate and provided on at least one surface with a plurality of stiffening flanges (not shown).

It will be seen that all of the tank portions are of cylindrical shape and thus are inherently adapted to provide maximum resistance to internal forces. Since all of the junctures between the tank portions involve attachment of like cylinder bodies in right angle disposition, such junctures are inherently rigid and do not require special joint constructions.

While this embodiment is illustrated as resting at least substantially on the ocean floor, it is to be understood that all vertical forces involved are assumed directly by piles 2, which piles extend through the soft overburden of the floor into the underlying hard and stable formation. Since the piles are distributed uniformly around the periphery of the base tank structure and are grouped symmetrically, all vertical forces involved are transferred to the stable formation of the floor of the body of water directly and uniformly via the piles.

The apparatus is completed on shore and then floated

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and towed to the off-shore site of installation. In this connection, it will be noted that when empty or when supplied with some water as ballast, the structure is of such nature as to float in stable condition, so that difficulties of towing are minimized. Completion of the apparatus on shore includes attachment of the pile guides 13, 15. At the site of installation, the entire structure is handled by a floating crane, the structure being initially partially filled with water, by operation of pump means 26, so that the structure begins to sink. With the floating crane now supporting the structure, additional water is pumped in and the structure is lowered, continuously under control of the crane, until it reaches its desired position at the floor of the body of water in which it is to be submerged. With the structure positioned as desired, the piles 2 are now driven through guides 13, 15 and rigid mounting is accomplished by grouting between the guides 13, 15 and the piles 2. It will thus be clear that proper mounting, involving rigidly securing the apparatus as a unit to the hard, stable formation of the floor of the body of water, in no way depends upon the surface characteristics and grade of the floor. It is not necessary that the base tank structure rest directly upon the floor, nor is it required that the base structure directly engage a hard floor surface. Thus, the surface of the floor of the body of water may be mud, or the like, so that the base tank structure actually sinks therein. Also, it is practical to have the base tank structure spaced somewhat above the floor, where such an arrangement is desirable or convenient, since it is the piles and not the surface of the floor which support vertical loads. It will also be obvious that, after installation, the floor of the body of water may scour away beneath the base of the structure without any adverse effect on the apparatus.

Because of the manner in which the apparatus is rigidly secured to a hard formation of the floor of the body of water by piles 2 and skirts 13, 15 and because the entire tank structure is rigid and stable, the apparatus when installed is capable of resisting tremendous forces, whether those forces be directed vertically or horizontally. It is feasible to construct an apparatus in accordance with this embodiment of the invention which will withstand the effect of hurricane forces without the necessity of unusually expensive design features.

While provision for resistance to forces applied directly by wind, waves and the like, is an important consideration, it is perhaps more important to assure that the base tank structure, and that portion of the upright tank structure which is deeply submerged shall not be collapsed as a result of certain increases of exteriorly applied hydrostatic pressure during the passage of large waves, such as hurricane waves, over the site of installation. In this connection, if it be assumed that the base tank structure is on the order of 100-150 ft. below the mean surface level of the ocean or other body of water, it is obvious that a very significant increase in the hydrostatic head applied to the base tank structure will occur during passage of, for example, a 50 ft. hurricane wave. To protect the structure from damage as a result of such an occurrence, all portions of the tank structure which are submerged are internally pressurized to provide an internal pressure substantially greater than the pressure applied externally to the structure by the body of water in which it is submerged. This is accomplished because of the hydrostatic head established by introducing water to chamber 25 and communicating it to the interior of the device via conduit 38 and manifold 39, is substantially in excess of the hydrostatic head applied exteriorly by the ocean or other body of water. In this connection, chamber 25 is disposed at a substantial distance above the mean surface level S. As a typical example, the bulkhead 24 may be located 20 ft. above the mean surface level and the overflow pipe 41 10 ft. above the bulkhead. Obviously, these locations can be selected in accordance with the requirements involved in each particular installation, to give a greater or lesser hydrostatic head for application interiorly to the

tank structures. It is to be noted that the location of the overflow pipe 41 provides a simple means for setting a maximum limit on this hydrostatic head without requiring special control of the pump means 26 during supply of water to the chamber 25. All portions of the tank structure being cylindrical, maximum resistance to internal pressures is easily provided; hence, internal pressurization substantially in excess of the externally applied pressures is feasible without the use of expensive constructions.

Assuming that the apparatus has been securely mounted on the ocean floor, or on the floor of a lake or other body of water, in the manner hereinbefore described, operation of the apparatus in use is as follows: oil is supplied via conduit 30 and enters the top of portion 4 of upright tank structure 3, that is, the portion of the upright tank structure immediately below bulkhead 24. As the entry of oil progresses, water exhausts, via manifold 39 and duct 38, into chamber 25, and outwardly to discharge via the overflow pipe 41. Supply of oil is continued until the interface between the oil and water reaches a point in base tank structure 1 just above the manifold 39. The supply of oil is then terminated either by operation of manual valve 34 or by automatic operation of valve 35. The apparatus can now be considered to be full insofar as oil storage is concerned.

At this stage, it is to be noted that, while the hydrostatic head within the tank structures has decreased somewhat (since heavier water has been displaced by lighter oil), the hydrostatic pressure within the tank structure is still maintained at the desired high level because of maintenance of the substantial volume of water in chamber 25.

Assuming that oil is now to be discharged, valves 36 in unloading line 33 are opened and pump means 26 is operated to continuously supply water from the ocean or other body of water into chamber 25, the water being supplied by the pump means at a rate at least equal to the desired rate of oil discharge. This supply of water is continued, the water flowing downwardly through conduit 38 and discharging by manifold 39 until the desired quantity of oil has been removed from the apparatus. The valves 36 are then closed and operation of the pump means terminated. During such operation, any excessive supply of water to chamber 25 is compensated for by the presence of overflow pipe 41.

From a consideration of FIGS. 3 and 4, it will be observed that the interior volume of that portion of the upright tank structure below bulkhead 24 is substantially smaller than the interior volume of the base tank structure 1. In actual installations, the interior volume of the base structure may be, for example, three times that of the portion of the upright tank structure below the bulkhead. This relationship is advantageous when considering the fact that the rate at which oil is discharged during operation of the apparatus depends upon the overall hydrostatic head applied within the tank structure. With the apparatus designed as just described, variations in flow rate can be held below 10% during discharge of up to 75% of the total oil stored.

Considering practical design limitations, storage apparatus can be constructed in accordance with this embodiment of the invention to have relatively large storage capacities. Thus, with tanks 7 being 22 ft. in diameter and 110 ft. in length and spaced 60 ft. apart on centers, and with the vertical tank structure rising to an overall height of about 150 ft., the apparatus will have a storage capacity of approximately 24,000 barrels.

It is also to be noted that the apparatus provides adequate support for a work platform which can be of very substantial horizontal extent. This is an important economic consideration in view of the fact that the presence of a stable work platform is highly desirable, if not essential, at the site of a producing off-shore well. In this connection, the cost of constructing a conventional off-shore platform is very considerable, frequently running to a figure on the order of a million dollars, which amounts to a predominant proportion of the total cost

of the underwater storage apparatus illustrated in FIGS. 1-5. Thus, with the present invention, an effective and dependable underwater storage facility, also providing adequate platform space, can be provided for little more than the cost of a conventional off-shore platform.

The apparatus is also advantageously provided with a laterally disposed boat landing platform, as indicated generally at 45, FIGS. 1 and 2. Platform 45 is mounted in any suitable fashion directly on the top portion of lower section 4 of upright tank structure 3. Suitable ladders, stairways or the like, indicated at 46, are provided in order that personnel may gain ready and safe access to the main platform or deck 6.

Service platform 6 is of substantial extent and is rigidly supported. Any desired components of the apparatus, and any other apparatus desired, can be provided on the platform. Under normal circumstances, the platform will support, in addition to the pump means 26, a plurality of swinging booms or "stifflegs" 47 for supporting and manipulating the loading or discharge lines or hoses. The platform will also ordinarily support the usual skim tank, a diesel electric generator, separator and test units, personnel quarters, and the like.

While the construction illustrated in FIGS. 1-5 is particularly advantageous, it will be understood that the apparatus may have various other configurations without departing from the scope of the invention. Thus, instead of employing a base tank structure of H configuration, various other configurations are practical. As seen in FIGS. 6 and 7, the apparatus can comprise a base structure 101 mounted on the floor of the ocean or other body of water by piles 102, in the same manner described hereinbefore, and may include two upright tank structures 103, each supporting a horizontally extending platform 106. In this embodiment, the base tank structure 101 includes two elongated, spaced, parallel, cylindrical tank portions 107 joined by three cylindrical cross tank portions 108, the interiors of all of the tank portions 107 and 108 being in communication with each other. From FIG. 6, it will be noted that two of the cross tank portions 108 are located each adjacent corresponding ends of the two tank portions 107. The two upright tank portions 103 are each mounted on a different one of these two cross tank portions. The interiors of upright tank structures 103 communicate with the interiors of the corresponding cross tanks 108 in the same manner hereinbefore described with reference to FIGS. 1-5. Thus, all of the tank portions 107 and 108, and also the upright tank structures 103, are available for storage of liquid.

Either one or both of the upright tank structures 103 may be constructed precisely as described with reference to upright tank structure 3, FIGS. 1-5, so as to provide a separate water storage chamber, disposed substantially above the mean surface level of the body of water, to establish a hydrostatic head applied internally to the tank structures for the purpose of effecting discharge of oil and for internally pressurizing the tank structures, as hereinbefore described. The embodiment of the invention shown in FIGS. 6-7 will, of course, include water and stored liquid ducting, controls, and pump means the same as or equivalent to that described with reference to the embodiment of FIGS. 1-5.

This embodiment of the invention has the advantage of providing increased storage space and of also providing two platforms 106 which are spaced from each other. The provision of separate platforms is desirable in order that operations involving flame, for example, can be limited to one platform and segregated from operations carried on on the other platform.

Various types of control equipment can be employed in accordance with the invention to assure proper operation during filling and discharging of the oil. Thus, automatic oil supply valves can be controlled by conventional means responsive to the location of the oil-water interface with-

in the tank structures. Similarly, an emergency shut-down control can be employed, as additional means for terminating oil supply, in the event the oil level within the apparatus exceeds a predetermined desirable maximum. For example, a conductivity probe or like oil sensing device can be disposed in overflow 41, FIG. 4, and connected to conventional circuitry to control the automatic oil supply valve 35.

While the invention has particular application to storage of crude oil at the side of an off-shore well, it is to be understood that the apparatus can be used to store any liquid which is water-immiscible and which has a specific gravity less than that of water.

What is claimed is:

1. In apparatus for storing, under a body of water, a water-immiscible liquid having a specific gravity less than 1.0, the combination of storage tank means submerged in the body of water and including a substantially horizontal base portion disposed adjacent the floor of the body of water, said base portion comprising two spaced parallel elongated cylindrical tank portions and at least one cylindrical cross-tank portion connected at its ends to said parallel tank portions at points intermediate the ends thereof and extending therebetween, said storage tank means further including an elongated cylindrical vertical tank portion secured at its base to such cross-tank portion and disposed between said parallel tank portions, the interiors of all of said tank portions being in communication, said vertical tank portion extending to a point substantially above the surface of the body of water; a plurality of horizontally spaced piles extending downwardly into the floor of the body of water and located adjacent to said parallel tank portions; and means securing said piles rigidly to said parallel tank portions.

2. In an apparatus for storage of oil below the surface of a body of water, the combination of a hollow base tank structure comprising two spaced apart tank sections and an intermediate tank section extending between said spaced tank sections, said intermediate tank section being at least generally cylindrical and having its ends connected rigidly each to a different one of said spaced tank sections, the interiors of all of said tank sections being in communication with each other; means mounting said base tank structure rigidly on the floor of the body of water and maintaining said intermediate tank section in fixed horizontal position; an upright hollow columnar tank section rigidly mounted at its lower end on said intermediate tank section, said columnar tank section having a transverse cross section substantially smaller than the horizontal extent of said base tank structure, the interior of said columnar tank section being in communication with the interior of said intermediate tank section, said columnar tank section extending to a point substantially above the mean surface level of the body of water; means for supplying oil to and removing oil from said base tank structure via said columnar tank section; means for supplying water from the body of water to the interior of said base tank structure, said last-mentioned means including means for establishing and applying to the interior of said base tank structure and said columnar tank section a hydrostatic head greater than the hydrostatic head applied exteriorly thereto by the body of water; and a horizontally extending work platform mounted rigidly on the top of said columnar tank section above the surface of the body of water.

3. An apparatus in accordance with claim 2 and wherein said two spaced tank sections are elongated, horizontally extending and parallel, and all of said tank sections are cylindrical.

4. Apparatus in accordance with claim 1 and wherein said cross-tank portion is disposed with its ends at the respective midpoints of said parallel tank portions and said vertical tank portion extends upwardly from the center of said cross-tank portion.

5. Apparatus in accordance with claim 4 and further

comprising transverse brace means extending between adjacent end portions of said parallel tank portions, and additional brace means connected between the end portions of said parallel tank portions and a portion of said vertical tank portion spaced substantially above said base portion.

6. In an underwater storage apparatus, the combination of

storage tank means submerged in the body of water and including a substantially horizontal base portion disposed adjacent the floor of the body of water, said base portion comprising

two spaced parallel elongated cylindrical tank portions,

two cylindrical cross-tank portions spaced apart lengthwise of said parallel tank portions and each having its ends connected to the corresponding end portions of said parallel tank portions,

said storage tank means further comprising two elongated cylindrical vertical tank portions,

each of said vertical tank portions being secured at its base to a different one of said cross-tank portions at a point between said parallel tank portions,

said vertical tank portions extending to points substantially above the surface of the body of water,

the interiors of all of said tank portions being in communication;

a plurality of horizontally spaced piles extending downwardly into the floor of the body of water and located adjacent to said parallel tank portions;

means securing said piles rigidly to said parallel tank portions; and

two horizontal work platforms,

said platforms each being mounted on the top portion of a different one of said vertical tank portions and spaced horizontally from each other.

7. In an apparatus for the storage of oil beneath a body of water, the combination of a base tank structure comprising

two spaced parallel tank sections, and

at least one intermediate tank section extending between said parallel sections and having its ends rigidly connected each to a different one of said parallel tank sections,

said base tank structure being disposed at the floor of the body of water with all of said tank sections extending horizontally;

pile means secured to said base tank structure and mounting said base tank structure on the floor of the body of water to positively restrain said tank structure against both vertical and horizontal movement; an upright columnar tank section having its lower end rigidly connected to said intermediate section,

said columnar tank section extending upwardly to a point substantially above the mean surface level of the body of water,

the interior of all of said tank sections being in mutual communication;

pump means supported by said columnar tank section and having an inlet and an outlet;

conduit means leading from a point in said base tank structure adjacent the bottom thereof to a point substantially above the mean surface level of the body of water;

means connecting the inlet of said pump means to draw water from the body of water, the outlet of said pump means being connected to supply water to said conduit means,

whereby water can be introduced into said base tank structure to displace oil therefrom and said conduit means can be maintained filled with

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water to apply to the interior of said base tank structure a hydrostatic head greater than the hydrostatic head applied exteriorly to said base tank structure by the body of water in which the same is immersed; and 5

other conduit means for introducing oil to and withdrawing oil from the interior of said columnar tank section at a point above the mean surface level of the body of water.

8. An apparatus in accordance with claim 7 and wherein 10

all of said tank sections are cylindrical and the diameters of said intermediate and columnar tank sections are substantially equal at the point of connection of said columnar tank section to said intermediate tank section.

9. An apparatus for storing oil at a substantial depth, beneath a body of water under circumstances such that the apparatus may be subjected to hurricane conditions, comprising in combination 20

a horizontal base tank structure;

an upright columnar tank structure;

said base tank structure having horizontal dimensions substantially greater than its height and being disposed at the floor of the body of water, 25

said columnar tank structure having its bottom end rigidly secured to the central portion of said base tank structure, the upper end portion of said columnar tank structure projecting above the mean surface level of the body of water by such a distance that the top of said columnar tank structure will remain unsubmerged during passage of hurricane waves, 30

the interiors of said base tank structure and said columnar tank structure being in mutual communication; 35

means rigidly mounting said base tank structure on the floor of the body of water, said means comprising

a plurality of piles each extending downwardly 40

into the floor of the body of water, said piles being spaced in a horizontal series extending around said base tank structure, and

means securing said piles rigidly to said base tank structure, 45

the combination of said base tank structure and said columnar tank structure being positively restrained by said piles against both vertical and horizontal movement;

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pump means having an inlet and an outlet and mounted on said columnar tank structure;

a conduit disposed within said columnar tank structure and extending from a point within said base tank structure adjacent the bottom thereof upwardly to a point substantially above the mean surface level of the body of water,

the inlet of said pump means being connected to draw water from the body of water and the outlet of said pump means being connected to supply water to said conduit, whereby water can be supplied to said base tank structure via said conduit for the displacement of oil and said conduit can be maintained filled with water to apply to the interior of said base tank structure a hydrostatic head which is greater than the hydrostatic head applied exteriorly to said base tank structure by the body of water; and

other conduit means for introducing oil to and withdrawing oil from the interior of said columnar tank structure at a point above the mean surface level of the body of water.

10. An apparatus in accordance with claim 9 and wherein 50

said base tank structure comprises

two parallel cylindrical tank sections, and

an intermediate cylindrical tank section extending between said parallel tank sections and having its ends rigidly secured each to a different one of said parallel sections,

the interiors of all of said tank sections being in mutual communication,

said columnar tank structure being rigidly secured to the center of said intermediate tank section,

said piles being spaced about and secured to said parallel tank sections.

References Cited in the file of this patent

UNITED STATES PATENTS

2,503,516	Shrewsbury	Apr. 11, 1950
2,525,955	Scott	Oct. 17, 1950
2,622,404	Rice	Dec. 23, 1952
2,687,017	Gerwick	Aug. 24, 1954
2,747,774	Britenbach	May 29, 1956
2,748,739	Monti et al.	June 5, 1956
2,919,552	Hayward	Jan. 5, 1960
2,938,354	Knapp	May 31, 1960
3,000,185	Brinkmann	Sept. 19, 1961