

[72]	Inventor	Robert B. Burns Huntington, N.Y.
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[73]	Assignee	Texaco Development Corporation

[56]

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Primary Examiner—Houston S. Bell, Jr
Attorneys—K. E. Kavanagh and Thomas H. Whaley

[54] OFFSHORE LIQUID STORAGE FACILITY
8 Claims, 4 Drawing Figs.

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114/0.5, 137/236, 141/388

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B67c 3/00

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284, 383, 387, 388; 114/0.5 (T), (Inquired);
166/0.5 (Inquired); 61/46, 46.5, 69, (Inquired);
137/236, 572, (Inquired); 9/(Inquired);
222/(Inquired); 214/(Inquired)

ABSTRACT: The invention relates to an oil or liquid storage facility positioned at an offshore location in a relatively deep body of water and adapted for remote operation. The facility includes a main oil storage tank which is communicated with, and supplied by a plurality of satellite wells or smaller feeder tanks. A transfer tank is adapted for removable connection with the main tank to be periodically filled with oil stored in the latter. At predetermined intervals, the filled transfer tank is disconnected from the main tank, elevated to the surface of the water for removal, and replaced by an empty tank. The latter is then lowered to the main tank beneath the ocean surface where it is automatically connected to the main tank for continuing the filling operation.

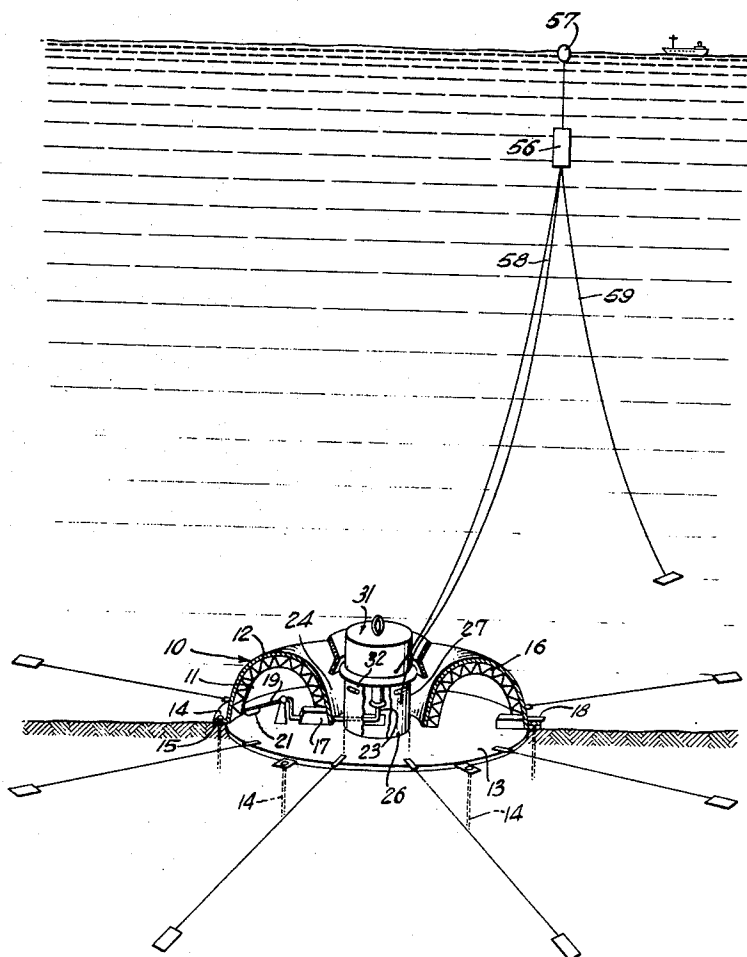


Fig. 1.

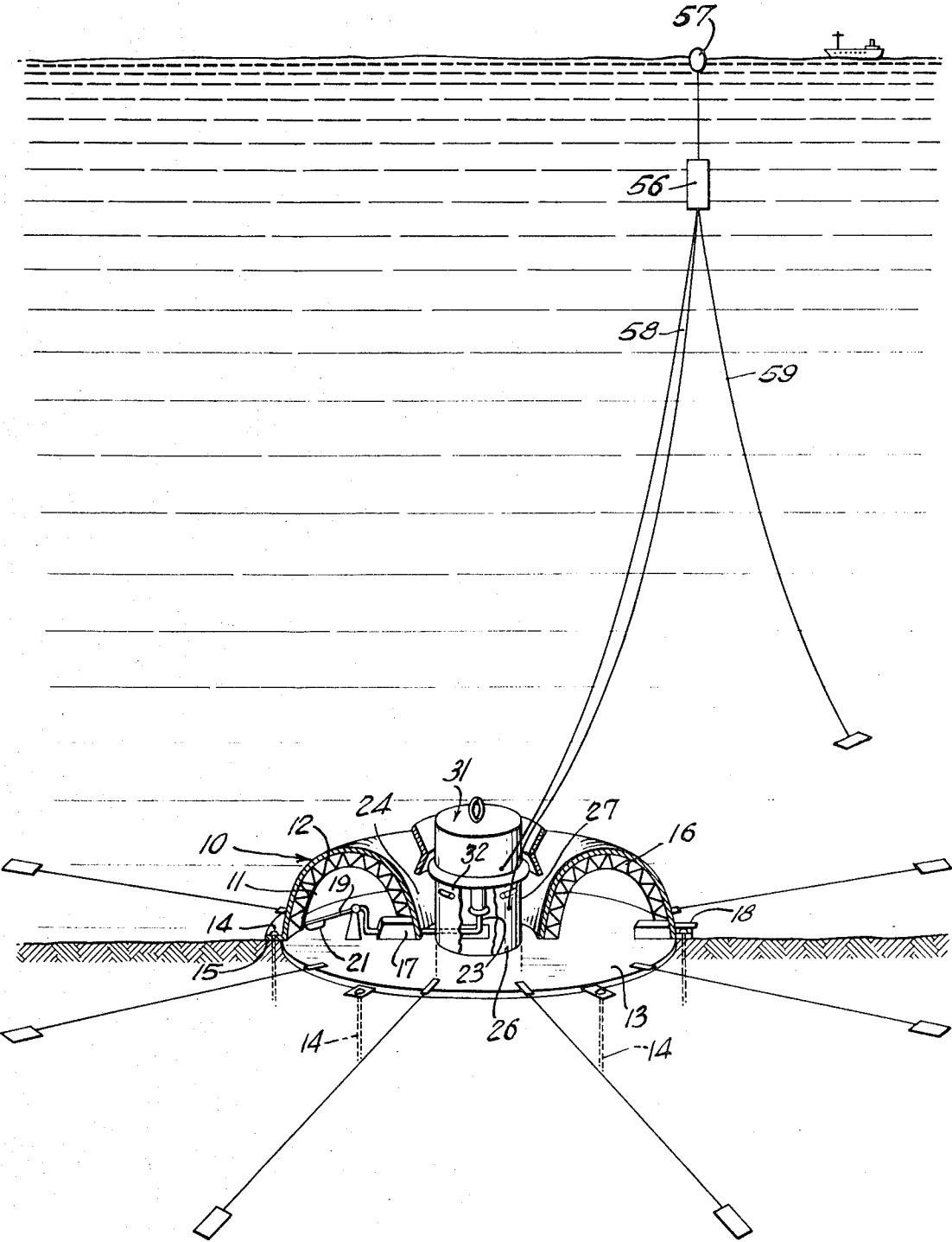


Fig. 2.

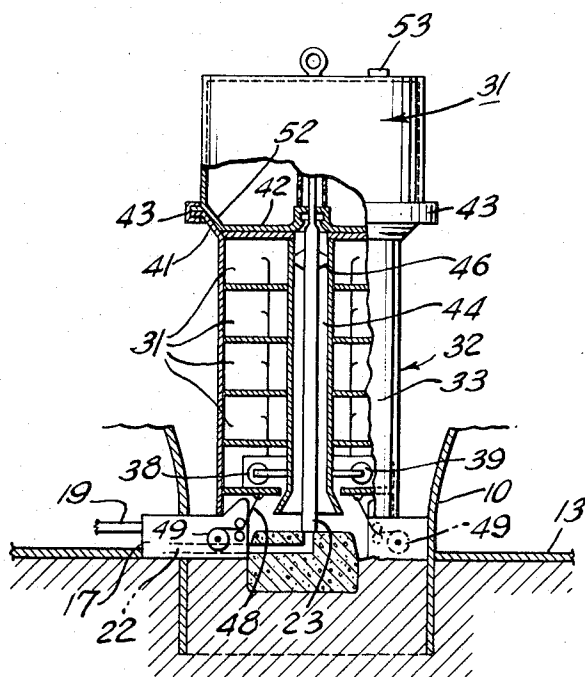


Fig. 3.

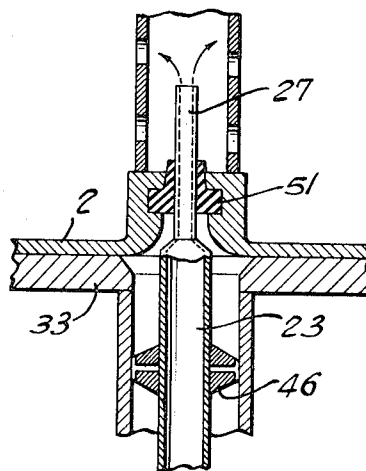
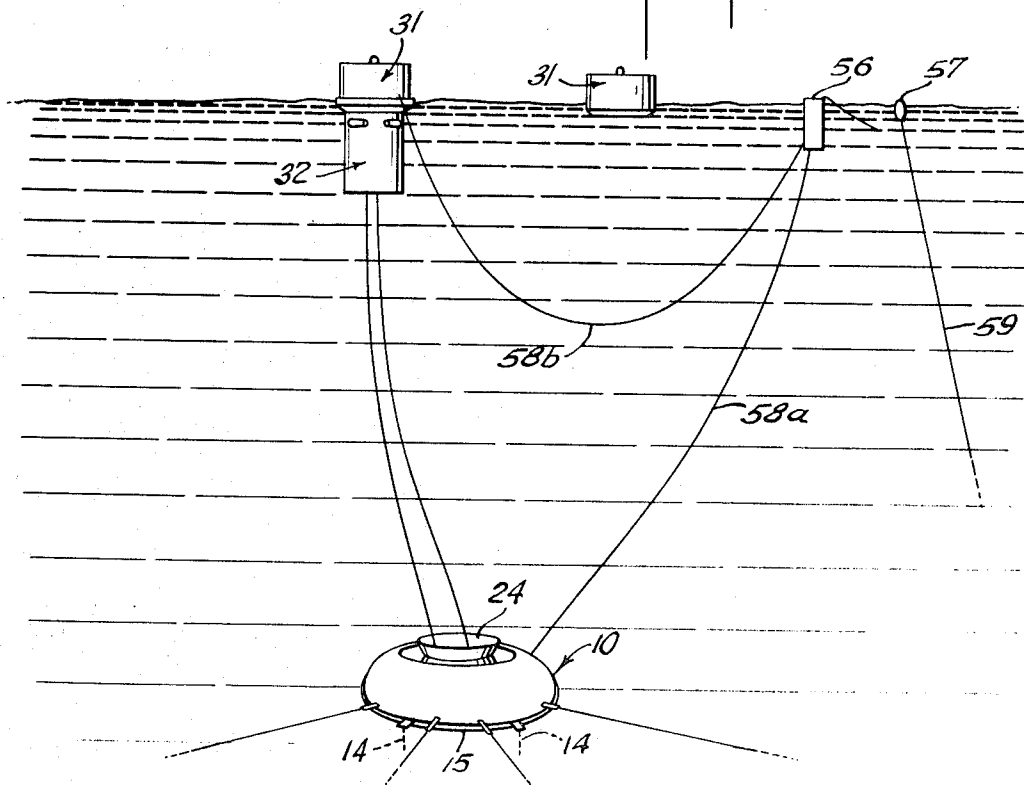


Fig. 4.



OFFSHORE LIQUID STORAGE FACILITY

BACKGROUND OF THE INVENTION

Much of the world's supply of crude oil, and present oil exploratory activity, is being carried out in offshore locations. A great deal is known today of the relatively new technology for removing the crude product from strata in the tidelands or in the immediate offshore area. However, as future sources of oil are sought farther offshore, the waters in which the drilling and producing operations will be conducted are much deeper, in the order of magnitude or 1000 feet and greater.

Efficient working in such an underwater environment poses many problems to both men and equipment, which problems have been heretofore unrealized in the normal production of crude from lesser water depths. Among the primary problems constituting a deterrent to further progress in offshore technology is the inability of the human body to withstand for extended periods of time, the high pressures encountered at deeper water conditions. As the depth of water increases the pressure will increase commensurably thereby amplifying the problems to both men and equipment associated with a successful operation.

Further, in the extraction and storage of crude product drawn from the earth, the necessity exists for provision of suitable means to bring the crude to a refinery or land storage point from the well head. The most practical, albeit expensive mode normally employed, is a pipe line extending directly from the drilling site or well head to the refinery. This expediency is utilized, however, only where the output of an offshore field promises to be of sufficient volume to warrant the high cost of a pipe line.

Another means for conveying the oil is by tankers, barges and the like, which are adapted to handle large quantities during each passage between the oil field and the refinery. The latter carrying means however, requires the use of a relatively expensive ship or tanker as well as embodying the disadvantage inherent to the slowness of such transportation. Further, ship transport necessitates the need for extensive oil storage facilities at the refinery to separate and hold varying grades of both crude and refined product.

The storage of crude oil in relatively deep waters, at or near the well head, has become a virtual necessity if deep water operations are to remain within the confines of economic practicality. It has been found that the use of completely submerged production and storage facilities embodies the primary advantage of being protected from adverse weather conditions at the water surface. Further, such a facility is subjected to a minimum degree of structural stress and wear.

The present invention in its basic form contemplates a means for overcoming the aforementioned problems by the provision of a convenient underwater storage facility. The latter embodies features for assuring a constant, rapid supply of oil from a remotely located offshore well or drilling site to a shore based refinery or storage area. It further constitutes a facility that is entirely submerged in the body of water for protection against the elements normally present at the water surface.

It is, therefore, one of the objects of the invention to provide a submerged oil storage facility of the type described adapted for remote automated control, with a minimum degree of monitoring and maintenance. A further object is to provide an oil storage facility of the type described including means for conveniently transporting oil from the facility to a shore based refinery. A still further object is to provide such a facility or storage system wherein predetermined amounts of oil in bulk form is removed periodically from a main storage pool to a shore based refinery. Still another object is to provide a system of the type described which utilizes a convenient transfer container adapted for easy conveyance to and from a storage area either in full or empty condition.

In the drawings, FIG. 1 is an environmental representation of the presently described liquid storage facility shown anchored to the floor of a body of water. FIG. 2 is a segmental

view in partial cross section of a portion of the tank and carrier vehicle shown in FIG. 1. FIG. 3 is a segmental view of an enlarged scale and is cross section, of a portion of the tank connecting means shown in FIG. 2. And FIG. 4 is an environmental view of the storage facility showing the transfer tank disconnected from the main storage tank and elevated to the water surface.

The invention in brief contemplates a main storage tank positioned at or near an offshore oil field. Said main tank is communicated with one or more dispersed well heads or tanks to receive constant flows of crude or refined oil from the latter. The main tank includes a docking facility adapted to receive a carrier vehicle or transfer tank which travels periodically, filled with oil, from the main tank to the water surface. The carrier is adapted to removably support and carry the transfer tank from the main tank to the surface in a full condition, and return a similar empty tank from the surface to the main tank.

Means are further provided for automatically connecting the main to the transfer tank when the latter is at the submerged loading position. Control means extending from the storing facility to the water surface incorporates a diver accessible buoy or capsule. Said control means is adapted to permit remote operation of the storage facility from a point at or slightly beneath the water surface without the necessity of divers approaching the depth at which the main tank is located.

Referring to FIG. 1, main tank 10 comprises, in essence, a liquid storage facility adapted to hold a relatively large quantity of crude oil. Tank 10 embodies essentially a storage compartment 11 for holding a liquid pool normally comprising quantities of oil and/or water. The storage compartment may be formed of individual separate units, or as shown, as a single compartment.

Tank 10 is formed of a base having a shell like enclosure 12 fixed to the latter to form a fluidtight connection. Shell 12 may constitute a steel fabricated assembly with internal archlike reinforcing members 16 spaced about the compartment to support the shell. However, shell 12, as well as the entire structure of tank 10, may comprise a preformed concrete container which is fabricated on land, floated to location, and thereafter controllably submerged into position either at the ocean floor or at an intermediate depth.

With main tank 10 positioned at the ocean floor, base 13 is provided with a peripheral skirt 15, or a plurality of peripherally spaced anchoring platforms adapted to receive one or more skirt piles which attach to the platform after imbedment in the substratum. While the piling method is preferred for fixedly locating tank 10 at the ocean floor, other compatible methods such as imbedment of the tank or a part of the same in the substratum, or even anchoring by cables and the like may also be followed.

Also, while the present tank includes a base 13, it is appreciated that a suitable oil storage compartment would be formed by use of an enclosure 12 without a base. In the latter instance, the shell periphery, as well as inner, lower edge are urged into the ocean substratum to form a seal.

Because tank 10 is essentially a closed buoyant storage member, its natural buoyant features are overcome by normally maintaining the tank in filled condition with water and/or oil. Thus, the tank interior may comprise, as noted, a single storage compartment or a plurality of discrete compartments. In either instance, the respective compartments are manifolded and interconnected by coacting oil as well as water pumping systems.

In the present arrangement, the single storage compartment 11 is provided with pumps 17 and 18 to regulate the capacity of compartment 11. Pump 17, for example, is positioned within compartment 11 and includes a pump suction connected to a suction conduit 19 inlet within the oil holding portion of the liquid pool and normally senses the interface of the water and oil thereby to adjust the inlet of 19 to remain within the oil section. Pump 17 includes a discharge outlet commu-

nicated with conduit 22 which passes through the wall of shell 12 and into the central cavity 24 in tank 10.

Tank 10 is arranged, as presently shown, to incorporate a central docking means whereby to accommodate at least one transfer tank 31 and/or carrying vehicle 32. Tank 10 is therefore provided with a generally circular disposition or semitaurus configuration which defines internal cavity 24 surrounded by the inner walls of shell 12. The primary function of central cavity 24 is to guidably receive the transfer tank 31 and to protect the same from external forces such as ocean currents and underwater disturbances which would tend to displace the tank.

The docking facility disposed within cavity 24 includes primarily a foundation member 26 normally formed of concrete or the like, connected to tank shell and being at least partially imbedded into the ocean floor. Foundation 26 functions to receive and support carrier vehicle 32 as well as transfer tank 31. A guide structure 28 positioned at the upper end of cavity 24 includes a ringlike member for receiving and guiding the downward moving carrier vehicle 32 into proper docking position on foundation 26.

Referring to FIGS. 2 and 3, the docking facility further includes upstanding discharge tube 23 which connects at one end to conduit 22 for carrying a stream of oil from the tank 10 interior, into transfer tank 31. The upper end of discharge tube 23 is provided with a sealing nozzle 27, so formed and adapted to engage a corresponding receptacle in the lower wall of tank 31 to sealably register within the latter.

Carrying vehicle 32 and tank 31 are removable from the docking facility within cavity 24 to permit the transfer tank to be raised in full condition to the water's surface. While docking facilities presently shown are contained within the confines of main tank 10, this illustrates a desired arrangement which affords maximum protection to the carrier 32 and tank 31. In a similar manner, a suitable, protected docking facility could be disposed adjacent to or spaced from the tank 10 with appropriate connections extending therebetween for carrying oil to the moored transfer tank 31.

The primary function of vehicle 32, shown in FIGS. 2 and 4, is to convey one or more filled transfer tanks 31 to the water's surface and thereafter to return a similarly empty tank for connection to main tank 10. Vehicle 32 comprises a generally cylindrical body 33 adapted to be remotely controlled and submerged in a body of water in the manner of a submarine type vessel. Body 33 includes an upper engaging face 34 at one end, and a seating ring 36 at the other or normally lower positioned end. Body 33 is made controllably buoyant by a series of ballast tanks 37 spaced longitudinally of the unit. Said ballast tanks are controlled by a piping system interconnecting the respective tanks connected to pumps 38 and 39. The buoyancy system operates in general as does any fluid system, being adjustable to regulate the attitude of vehicle 32 normally in an upright position while the latter supportably carries a tank 31.

In one embodiment, the upper engaging face 34 of vehicle 32 is substantially dish shaped with an upstanding peripheral rim 41. Face 34 is adapted to engage, and securely hold to the corresponding base of tank 31. Clamping means 43 spaced about the rim 41 firmly lock the transfer tank and engaging face into a tight unit during the loading and transporting phases.

Axial passage 44 extends the entire length of the vehicle body 33 and registers the upstanding discharge tube 23 when the vehicle is docked at main tank 10. A guide ring 46 in the form of radially extending arms is carried on tube 23. The function of said ring is to provide lateral support to elongated discharge tube 23 prior to the latter engaging the inlet receptacle tank 31.

To facilitate manipulating the carrier vehicle 32 between the water surface and main tank 10, a guidance system is provided for affecting the attitude of the transfer tank 31 in response to a given situation. Said guidance systems include a plurality of attitude thrusters 47 carried on the external sur-

face of the body 33. These thrusters comprise in effect, a variable speed, motor driven propeller unit. Each thruster is adjustably mounted on a pivotal connection for controllably urging the carrier into any direction for proper alignment either with main tank 10 during a lowering operation, or with an empty transfer tank 31 while the latter is floated at the water surface.

The lower end of vehicle 32 is provided with means for connecting to one or more tethering cables 48. The latter are positioned within, or adjacent to foundation 26 and are normally, when the carrier vehicle is in a docked position, wound upon motor driven reels 49. The latter are powered for tethering or controlling the passage of vehicle 32 through the water, supplemental to the vehicle's buoyancy controls.

In one embodiment, tank 31 comprises, in effect, a rigid walled, cylindrically formed tank including base 42 to which is affixed closed cap 45. Base 42 includes a peripheral lip 52 which conforms in general to the corresponding rim 41 and engaging face 34 of carrier vehicle 32. When the respective carrier vehicle 32 and tank 31 are in locked engagement, axial passage 44 of the vehicle is disposed in alignment with entry receptacle or coupling 51 carried in the base 42 of tank 31.

As shown in FIG. 4, when in the docked position, the respective carrier vehicle 32 and transfer tank 31 are so positioned that conduit 23 protrudes into the interior of tank 31. Thus, the base 42 is provided with self-sealing receptacle 51 which includes a center opening adapted to guidably receive forward nozzle 27 of conduit 23. When so received receptacle 51 locks on to and holds the nozzle, 27 thereby forming a fluidtight holding seal to permit oil to be pumped from main tank 10 through conduit 22, and thereafter through tube 23 and into the transfer tank.

As shown in FIGS. 2 and 3, with the carrier vehicle 32 in a proper seated position on foundation 26 and held by the tethering cables 48, a stream of oil is automatically fed to the transfer tank 31. Simultaneously, the internal pressure in the tank is stabilized by a vent and safety valve 53. When tank 31 is filled to a desired level, the carrier vehicle 32 is activated by increasing the buoyancy thereof thereby permitting the transfer tank 31 to become disengaged from main tank 10. Upward withdrawal of tank 31 separates tube 23 and nozzle 27 from receptacle 51, thereby causing the latter to assume a closed, locked position to avoid the further passage of oil or water therethrough.

As shown in FIGS. 1 and 4, the storage facility is automatically operable to avoid unnecessary use of divers in water great depths at which the system is designed to operate. There is thus provided a buoy or diver access capsule 56 which is normally positioned beneath the surface of the water and attached to a floating marker buoy 57. The function of the latter is to locate the position of the storage system on the water surface without providing a navigational hazard. Buoy 57 further maintains the lower most control buoy 56 in a submerged although accessible depth. Buoy 56 is connected through an umbilical line 58 which comprises one or more cables which extend from buoy 56 to the respective main tank 10, transfer tank 31 and carrier 32. Each of said elements is thereby controllable electrically and/or pneumatically to the extent that the fluid pumping and monitoring facilities are accessible from the water surface.

The buoy arrangement is preferably spaced laterally from main tank 10 and anchored to the ocean floor by means of a suitable anchor and anchoring line 59.

OPERATION OF THE SYSTEM

In the normal filling position as shown in FIG. 1, carrier vehicle 32 and tank 31 are firmly docked within the cavity 24 of main tank 10. As so positioned, discharge tube conduit 23 is the sealably registered in receptacle 51 in the lower wall of tank 31 thereby automatically latching to the same. In such condition pump 17 within the main tank 10 is automatically actuated to introduce a stream of oil through the pump by way

of conduit 22 and discharge tube 23 into the tank 31. The stabilizing or float control mechanism 21 maintains the inlet of pipe 19 in communication with the oil pool held within the tank as the level of the same decreases during the loading operation or rises when the water volume increases.

Automatic control of the flow of oil from main tank 10 to transfer tank 31 is achieved by sensing means which monitors the condition of the oil volume in the main tank 10. As oil is pumped into the pool of main tank 10, a commensurable amount of water is simultaneously removed by way of pump 18. Tank 10 is thus maintained liquid filled at all times thereby precluding a pressure differential across the tank walls which would otherwise impose a stress on the latter.

In a preferred procedure for operating the disclosed storage system, the automatic pumping controls will be programmed such that tank 31 will achieve a condition of fullness periodically. For example, transfer tank 31 might be filled once with in a 24 hour period and thereby achieve a condition to be raised to the water surface on a daily basis. Therefore, during the entire filling period of tank 31, the latter is completely immersed usually at the floor of the body of water thereby being removed from natural hazards normally inherent to being near to or protruding from the water surface.

To facilitate operation of the described storage facility tank 31 is removed after being raised to the water surface. Simultaneously, the removing vessel such as a helicopter, ground effect vehicle or the like may attach to tank 31 as by holding ring 54, for carrying the latter to a storage area. The removing vessel will thus advantageously carry a second or empty tank 31 to the storage site; deposit the same to float on the water surface in the vicinity of the storage facility. With filled tank 31 raised above the water's surface as shown in FIG. 4, the removing vessel then attaches to tank 31 for removal thereof after being disengaged from carrier 32.

The entire operation may be facilitated by personnel through the control capsule 56 which is raised to the water surface. However, it may also be achieved by maintaining capsule 56 at diver access such that the capsule will remain submerged and in a protected atmosphere.

With the full tank 31 disconnected from carrier vehicle 32, the latter is stabilized by the water controlled alteration of its buoyancy and by regulation of attitude thrusters 47 whereby the vehicle is brought in a submerged condition beneath the empty tank 31. The vehicle 32 is then manipulated into engaging contact with the lower surface of the empty tank 31 and fastened to the same. Again by regulating the buoyancy of the carrier vehicle, the latter is caused to submerge and carry the empty tank 31 to its loading position as shown in FIG. 2 at the main tank 10.

Operation and use of the disclosed facility has been illustrated with reference to the storage of liquids including sea water together with crude oil. It is understandable, however, that other liquids or combination thereof could be as readily stored and transferred.

While the foregoing description encompasses one embodiment of the inventive concept, it is appreciated that certain changes and modifications can be made therein without departing from the spirit and scope of the invention as defined in the following claims.

I claim:

1. A submerged offshore facility for storing oil and other liquids which includes;

a. a main liquid storage tank adapted to be positioned beneath the surface of a body of water, said liquid storage tank having a liquid holding compartment communicated with at least one remote source of said oil to receive and form a pool thereof in said compartment;

b. a discharge tube having an inlet at one end communicated with said liquid holding compartment whereby said inlet opens into said pool, and a discharge nozzle at said tube other end disposed externally of said main tank;

c. a transfer tank having a liquid storage chamber, coupling means depending from said transfer tank and communicated with said main tank holding compartment for receiving a flow of liquid from the latter, said coupling means being adapted for automatic removable connection with said discharge nozzle to form a flow passage therethrough during transfer of liquid therebetween, whereby said transfer tank, holding a quantity of said liquid may be elevated to the water surface for removal from said storage facility.

2. In a storage facility as defined in claim 1 including at least one tethering cable restrainably connecting said main tank to said transfer tank for guiding the latter during movement thereof between said main tank and the surface of said body of water.

3. In a storage facility as defined in claim 1 including a docking slip means positioned adjacent to said main tank and being adapted to receive and align said transfer tank for loading thereof, said discharge tube nozzle protruding from said main tank into said docking means for engaging said transfer tank coupling means when the transfer tank is guidably urged into said docking slip.

4. In a storage facility as defined in claim 1 wherein said main liquid storage tank includes a shell forming an enclosure about said liquid holding compartment, and a cavity defined in said shell, said cavity including docking means for removably engaging said transfer tank prior to introduction to the latter of said flow of liquid said discharge nozzle at said tube other end being disposed in a generally upright disposition within said cavity.

5. In a storage facility as defined in claim 1 including; a carrier adapted to detachably engage said transfer tank and said main tank respectively, and control means connected to said carrier for remotely controlling and guiding the same during passage thereof between the main tank and the water's surface, said carrier including a controllably submersible body having a face at one end adapted to engage said transfer tank, and seating means at said body other end adapted to slidably engage said discharge tube.

6. In a storage facility as defined in claim 2 including a cable windup mechanism positioned at said main storage tank and being operable to maintain tension on said at least one tethering cable during movement of said transfer tank between said main tank and the water surface.

7. In a storage facility as defined in claim 5 wherein said carrier further includes buoyancy tanks located therein and a pumping means communicated with said buoyancy tanks regulating the attitude of said carrier in the water.

8. In a storage facility as defined in claim 5 wherein said control means includes at least one control cable extending from a position adjacent to the water surface to said main storage tank, and a submerged control capsule operably connected to the upper end of said control means.