

[54] **LIQUID STORAGE FACILITY
INCLUDING SELF-ACTUATING
DISCHARGE CONDUIT**

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141/279

[51] Int. Cl. B65h 75/38

[58] Field of Search 141/387, 388; 138/103, 118,
138/119, 178; 291/294; 137/355.16-355.28, 615,
236; 9/8; 141/279, 284; 61/46, 46.5; 166/5

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[57] **ABSTRACT**

The invention relates to an underwater storage facility particularly adapted for holding a hydrocarbon liquid having a specific gravity less than the specific gravity of water. The facility includes a liquid storage tank fixedly positioned beneath the water's surface usually at the ocean floor. A network of conductors communicates the storage tank with one or more offshore wells whose production is delivered to the tank. A discharge conduit communicated with said tank, when in operating position extends to the water's surface. When in a non-operating position, the conduit is coiled into a compact bundle at the tank whereby to be beyond the reach of floating vessels, and yet not subject to abrasive wear at the ocean's floor.

7 Claims, 7 Drawing Figures

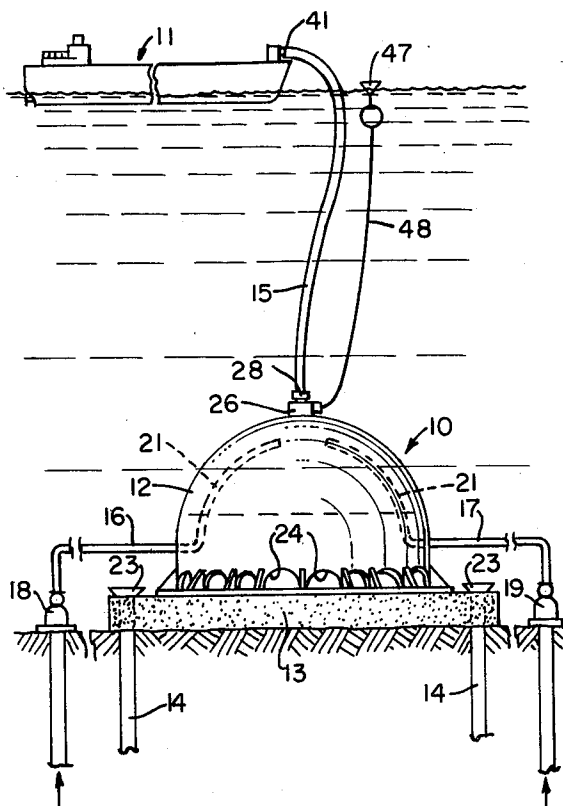


FIG. 1

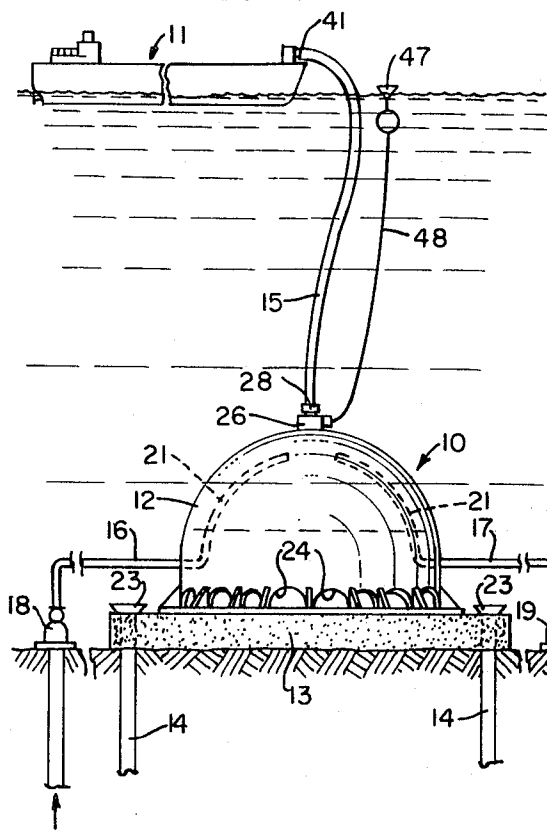


FIG. 2

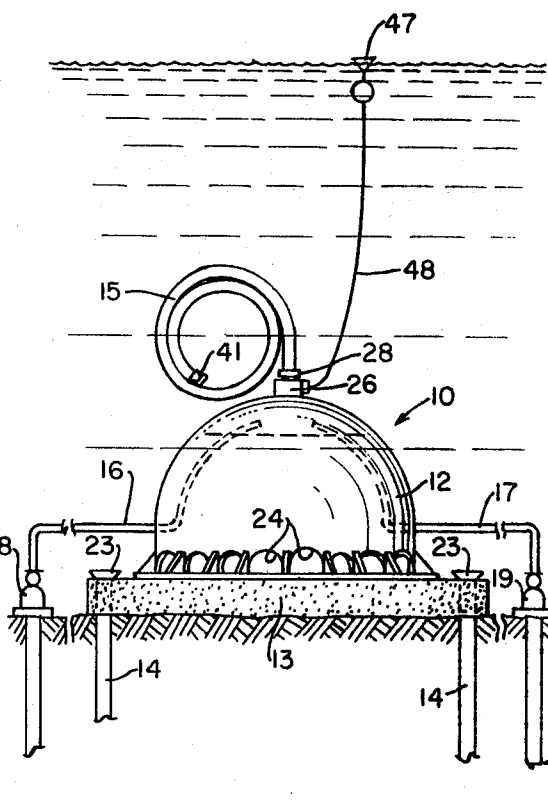


FIG. 3

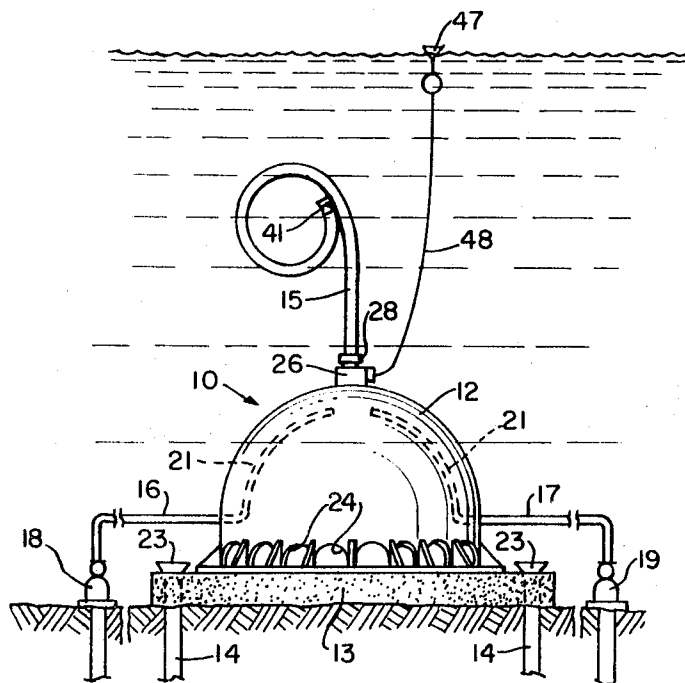


FIG. 4

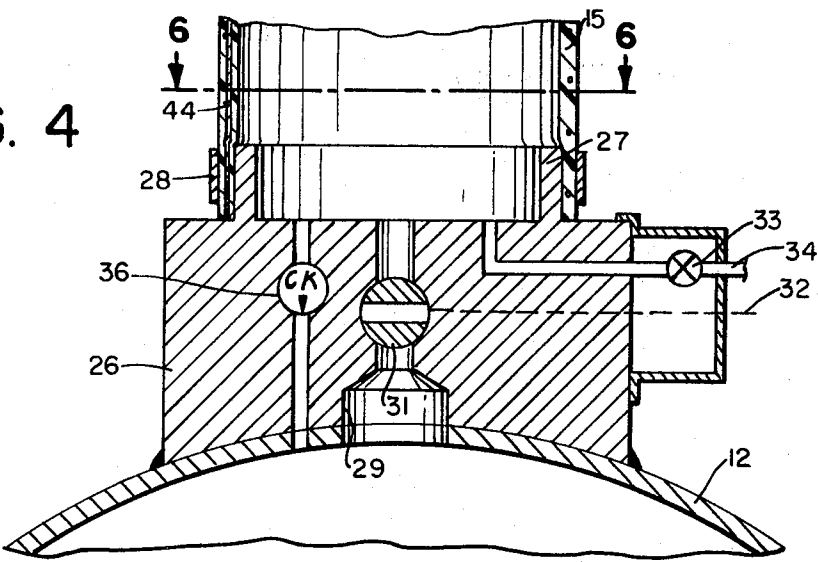


FIG. 5

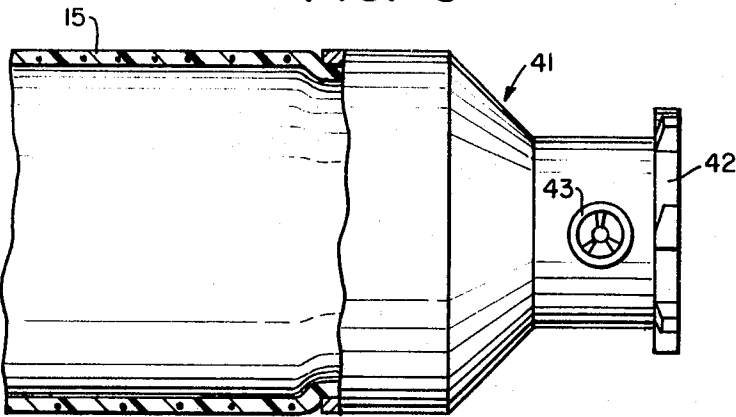


FIG. 6

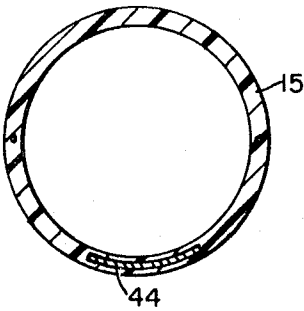
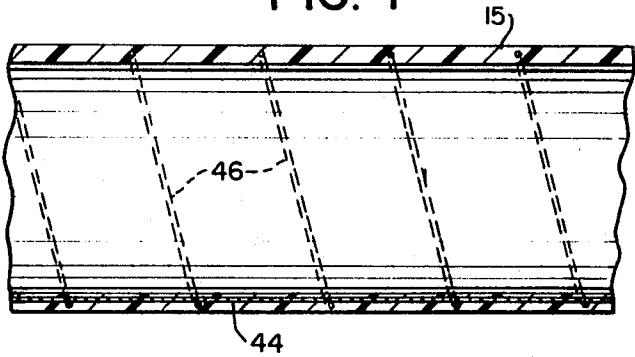


FIG. 7



LIQUID STORAGE FACILITY INCLUDING SELF-ACTUATING DISCHARGE CONDUIT

BACKGROUND OF THE INVENTION

In the continuing search for new crude oil sources in offshore water, the depth of the latter is progressively increasing as the search goes further offshore. With the increased water depth, usually the distance from a refinery or other land based storage terminal or refinery increases. It has been found expedient, particularly in the instance of remotely positioned offshore oil fields, to at least partially process and store the field's production until it can be removed by tanker, barge or other vessel.

Since a pipeline to such a field usually involves great expense and is non-salvageable, economic factors demand that such a facility be practical both from an operating point of view, and be mobile to insure an extended life.

At least one problem associated with all equipment used in offshore oil operations is the exposure of such equipment to the elements. Further, the equipment is frequently located at the water's surface and thereby constitutes a navigational hazard.

As the water depth increases, such underwater facilities become increasingly difficult to operate. This is due primarily to the present sparsity of technology related to great water depths, and the inability to provide personnel to maintain and operate such a facility. Notably, when the water depth exceeds convenient diver access depth, the entire unit must be operated remotely or with the aid of submersible vessels.

Of further consideration, surface based facilities are not only exposed to weather conditions such as wind and turbulent waters, but such exposure increases the possibility of accidental pollution of the surrounding environment. When however, a storage and/or processing facility is submerged and positioned at or near the ocean floor, a wear problem is introduced by movement of the facility such as connecting lines and pipes across the ocean floor, which movement tends to abrade the latter through constant rubbing against the floor. When the floor is primarily sandy, it can be appreciated that abrasive wear will be quite severe.

Toward overcoming the above delineated problems and operating conditions in offshore waters, there is here provided a novel storage facility adapted to be submerged beneath the ocean's surface and preferably anchored to the floor thereof. The facility includes at least one storage tank having a base adapted to be fixedly positioned at the ocean floor by piling, anchoring or other means. The tank is communicated with the water's surface by an elongated conductor means comprising a resilient, or flexible discharge conduit. The latter not only extends toward the surface, for discharging crude oil, but when not being used is coiled into a compact convenient bundle for convenient storage above the ocean floor beyond reach of abrasive and wearing elements.

DESCRIPTION OF THE DRAWINGS

In the drawings,

FIG. 1 illustrates a facility of the type contemplated including a storage tank communicated with a surfaced vessel by means of a resilient discharge conduit.

FIG. 2 is similar to FIG. 1, showing the flexible conduit in the contracted position.

FIG. 3 is similar to FIGS. 1 and 2, illustrating the flexible conduit in a state of partial erection.

FIG. 4 is a segmentary view on an enlarged scale and in cross-section showing the top portion of the storage tank.

FIG. 5 is a segmentary view in partial cross-section and on an enlarged scale showing the upper end of the flexible conduit.

FIG. 6 is a cross-section taken along the line 6—6 in FIG. 4.

FIG. 7 is a cross-sectional view along line 7—7 in FIG. 6.

Referring to FIG. 1, the contemplated underwater storage facility 10 is shown in the preferred operating position whereby a stream of hydrocarbon liquid such as crude oil is

delivered through a flexible discharge conduit 15 to a surface based tanker 11. A storage tank 12 is mounted to a foundation pad 13 which in turn is fixed to the ocean floor by peripherally disposed piles 14. The latter are at least partially imbedded into the substratum and connected at the upper end thereof to pad 13. In any event, tank 12 is rigidly held to avoid being buoyed upwardly, or displaced laterally.

Storage tank 12 is communicated by a distribution network of conductors 16 and 17 that extend from the tank lower end to remotely positioned well heads 18 and 19. The latter, in the manner of such wells, extend into the substratum and are provided at the upper ends with the usual control equipment to choke down the pressurized flow of liquid and gases being emitted from the wells. While not presently shown, the distribution network further includes means for separating gas from the liquid product whereby the separate streams can be passed to appropriate facilities.

As shown in FIG. 1, the interior of liquid storage tank 12 is communicated with the surrounding water whereby to stabilize internal pressure. Further, said arrangement facilitates the creation of a water-oil interface within the tank whereby solids will tend to separate by gravity flow from the crude oil and fall to the tank floor. The liquid distribution system further includes one or more internal manifolds such as lead in pipes 21 that introduce flows of crude oil to the upper end of the tank whereby to displace water and form a pool at the tank top. At the oil pool increases in volume the resulting water-oil interface will be depressed further toward the tank floor.

The unit functions on the presumption, as is normally the instance, that the hydrocarbon fluid or crude oil passing from the various wells will have a specific gravity less than the surrounding environment, which is normally sea water. Further, and as previously mentioned, hydrocarbon product removed from the respective wells 18 and 19 will be pre-separated into liquid and gaseous phases whereby substantially the entire content of tank 12 will be in liquid form.

The storage facility is usable at virtually any depth of water. However, its most desirable features are accentuated in the instance of relatively deep waters of 300 feet and deeper, which depth exceeds normal diver access depth.

Base member 13 comprises a relatively rigid foundation pad formed of steel or reinforced concrete, which is prefabricated at the water's surface and floated into position. To facilitate use and subsequent salvage of tank 12, base 13 can be provided with buoyancy means such as internal buoyancy tanks communicated with a suitable pumping system for controllably regulating the buoyancy of the unit.

The periphery of foundation pad 13 includes means such as funnel piece 23 to guide the respective piles 14 into the substratum wherein the tank will be retained. Such piles are in the normal manner positioned about the tank and subsequently driven into the substratum by pile driving means at the water's surface. The piles are then cemented or otherwise fastened to the foundation pad.

Tank 12 is supportably positioned on the foundation pad 13 and connected to the latter in such manner as to prohibit movement therebetween. As shown, the tank 12 may comprise in essence a rigid steel or reinforced concrete hemispherical shell having openings 24 spaced about the lower end thereof to communicate the shell interior with the surrounding water. Since the stored crude oil will exert a substantial buoying effect on the tank 12 top wall, the latter must be of sufficient strength and thickness to withstand tensional stresses introduced into the tank walls.

Tank 12 can be fabricated of a non-rigid material such as a reinforced resilient plastic or the like. The latter however would limit the size of a tank in view of the upward force exerted by stored oil particularly when the tank is in a full condition.

Tank 12 can also be fabricated of a rigid material such as reinforced concrete in the form of a hemisphere as presently shown, or an appropriate geometric shape best adapted to withstand the pressures at the subsea location as well as the in-

ternal pressures exerted by the upward lift of the stored crude oil. The upper end of tank 12 is provided with cap means 26 to accommodate flexible discharge conduit 15 which is extendable to the water's surface.

Referring to Figure 4, the upper end of tank 12 is provided with a cap 26 having a central body from which a peripheral rim 27 extends upwardly. Said rim 27 is adapted to receive and form a fluid tight annular seal with the wall of flexible conduit 15. As shown, conduit 15 is closely fitted against the rim outer edge and held in place by a peripheral clamping means 28 such as a circular, contractable ring having intermittent means to tighten the ring into sealing contact with conduit 15.

A central passage means 29 formed in said cap 26, communicates the interior of tank 12 with the upper positioned conduit 15. Flow control valve means disposed in said passage means 29 includes in the instant arrangement, an actuatable closure element 31 having a lateral valve actuator 32 extending therefrom to the cap exterior. The actuator is provided with transmission means communicated with the water's surface whereby said control valve 31 can be remotely controlled through a hydraulic, electrical or mechanical medium. Preferably, and from a safety point of view, actuation of control valve 31 embodies at least two optionally usable systems whereby the unit can still be operated in the event that one of the control facilities should become inoperable.

A second valve 33 disposed within cap 26 includes an inlet opening 34 communicated with the surrounding water such that the outlet is communicated with the conduit 15 interior. Thus, conduit 15 can be communicated with an external source of water by actuation of said valve 33 to open position. The latter functions primarily for flushing or purging conduit 15 of crude oil at such time as the latter is to be returned to its retracted position at the ocean floor.

Third valve means embodied in the cap 26 includes a pressure sensitive safety valve 36. Said valve is arranged such that an undue build-up of pressure within the tank 12 will automatically actuate the normally closed valve 36 to open position. Thus, with the excessive build-up of pressure within tank 12, safety valve 36 will be automatically opened to pass a flow of crude oil into conduit 15 rather than have the tank filling beyond its capacity with the undesired consequence of prompting a water polluting situation.

Conduit 15 as mentioned herein, is constructed as to permit said member to assume either an extended or retracted position. In the retracted position as shown in FIG. 2, conduit 15 is in essence coiled upon itself and supported at the upper side of the tank 12. When so positioned, conduit 15 is submerged well below the surface of the water and consequently will not constitute a navigational hazard.

Said conduit structurally comprises an elongated flexible member having walls which define one or more closed passages. The conduit is fabricated of a material such as nylon or other non-corrosive material and can be of a diameter appropriate to the size and capacity of tank 12. Conduit 15 lower end as mentioned is communicated with the tank cap 26 and sealably fastened to the latter by ring 28. As shown in FIG. 5, the conduit upper end is provided with a head 41 adapted to connect to a corresponding fitting on tanker 11, barge or other floating facility whereby to permit a flow of crude oil from tank 12 to said tanker.

Head 41 as shown, includes a metallic body incorporating a flange 42 having means therein to engage connecting lugs or bolts carried on a mating tanker loading flange. One or more control valves within head 41 are manually operable by control means 43 extending externally to the head. Normally, with conduit 15 in the closed or contracted position, the respective control valve or valves are set to a closed position. Thus, there will be no flow of oil from tank 12 to the conduit head 41, thereby precluding the inadvertent passage of oil from the conduit into the surrounding waters.

Said head control valve or valves will remain in closed condition until such time as head 41 is connected to a loading flange on a tanker at the water's surface. Thereafter, the con-

trol valves 43 are opened to allow a controlled flow of crude oil to pass upwardly through conduit 15 and into tanks on the floating vessel.

Conduit 15 as mentioned, is fabricated of a relatively heavy walled non-rigid material such as nylon. Since conduit 15 will at all times be filled with liquid, either water, oil, or a mixture thereof, there will be no appreciable external pressure exerted on said walls regardless of water depth.

Referring to FIGS. 6 and 7, to facilitate the back coiling of conduit 15 into its retracted position, a self-coiling mechanism is incorporated into the conduit wall. One embodiment of said element includes an elongated, prestressed metal strip 44. Tensional stress induced into said strip 44 will normally urge conduit 15 into the above noted coiled or retracted position above the floor of the ocean. To further strengthen the conduit, whereby to maintain a predesired cross-sectional configuration thereof, the conduit walls are provided with a reinforcing element such as a helically formed spring member 46, imbedded therein to provide the desired rigidizing characteristic.

Operationally, with conduit 15 in the retracted or coiled position, the conduit head 41 is centrally located with the entire conduit wound about said head in a substantially vertically oriented disposition. In such a position conduit 15 will be filled with water.

As the storage area within tank 12 becomes at least progressively filled with crude oil, the water-oil interface will be depressed toward the tank 12 lower end. Sensor means is provided within tank 12 to monitor the position of the interface whereby the tank can be unloaded at a predetermined maximum point of loading. Such monitoring means can include any one of several known systems such as a remotely positioned indicator at the water's surface, or transmitting means such as a shortwave transmitter adapted to deliver a signal to a shore based location indicating the condition of the storage tank.

At such time as it becomes expedient to unload all or a part of the stored liquid, tanker 11 is anchored above the storage facility. The respective control valves 31 and 33 at the tank 12 are connected to a remote control cable 48 extending to the water's surface, which in turn is buoyed by float 47. Thus, with the tanker 11 in position, the respective control valves are opened to communicate the tank interior with the water filled conduit 15.

Because of the density differential existing between the oil and the water, the crude liquid will gradually rise into the conduit 15 thereby displacing the water which will in turn pass to the bottom of tank 12. As the buoying force within the conduit 15 is increased by the presence of the oil, said force will overcome the coiling or retracting force of the strip element 44, whereby to progressively straighten the conduit 15 until head 41 is at the water's surface.

With conduit head 41 above the surface, it can be sealably connected to a loading connection on the tanker 11. Thereafter, by opening the flow control valve 43 in the conduit head 41, crude liquid can be transferred from the storage tank 12 into the tanker 11 as required.

The loading operation is terminated by substantially discontinuing flow from the storage tank 12 into the conduit 15 by choking down the control valve 31. Simultaneously, purging valve 33 communicated with the surrounding sea water is opened.

Continued upward movement of the crude oil column through the conduit 15 will permit the sea water to enter and likewise rise through conduit 15. At such time as said conduit 15 is evacuated of oil and filled with water, control valve 43 at the head 41 is closed. At this point the conduit 15, being filled with water, will consequently lack the previously noted buoying force exerted by the contained crude oil. Thus, as the head 41 is released from tanker 11, the recoiling action of the spring element 44 will cause the conduit head to be slowly submerged beneath the water and the entire conduit to be self-coiled about the head at the storage tank.

While conduit 15 is herein disclosed as being coiled closely upon itself when contracted, the essential purpose of such a disposition is to submerge the conduit beneath the water's surface and yet maintain it above the ocean floor. Thus the conduit will not interfere with floating vessels, nor will it suffer abrasive wear by moving about said floor.

Further, the conduit is disclosed as normally maintained full of either water or crude product. However, for optimum operation, the conduit can, by regulation of the various control valves, be buoyantly adjusted to hold a desired position in the water.

Obviously many modifications and variations of the invention, as hereinafter set forth, may be made without departing from the spirit and scope thereof, and therefore, only such limitations should be imposed as are indicated in the appended claims.

We claim:

1. In an underwater facility for storing a hydrocarbon liquid having a specific gravity not exceeding the specific gravity of water, and being immersed at an offshore location, said facility including;

a liquid holding storage tank positioned beneath the water's surface at said offshore location and being fixed to the ocean floor,

pipng means communicating said liquid holding storage tank with at least one source of said hydrocarbon liquid, conductor means having opposed upper and lower ends for directing said liquid from said liquid holding storage tank to a floating vessel, said conductor means including, an elongated resilient discharge conduit having said lower end communicated with said storage tank and being of sufficient length to dispose the upper end thereof beyond the water's surface, and said discharge conduit being ad-

justable between an extended position with said upper end disposed beyond the water's surface, and a retracted position, wherein said upper end is immersed beneath said surface,

flow control means carried on said conduit and being operable to regulate the liquid flow therethrough, and means for controllably adjusting said conduit between said retracted and extended positions and comprising, valve means disposed at said discharge conduit lower end and being actuatable to selectively deliver a stream of crude oil or water to said discharge conduit lower end.

2. In an underwater facility as defined in claim 1 including; control means connected to said valve means and being operable to regulate said valve means from the water's surface to remotely regulate the disposition of said discharge conduit between said extended and retracted positions.

3. In an underwater facility as defined in claim 1 wherein said discharge conduit includes; a flexible walled cylindrical member having longitudinally extending retracting means incorporated therein.

4. In an underwater facility as defined in claim 3 wherein said retracting means includes; an elongated spring member imbedded longitudinally in a wall of said conduit.

5. In an underwater facility as defined in claim 3 wherein said elongated spring member includes; a metallic strip imbedded along one wall of said conduit and being prestressed to normally urge the spring into a coiled disposition.

6. In an underwater facility as defined in claim 3 wherein; said discharge conduit is formed of a non-metallic resilient material.

7. In an underwater facility as defined in claim 6 wherein; said material is nylon.

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