

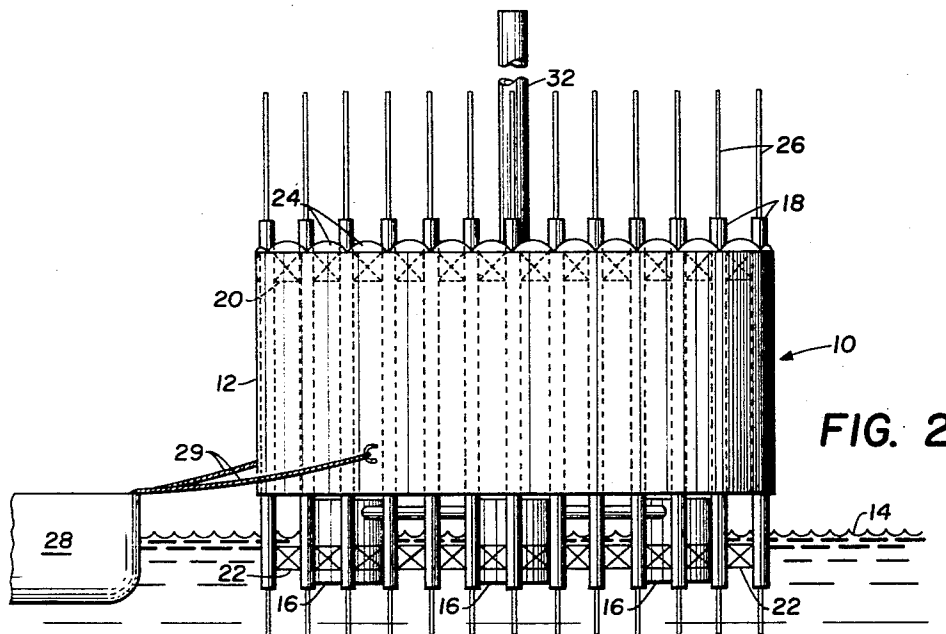
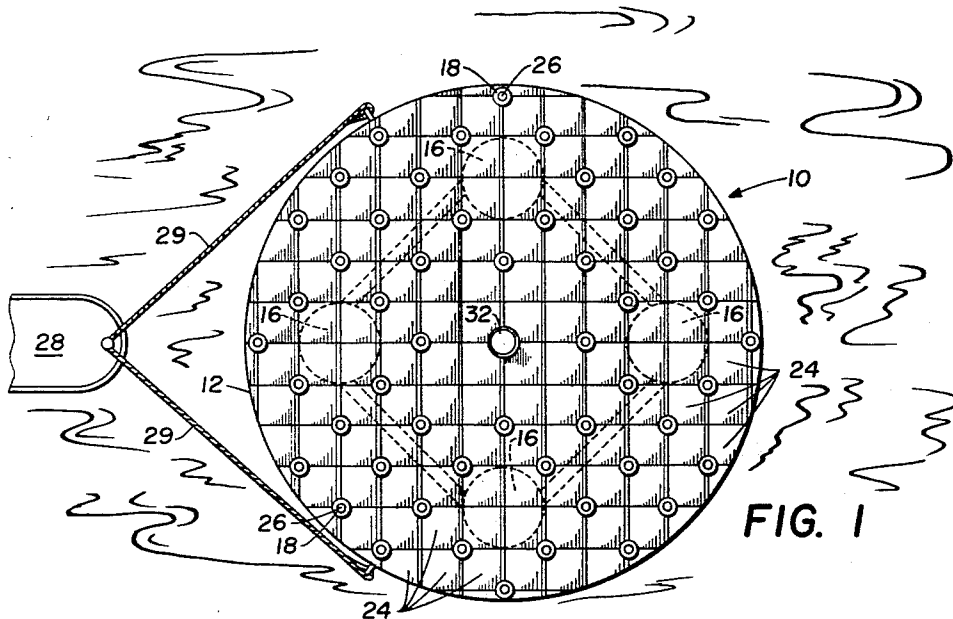
Aug. 13, 1968

W. F. MANNING
STORAGE TANK FIXED ON THE OCEAN BOTTOM
AND METHOD OF INSTALLATION

3,396,544

Filed Nov. 7, 1966

5 Sheets-Sheet 1



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Filed Nov. 7, 1966

STORAGE TANK FIXED ON THE OCEAN BOTTOM AND METHOD OF INSTALLATION

5 Sheets-Sheet 2

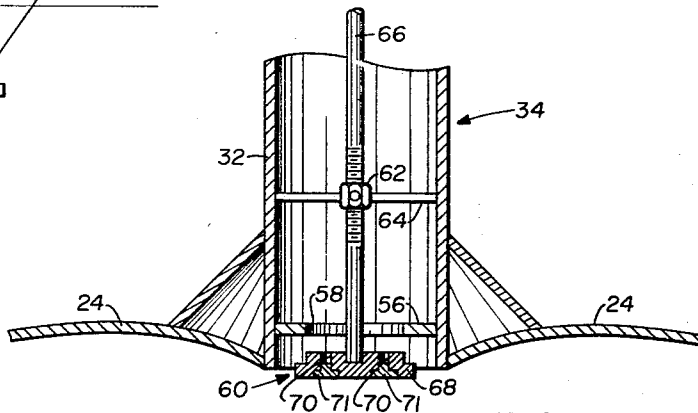


FIG. 4

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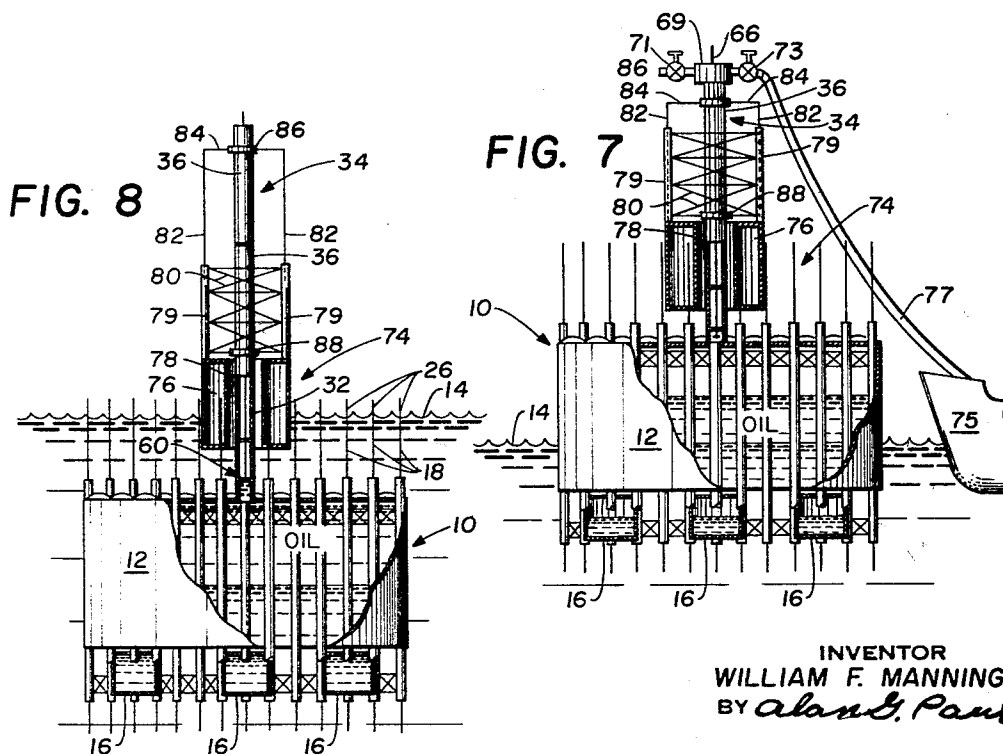
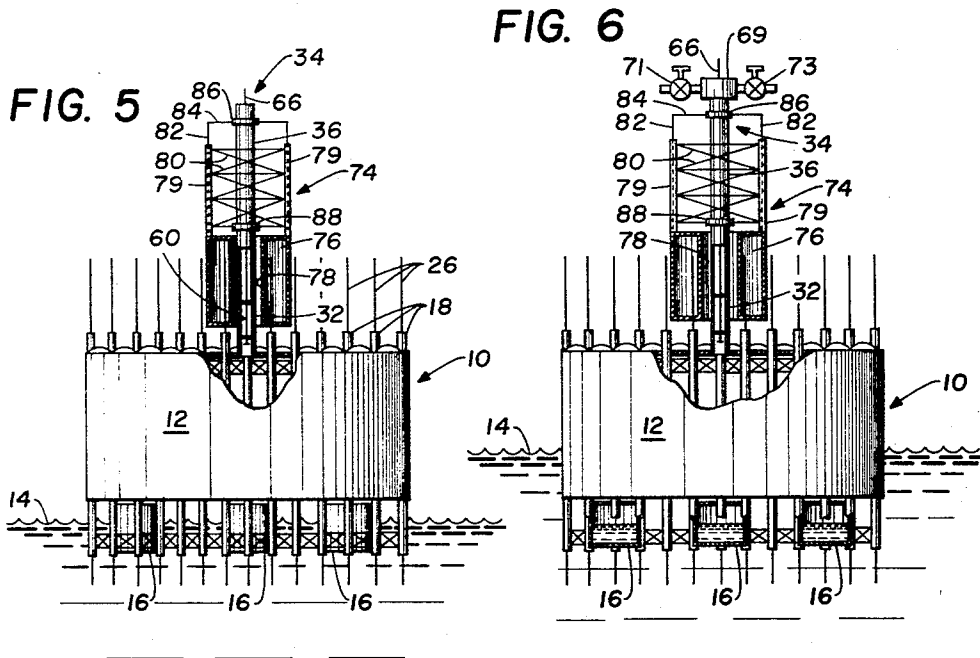
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5 Sheets-Sheet 3



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5 Sheets-Sheet 4

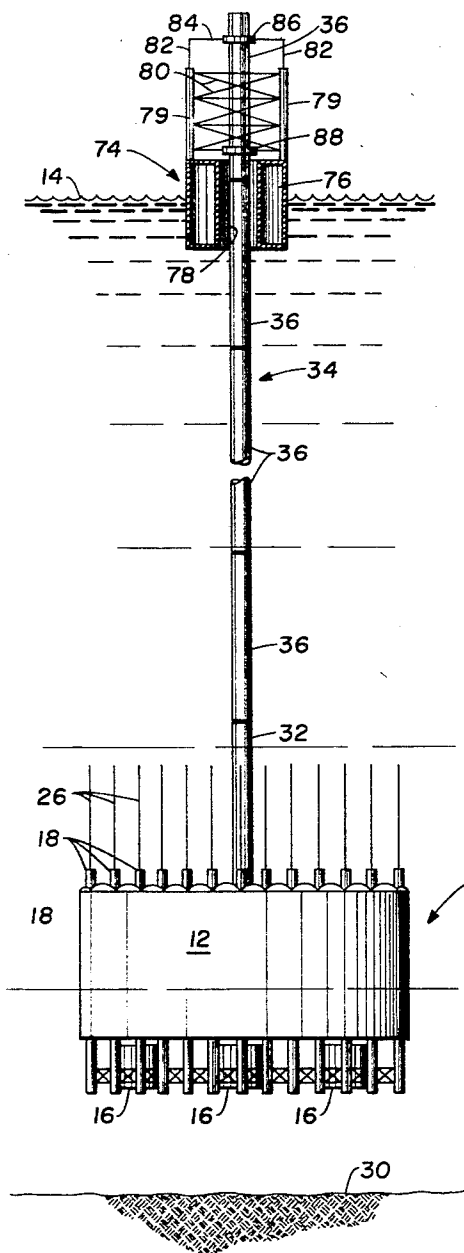


FIG. 9

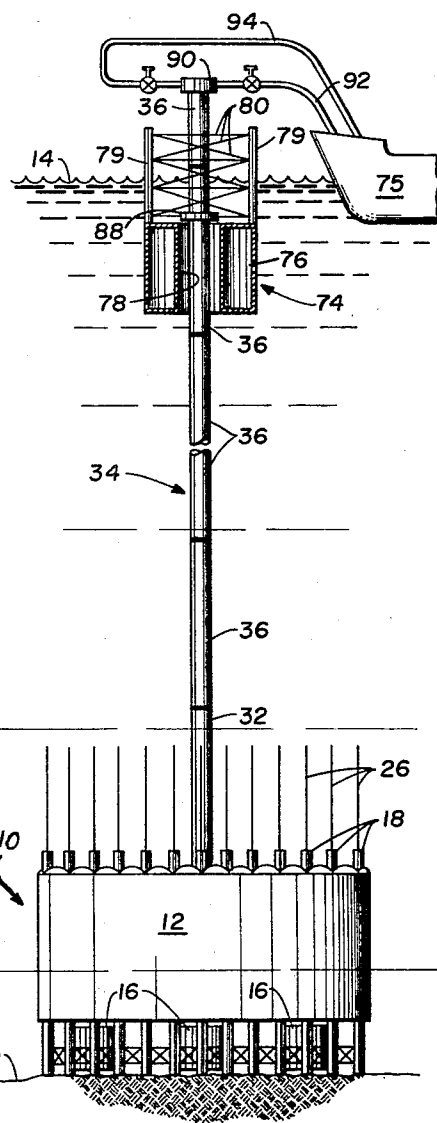


FIG. 10

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Filed Nov. 7, 1966

5 Sheets-Sheet 5

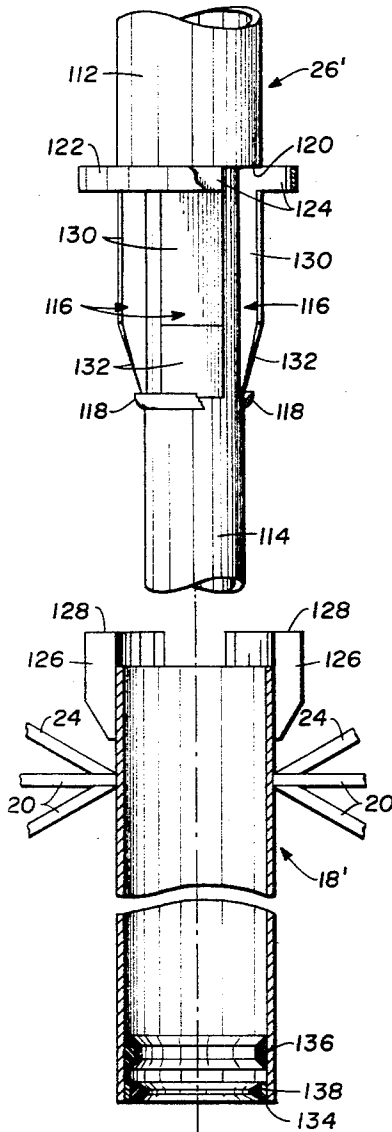


FIG. 12

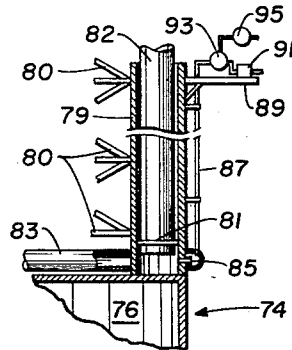


FIG. 5A

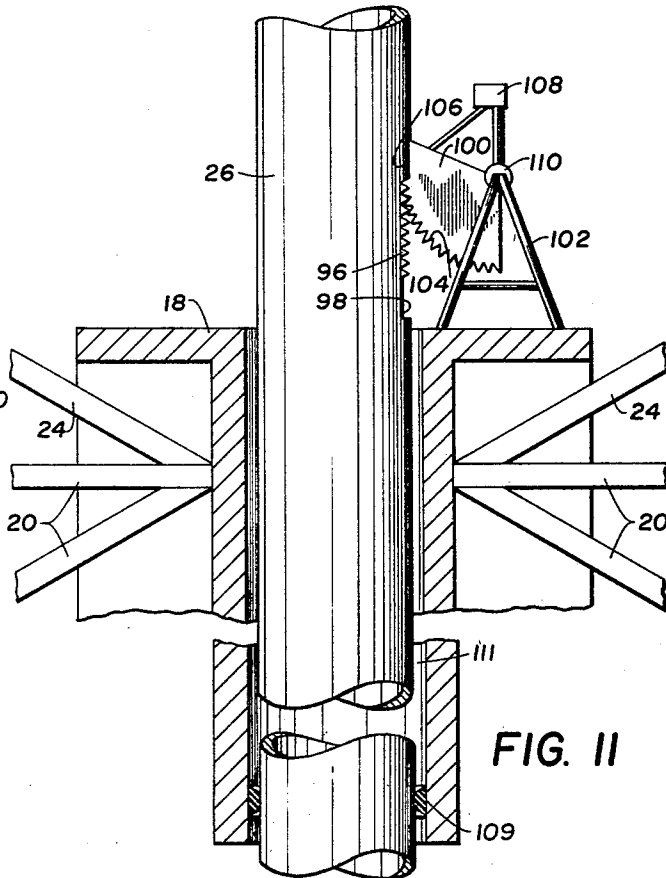


FIG. II

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3,396,544

STORAGE TANK FIXED ON THE OCEAN BOTTOM AND METHOD OF INSTALLATION

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Filed Nov. 7, 1966, Ser. No. 592,412
26 Claims. (Cl. 61-46)

ABSTRACT OF THE DISCLOSURE

This specification and drawings disclose a storage tank structure to be installed on a marine bottom. Anchoring piles are preinstalled in jackets fixed to the structure, the piles being automatically released, for a later pile setting operation, as the structure comes into full contact with the marine bottom. Also disclosed is a method for lowering the main body of the storage tank structure to the marine bottom utilizing a flotation unit which becomes the buoyant base of a later installed surface terminal for servicing the bottom-anchored equipment. A rigid tether pipe provides mechanical and fluid connection between the surface terminal and the interior of the bottom storage tank structure.

This invention relates to a submersible storage tank structure and to the method and apparatus for installing the structure on a marine bottom far beneath the surface of a body of water at an offshore site.

Present developments in the offshore oil and gas industry indicate that drilling and production efforts will be extended to undersea areas, such as the outer fringes of the continental shelves and the continental slopes, where a submarine production system is believed to be the most practical method of reaching subaqueous fluid mineral deposits. Bottom-supported submerged storage tanks, able to accommodate approximately ten days' supply of accumulated fluid minerals, are an integral part of these submarine systems. Such storage tanks, while necessarily being large enough to accommodate the fluid minerals that will be collected in a prolific enough field to be produced under the sea economically, must also be adapted to float on the surface of the body of water prior to installation so as to be manageable by tugs when being towed long distances and must be substantially remotely installable at the offshore site by surface equipment.

Furthermore, as envisioned, in six hundred to two thousand or more feet of water, such a system would include a surface station, including the central floating terminal of a single point mooring system. With the wellheads, production satellites, gathering systems, and storage tanks all being located on or near the marine bottom, far below the surface, more rigid means than the usual unsupported flexible lines will be necessary for transporting the produced fluid minerals from the marine depths to the surface station for processing prior to storage, then back down to the storage tanks where they are accumulated, and later back to the surface for loading a tanker moored to the floating terminal. The term "fluid minerals," for purposes of this discussion, is to be construed broadly and is intended to encompass minerals in slurries or other similar states of matter that may be transported up through a production passage of a well and/or through flowlines.

One of the problems associated with a submerged storage tank structure is that of providing for the rigid and positive anchoring necessary, due to the tremendous buoyancy of a very large tank structure when it is filled with the lighter-than-water hydrocarbons. A submersible storage tank structure, such as contemplated for a subsea system for the exploitation of subaqueous deposits of oil, for example, must have a tank shell able to accommodate

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in the range of 500,000 barrels of the oil. Such a tank shell, if one hundred feet in height, would have a diameter of two hundred feet. The type of anchoring normally utilized with bottom-supported structures includes open-ended jackets, attached to the main body of the structure, through which piles are set into the formations underlying the marine bottom, the piles being then at least cemented into the jackets. Due to the enormous size of a tank shell, such as discussed here, it is not practical merely to anchor the storage tank structure by peripheral piles. With a tank of 500,000-barrel capacity, it has been estimated that fifty piles, each driven one hundred to two hundred feet into the marine bottom, would not be too large a number. Therefore, it would be sound engineering to provide piles extending through the roof and the interior of the tank shell itself, as well as peripheral piles, so as to distribute the buoyant loads. However, if long piles must be lowered from the surface after the tank is on the bottom and stabbed through jackets already extending vertically through the interior of the tank shell, there is an excellent probability than one or more of the fifty piles will break away from the surface handling equipment and rupture the roof of the tank shell or miss the respective jacket in a stab-in attempt, with the same result.

As previously mentioned, the submerged and anchored storage tank structure would be connected to a floating surface terminal. A rigid tether pipe, serving to tie the storage tank structure to the terminal, could also function as a transportation and/or communication pipe. Problems similar to that of stabbing the piles into the jackets occur when a six hundred to two thousand or more foot tether pipe must be stabbed into the upper end of the tank shell from the surface.

Another problem to be overcome by the present invention is that of controlling the buoyancy of the storage tank structure as it is being lowered to the marine bottom. To control the storage tank structure during submergence, it is necessary to contain enough of a buoyant fluid trapped in the tank shell to provide a prescribed negative buoyancy, so that the structure will settle to the bottom under its own weight, although the negative buoyancy must be held within the limits of the surface handling apparatus. A means for re-establishing fluid communication between the tank shell and the surface after the storage tank structure reaches the bottom is needed for releasing the trapped fluid and transporting the accumulated fluid minerals, later to be stored, between the surface and the tank shell. The above functions should be accomplished without auxiliary control lines that would present a hazard at a deep water site.

Another problem to be met during installation of the storage tank structure at a remote offshore site is that of the expense and/or scarcity of the handling equipment necessary for installing the very large storage tank structure. It would be advantageous if the storage tank structure could be lowered to the marine bottom without the aid of derrick barges which could be in short supply and expensive to rent in remote areas.

Accordingly, it is an aspect of the present invention to provide a submersible storage tank structure in which the piles therefor can be releasably preinstalled prior to submergence and which will automatically release as the structure comes in contact with the marine bottom.

It is another aspect of the present invention to provide surface communication with the storage tank structure during installation, by a tether pipe, made up to the storage tank structure as the structure is lowered through a body of water, the tether pipe subsequently serving also to connect the storage tank structure with a surface terminal.

It is still another aspect of the present invention to provide a submersible storage tank structure with a flotation unit that is utilized for lowering the storage tank structure

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to the marine bottom during the installation thereof and subsequently serves as a near-surface buoy.

It is a further aspect of the present invention to provide means for controlling the buoyancy of the storage tank structure during its installation, without outside lines.

Other aspects and advantages of the present invention will be readily apparent from the following description when taken in conjunction with the accompanying drawings which illustrate useful embodiments in accordance with this invention, in which:

FIGURE 1 is a top plan view of the storage tank structure of the present invention;

FIGURE 2 is a side elevational view of the storage tank structure of the present invention, shown floating on the surface of a body of water, under tow;

FIGURE 3 is an elevational view of the storage tank structure of the present invention anchored in the marine bottom and connected through a tether pipe to a terminal floating on the surface;

FIGURE 4 is a cross-sectional partial view of a stub pipe for connecting a tether pipe with the interior of the tank shell, illustrating the valving arrangement therein for controlling the buoyancy of the storage tank structure;

FIGURE 5 is an elevational view of the storage tank structure, of the present invention, floating on the surface of a body of water at an offshore site, just prior to installation, with a flotation unit affixed on the upper end of the storage tank structure by a stub pipe, fixed vertically to the upper end of the tank shell, extending there-through;

FIGURE 5A is an enlarged fragmentary view, partially in section, of a portion, of the flotation unit;

FIGURES 6-10 illustrate, in elevational views, a procedure for installing the storage tank structure of the present invention at a marine site with the aid of the flotation unit which later serves as a portion of the surface terminal;

FIGURE 11 is an elevational view, partially in section, illustrating a first embodiment of the automatic unlatching mechanism for retaining piles in vertically arranged fixed jackets, extending through the tank shell, prior to the installation of the storage tank structure; and

FIGURE 12 is an elevational view, partially in section, illustrating a second embodiment of the automatic pile unlatching mechanism.

Now looking to FIGURES 1 and 2, a storage tank structure, generally designated 10, is provided with a main body, circular tank shell 12, supported above the surface 14 of a body of water on a plurality of spaced buoyant compartments 16. A plurality of jackets 18, with their upper ends just above the tank shell 12, depend vertically therethrough, terminating in a plane approximately coincident with the bottoms of the buoyant compartments 16 and are supported by an upper framework of trusses 20 within the tank shell 12, and a lower framework of trusses 22 adjacent the lower ends of the buoyant compartments 16. The lower end of the tank shell 12 is open to the sea while the upper end is closed by a rigid multiarch corrugated roof 24. A pile 26 extends through each of the jackets 18 and is supported therein, as will be discussed subsequently, prior to the installation of the storage tank structure 10 on a marine bottom. A stub pipe 32, fixed in the center of the roof 24, forms a passage through the roof 24 into the interior of the tank shell 12. The storage tank structure 10, floating on the surface 14 supported by the buoyant compartments 16, is connected to a tugboat 28 by lines 29 so that it can be transported along the surface 14 of the body of water to an offshore site at which marine storage is needed. When the storage tank structure 10 has reached the predetermined offshore site, it is submerged and lowered to a marine bottom with the help of auxiliary equipment (derrick barges) or by a flotation unit designed to double as a portion of the floating terminal, generally designated 38, shown in FIGURE 3, as will be described later.

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FIGURE 3 illustrates the storage tank structure 10, after installation at an offshort site, anchored in a marine bottom 30, by the piles 26 previously supported there-within which have been released from the jackets 18 of the storage tank structure 10 (as will be subsequently described in detail) and driven into the marine bottom 30. A tether pipe, generally designated 34, comprising pipe joints 36, extends from the stub pipe 32 at the upper end of the storage tank structure 10 to the floating terminal 38, installed on the upper end of the tether pipe 34. The floating terminal 38 is provided with a polygonal above-surface deck 40 having wave transparent buoyant columns 42 supporting the deck 40 at each corner and interconnected at their lower ends by submerged floats 44. A central pipe 46, provided with a stab-over bell mouth 48, depends centrally from the floating terminal 38 and is telescoped over and fixedly connected to the tether pipe 34.

The deck 40 contains the above-surface equipment necessary for sustaining the subsea field for which the storage tank structure 10 has been provided. For instance, separation equipment may be mounted thereon, rather than in a subsea gathering station, as well as diesel or gasoline engines and electrical generators that could not be easily or safely installed underwater. The above-surface terminal 38 can also serve the secondary function of the floating central buoy of a single point mooring system for offloading the fluid minerals collected within the interior of the tank shell 12. As an illustration, a tanker 50 is shown moored to a loading boom 52, of the terminal 38, while fluid minerals are transported from the tank shell 12 to the terminal 38, and through a floating loading line 54 to the tanker 50. The construction and operation of this single point mooring system is fully disclosed in the application Apparatus for Transporting Fluids Between a Submerged Storage Tank and a Floating Vessel by William F. Manning, Ser. No. 594,461, filed Nov. 15, 1966. The various passages and/or flowlines necessary between the floating terminal 38 and the storage tank structure 10 for the separation of the oil at the terminal 38 prior to the storage thereof in the storage tank structure 10 is also discussed in the Manning application, Ser. No. 594,461. Neither the specific single point mooring system nor the particular configuration of flow passages forms a portion of the present invention and will not be more specifically discussed herein.

FIGURE 4 illustrates a valving arrangement for selectively controlling the buoyancy of the storage tank structure 10 while it is being lowered to the marine bottom 30, which includes means for interrupting the internal communication between the tank shell 12 and the tether pipe 34, within the stub pipe 32, while the storage tank structure 10 is a distance beneath the surface, and remotely actuated means for opening ports in the stub pipe 32, for re-establishing internal communication between the tether pipe 34 and the tank shell 12, subsequent to the storage tank structure 10 coming in contact with the marine bottom 30 and prior to being anchored in the underlying formations. The means within the stub pipe 32 for interrupting the internal communication between the tank shell 12 and the tether pipe 34 comprises a valve seat 56 rigidly fixed within the lower end of the stub pipe 32, and a central valve port 58 formed therethrough. A poppet type of valve 60 is centrally suspended in the lower end of the stub pipe 32 by a nut 62 fixed coaxially in a spider arrangement 64 in the stub pipe 32 just above the valve seat 56 and engaging a threaded portion of an elongated stem 66 of the valve 60, extending through the valve port 58. The head 68 of the valve 60 is fixed on the lower end of the valve stem 66 beneath the valve port 58 and is designed to fit sealably in the port 58, forming a pressure-tight seal therewith. By rotating the valve stem 66 at a point above the stub pipe 32, the valve head 68 can be moved into fluid-tight engagement with the valve seat 56 from the original spaced position in which fluid is allowed to pass through the port 58. Furthermore, the

valve head 68 has a plurality of ports 70 extending there-through and sealed off at their lower ends by force-fit plugs 71.

Looking now to FIGURES 5-10, a procedure for lowering the storage tank structure 10, with the piles 26 installed in the jackets 18, to the marine bottom, without auxiliary equipment such as derrick barges, is schematically illustrated. As shown in these figures, the procedure is implemented by a flotation unit 74 which functions in the same manner as a derrick barge during lowering of the storage tank structure 10 to the marine bottom 30, and becomes the submerged float and support columns of an above-surface terminal after the installation of the storage tank structure 10 on the marine bottom is completed. In FIGURE 5, the storage tank structure 10 is shown floating on the surface 14 of the body of water, with the flotation unit 74 centrally mounted over the stub pipe 32 of the tether pipe 34. Enough pipe joints 36 have been added to extend the tether pipe 34 above the flotation unit 74. The entire tank 12 floats above the surface 14 of the body of water on the buoyant compartments 16 which are filled with air. The valve 60 within the stub pipe 32 is in its open position with the valve stem 66 being extended by small diameter pipe joints through and above the upper end of the tether pipe 34, where it may be actuated by personnel on the flotation unit 74.

The flotation unit 74 comprises a cylindrical flotation chamber 76 having a central vertical opening 78 through which the tether pipe 34 extends. Mounted on the upper end of the flotation chamber 76 is a plurality of vertical tubular columns 79, interconnected by bracing 80. Extending out of the upper end of each of the hollow columns 79 is a piston rod 82 in sliding engagement therewith. The piston rods 82 are interconnected above the columns 79 by a framework 84 having a centrally mounted upper set of releasable pipe gripping jaws 86 adapted to coact with the tether pipe 34 which they encircle. A lower set of releasable pipe gripping jaws 88, mounted central just above the floating chamber 76 in the lower end of the bracing 80, also surrounds the tether pipe 34 and is adapted to coact therewith. The releasable gripping jaws 86 and 88 can be any of the conventional types of releasable slip sets presently used for handling drill pipe, or one of the more massive types found on the "jack-up" mobile offshore drilling rigs and used for adjusting the height of the legs as shown in the J. E. Lucas Patent No. 2,841,961, issued July 8, 1958.

As shown in partial section in FIGURE 5A the lower end of a piston rod 82 is fitted with at least one O-ring 81. A manifold 83 encircles the columns 79 at the upper end of the flotation chamber 76 and is connected to the interiors of the columns 79 by radial conduits 85. A pressure line 87 is also connected to the manifold 83 and is braced along the length of one of the columns 79, extending to a control station on a small platform 89 at the upper end thereof. A positive displacement gas pump 91 is connected to the upper end of the pressure line 87 through a two-position, three-way selective valve 93 to apply air under pressure to the interior of all of the columns 79 beneath the piston rods 82. A bleed valve 95 is alternatively connected to the manifold 83 through the pressure line 87 by the selective valve 93 to control the release of air under pressure in all of the columns 79 beneath the respective piston rods 82.

FIGURE 6 shows the first step in submerging the storage tank structure 10 at the offshore site. The buoyant compartments 16 have been partially filled with water to obtain a neutral buoyancy and lower the tank shell 12 far enough into the water so that a lighter-than-water liquid, for example, oil, poured into it will not escape through the open bottom. The storage tank structure 10 is prevented from submerging further during this transient condition by providing means for sealing the lower ends of the piles 26 in the jackets 18 during the installation thereof (as will be discussed later), the annuli there-

between providing the necessary buoyancy. Alternatively, a pressure cap 69, through which the valve stem 66 extends and is rotatably sealed (FIGURES 6 and 7) may be fixed atop the tether pipe 34, prior to the partial flooding of the buoyant compartments 16 to take advantage of the air trapped in the upper end of the tank shell 12. The pressure cap 69 has an air bleed valve 71 and an oil inlet valve 73.

In FIGURE 7, oil is pumped from a nearby barge 75 up through a hose 77, and down through the upper end of the tether pipe 34 into the tank shell 12. If the pile-jacket annuli are used to provide the buoyancy of the storage tank structure at this time, the upper end of the hose 77 is fixed in the upper open end of the tether pipe 34. If air trapped in the tank shell 12 is used to buoy the storage tank structure 10, by providing a pressure cap 69 (as shown), the hose 77 is connected to the oil inlet valve 73 thereof for pumping in the oil while a portion of the trapped air is bled out through the valve 71. Enough oil is pumped into the tank shell 12 so that when the buoyant compartments 16 are completely full of water, the storage tank structure 10 will have the prescribed negative buoyancy permitting it to be lowered to the marine bottom 30 while being supported by the flotation unit 74.

The flooding of the buoyant compartments 16 is resumed until each is completely filled with water. As a negative buoyancy is reached, the storage tank structure 10 submerges until the flotation unit 74, the lower set of gripping jaws 88 of which have been activated to grip the tether pipe 34 tightly (FIGURE 8), is drawn partially beneath the surface 14, the descent of the storage tank structure 10 being arrested by the buoyancy of the supporting flotation unit 74. With the oil within the tank shell 12 then completely filling the upper end of the tank shell 12 and the tether pipe 34 to at least the level of the valve port 58 in the stub pipe 32, the screw-operated valve stem 66 of the valve 60 is rotated to close the port 58 and seal the interior of the tank shell 12, the valve stem 66 having been extended, as the tether pipe 34 has been extended, to a point above the upper end of the tether pipe 34. If a pressure cap 69 is used, the valve stem 66 is rotated there-through to close the port 58, after which the pressure cap 69 is removed. The tether pipe 34 is extended a prescribed length with pipe joints 36 (the valve stem 66 is no longer extended), after which the piston rods 82 are driven upward, by pumping air into the columns 79 therebeneath, with the upper set of gripping jaws 86 open, until the piston rods 82 reach the upper end of their travel just below the upper end of the extended tether pipe 34. At this point, the upper set of gripping jaws 86 is activated, locking to the tether pipe 34. The lower set of gripping jaws 88 is released and the valve 93 is repositioned to bleed off the compressed air beneath the lower ends of the piston rods 82 in the columns 79, causing the storage tank structure 10 to sink slowly down an increment equal to the length of the stroke of the rods 82 in the columns 79. The lower set of jaws 88 are then again activated to regrip the tether pipe 34 above the point at which they gripped it earlier. Another joint 36 of tether pipe 34 is added at the upper end thereof after which the upper set of jaws 86 are released, the piston rods 82 are again driven upward, and the upper set of jaws 86 are then reactivated. The lower set of jaws 88 are again released and the storage tank structure 10 slowly submerges a second increment. This series of steps is continued as the storage tank structure 10 settles incrementally toward the marine bottom 30, as shown in FIGURE 9.

As the storage tank structure 10 approaches the marine bottom 30 it will vertically oscillate just above the marine bottom 30, due to the difference in weight between the storage tank structure 10, when supporting the piles 26 during the descent and when the weight of the piles 26 is transferred to the marine bottom 30 prior to the piles being irrevocably released from the storage tank structure 10, as will be discussed later. At the lower end of

the oscillation, the buoyant compartments 16 are still a distance above the bottom. The oscillation of the storage tank structure 10 is a signal to the surface personnel to decrease the remaining buoyancy by removing substantially all of the trapped oil from the tank shell 12 while allowing the tank shell 12 to completely fill with water.

Looking to FIGURE 10, the first step in decreasing the remaining buoyancy of the tank shell 12 is the re-establishing of communication between the tether pipe 34 and the tank shell 12. This is accomplished by attaching a pressure head unit 90 to the upper end of the tether pipe 34. A valved line 92 is connected between an oil pump, in an oil sump (not shown) of the nearby stationed barge 75, and a port in the pressure head 90. A second valved line 94 is connected between the pressure head 90 and the oil sump. By opening the valve in line 92 and closing the valve in line 94, oil can be pumped from the barge 75 through the line 92 into the upper end of the tether pipe 34 until the pressure therein is built up to a point where the plugs 72 in the valve head 68 (see FIGURE 4) are driven down and out, opening the ports 70 therethrough. The plugs 72 are preferably of heavy metal and drop down through and out of the open bottom of the tank shell 12. The valve in the line 92 is then closed and the valve in line 94 is opened to permit the previously trapped oil to be driven, by water pressure, from the tank shell 12, through the tether pipe 34 and into the standby barge 75 until the water-oil interface in the tether pipe 34 reaches an equilibrium. The compartments 16 are then bearing fully on the bottom 30 with a weight equal to the entire submerged weight of the storage tank structure 10, less the amount of buoyant force in the flotation unit 74, necessary to keep the tether pipe 34 from buckling under its own weight. The pressure head unit 90 is then removed from the upper end of the tether pipe 34.

As the storage tank structure 10 settles fully to the marine bottom 30, the lower ends of the compartments 16 function as footings to support the storage tank structure 10. The piles 26 are forced up with respect to the jackets and released therefrom. The piles 26, now irrevocably unsupported by the jackets 18, are set into the formations underlying the marine bottom 30, by means of expedients such as jetting or underwater pile driving. A tool (not shown) is suspended from above the surface 14 and is mated to the upper end of each of the piles 26, in succession, above the enclosed roof 24 of the storage tank structure 10, with the help of a submersible vehicle having articulated arms, guidelines, or television and jets attached to the tool. The piles 26 are set, into the formations underlying the marine bottom 30, to the prescribed penetration for resisting an upward force of the tank shell 12 when the tank shell is completely filled with oil. The piles 26 then are cemented into the respective jackets 18 by grout injected through releasable lines (not shown) connected to a surface vessel (not shown). The submarine vehicle is used to stab the grout lines into each pile 26 in turn and monitors the grout returns at the upper end of each jacket.

The flotation unit 74, to be now utilized as the lower portions of a surface terminal, is jacked down the tether pipe 34 until the flotation chamber 76 is beneath the surface of the water and the columns 79 extend up far enough to support a deck at the desired distance above the surface 14. This is accomplished by activating the upper set of jaws 86 while releasing the lower set of jaws 88. The extension of the piston rods 82 at this time will cause the buoyancy chamber 76 to be driven down beneath the surface 14. The same result can be achieved by locking the lower set of jaws 88 to the tether pipe 34 just prior to the storage tank structure 10 having reached the marine bottom 30. The decreasing of the buoyancy of the flotation chamber 76 will then cause the storage tank structure 10 to settle to the bottom, drawing down the flotation unit 74. With either method the lower jaws 88 are permanently locked to the tether pipe 34 to form

a unitary structure, and the framework 84 with the upper set of jaws 86 and the piston rods 82 are removed. Grout may be injected into the annulus, between the opening 78 through the flotation unit 74 and the enclosed tether pipe 34, to insure the permanency of the connection. With the placing of a deck on top of the columns 79, the storage tank structure 10 is ready for use in conjunction with a subsea producing field.

If derrick barges are used rather than the flotation unit 74 of FIGURES 5-10, the derrick cables can be connected directly to the shell 12 of the storage tank structure 10 for lowering the storage tank structure 10 to the marine bottom 30. Another auxiliary derrick barge will be necessary to support and make up the tether pipe 34 as the storage tank structure 10 is lowered. Alternatively, the auxiliary derrick barge can be dispensed with if the derrick cables, used to lower the storage tank structure 10, are attached to the tether pipe 34, being made up, rather than to the tank shell 12. In either case, after the storage tank structure 10 has been installed on the marine bottom 30, with a cable from a first derrick barge still supporting the tether pipe from a point beneath the surface 14 of the body of water the terminal 38 (as shown in FIGURE 3) is towed, or carried out to the offshore site on a barge, and then is lifted by a second derrick into the air above the upper end of the tether pipe 34, and is lowered back to the water with the depending pipe 46 of the terminal 38 stabbed over the upper end of the tether pipe 34. The floating terminal 38 is made to support buoyantly the tether pipe 34 by reducing the buoyancy thereof to a minimal value and then permanently connecting the telescoped stab-over pipe 46 to the tether pipe 34 after which the buoyancy of the terminal 38 is increased. A temporary connection between the telescoped pipes 34 and 46 may be made by utilizing underwater welding procedures or a remotely actuated connection, as described in the copending application Ballistic Jacket-Pile Connection of William F. Manning, Ser. No. 489,527, filed Sept. 23, 1965, now U.S. Patent No. 3,352,119, issued Nov. 14, 1967. The cable supporting the tether pipe 34 can at this time be released. The annulus between the tether pipe 34 and the stab-over pipe 46 is subsequently grouted to insure the permanency of the connection.

In FIGURE 11 is shown a preferred embodiment of a means for preinstalling the piles 26 by latching them within their respective jackets 18 during the transportation of the storage tank structure 10 on, and its gradual descent through, the body of water. Each pile 26 has an axial rack section 96 formed in the surface thereof with a cutout blank section 98 therebeneath. A sector gear 100, journaled on a support frame 102 fixed to an upper horizontal flange on the top of each jacket 18, has a tooth section 104 and a planar blank section 106. Connected to each sector gear 100 is a counterweight 108 located just above the pivot point 110 of the sector gear 100 when the pile 26 is in the latched position shown. When the pile 26 is to be inserted through the upper end of the jacket 18, the sector gear 100 is pivoted away (clockwise, as shown) from contact with the pile 26 until the lower end of the rack section 96 of the pile 26 is about opposite the pivot point 110. At this time the sector gear 100 is swung over (counterclockwise, as shown) so that the tooth section 104 of the sector gear 100 meshes with the rack section 96 of the pile 26. As the pile 26 continues to drop through the jacket 18, the planar blank section 106 of the sector gear 100 comes into contact with the portion of the pile 26 above the rack section 96, preventing further rotation of the sector gear 100. The engagement of the uppermost teeth of the tooth section 104 of the sector gear 100 with the uppermost teeth on the rack 96 prevents the pile 26 from dropping down further through the jacket 18 while the weight of the pile 26 tends to hold the sector gear 100 in tight engagement with the rack section 96 of the pile 26.

An annular seal 109 is fitted in the lower end of each of the jackets 18. The seal 109 in a jacket 18 is adapted

to slidably engage the outer surface of the pile 26 pre-installed in the respective jacket 18 to permit the annulus 111 to be utilized to create a buoyant force. After the piles 26 are set in the formations underlying the marine bottom 30, the seals 109 function as grout seals during injecting of cement into the annuli to connect permanently the piles 26 to the jackets 18.

When the storage tank structure 10 is lowered to the marine bottom 30, the lower ends of the piles 26 which extend down below the buoyant compartments 16, when the piles 26 are preinstalled in the jackets (see FIGURE 2), first contact the marine bottom 30. As previously mentioned, the storage tank structure 10 begins to oscillate vertically as it nears the marine bottom 30 due to the change from negative to positive buoyancy of the storage tank structure 10 resulting from the weight of the depending piles 26 being transferred from the storage tank structure 10 to the marine bottom 30 and back to the storage tank structure 10. As the piles 26 contact the bottom 30 and are supported thereby, the storage tank structure 10 begins to rise; however, there will be some lag in the reversal of movement of the structure due to inertia. As the storage tank structure 10 begins to rise, the weight of the piles 26 is again supported by the storage tank structure 10 and the structure begins to sink again to the bottom after an inertial lag. This oscillation is a signal for the plugs 72 in the valve 60 to be removed and the interior of the tank shell 12 to be flooded with water. The weight of the storage tank structure 10 then is great enough for it to settle firmly on the marine bottom 30 without the added weight of the piles 26. As the storage tank finally descends to the marine bottom 30, the piles 26 move upward with respect to the jacket 18, rotating the sector gear 100 (clockwise) past the point at which the blank cutout section 98 of the pile 26 opposes the toothed section 104 of the sector gear 100. Meanwhile the counterweight 108 has rotated until it is far to the right of the pivot point 110, and the now nonmeshing of the elements permits the off-center weight of the counterweights 108 to continue the rotation of the sector gear 100 (in a clockwise direction) until it engages the right side of the support frame 102 and remains in that position, permanently out of engagement with the pile 26. The pile 26 then is driven into the marine bottom 30.

From this description it can be seen that the irreversible release of the piles 26 from the jackets 18 cannot be allowed to take place as soon as the piles 26 strike bottom 30 or the storage tank structure 10 will rise back to the surface under the impetus of its now positive buoyancy, destroying itself and everything thereabove during the process. During the vertical length of the oscillation of the storage tank structure 10, the sector gears 100 must be in continuous mesh with the racks 96 of the piles 26 to permit the piles 26 to be resupported by the storage tank structure 10 near the upper end of its oscillatory travel.

If the marine bottom 30 should be found to have unconsolidated underlying formations deeper than anticipated, or there are local soft spots, and at least some of the piles 26 are not moved up far enough to be released, this may be accomplished by attaching a line, extending from a surface vessel, to the upper end of the recalcitrant pile 26 to raise it up far enough to be released. This procedure may also become necessary if the pile release mechanism of one of the piles should become jammed or if a pile 26 should buckle during the last stages of submergence of the storage tank structure 10.

A modified pile latching means is illustrated in FIGURE 12. Each pile 26' consists of an upper large diameter portion 112, which provides the desired annulus for grouting with respect to a modified jacket 18', and a lower smaller diameter portion 114. A plurality of expendable stops 116 are spaced around the circumference of the smaller diameter portion 114 of the pile 26', pre-

vented from axial movement by a welded-on annular stop rest 118 below the expendable stops 116, and the annular face 120, defining the junction of the upper and lower portions 112, 114, respectively, of the pile 26', which the upper ends of the expendable stops 116 abut. The expendable stops 116 are held to the pile 26' by a retainer ring 122 (shown broken away) press-fitted over the upper and outer sections 124 of each of the expendable stops 116. Each jacket 18' has a plurality of radial lugs 126 welded to its outer surface and extending thereabove. When a pile 26' is inserted into a jacket 18', the pile 26' is angularly oriented so that the lugs 126 are between the expendable stops 116 and an upper horizontal surface 128 of each of the lugs 126 abuts the retainer ring 122. The entire downward weight bias of the pile 26', being supported by the lugs 126 abutting the ring 122, causes the ring 122 to be driven up off of the stops 116. The pile 26' drops down slightly until the undersurfaces of upper and outer sections 124, on the expendable stops 116, abut the upper end of the jacket 18' to support the downward weight bias of the pile 26'. Constant width intermediate sections 130 of the expendable stops 116 bridge the hollow jacket 18' holding the expendable stops 116 in place against the smaller diameter portion 114 after the removal of the retaining ring 122. The constant width sections 130 of the expendable stops 116 must be long enough to accommodate the oscillations of the storage tank structure 10, as described above. The wedge-shaped lower sections 132 form a conical guide for centering the pile 26' in the jacket 18'. An annular knock-off ring 134, in the lower end of each jacket 18', below a grout seal 136 has an internal annular seal 138 affixed thereto serving to center the smaller diameter portion 114 of the respective pile 26' within the jacket 18', prior to the pile 26' being driven into the marine bottom 30 as well as permitting the annulus, between the smaller diameter portion 114 and the jacket 18', to provide buoyant support for the partially submerged storage tank structure 10.

When the interior of the tank shell 12 is fully flooded, and settles to the marine bottom 30, each of the piles 26' rises up out of the respective jacket 18' until the sections 130 of the expendable stops 116 are entirely above the jacket 18'. Without the retaining ring 122 or the latter encasing jacket 18', the expendable stops 116 pivot out around the annular stop rest 118 and drop off, permitting the pile 26' to be driven into the formations underlying the marine bottom 30 through the jackets 18'. As the upper, larger diameter portion 112 of the pile 26' is driven through the jacket 18', the annular knock-off ring 134 is disengaged from the inner wall of the jacket 18', permitting the larger diameter portion 112 of the pile 26' to pass.

Depending upon the distance between the port or shipyard at which the storage tank structure 10 is to be stored prior to use, and the offshore site at which it is to be installed, the piles 26 (or 26') may be inserted, prior to transporting the structure, at a sheltered intermediate site, or at the final offshore site. In the normal installation, the piles 26 would probably be driven 100 feet or more into the marine bottom 30 and since they must extend completely through the tank shell 12, which may be 100 feet in height, the piles 26 would obviously be required to be 200 to 300 feet in length each. If the available floating equipment does not permit the piles 26 that long to be inserted into the jackets 18, each in one piece, the piles 26 instead may be made into two or more sections. When using the latching means illustrated in FIGURE 11, each pile section can have a latching portion consisting of a rack section 96 and a blank section 98. The lowermost section of a pile 26 would then be inserted into the jacket 18, the pile section latched into the jacket 18, and a second section fitted thereover and welded thereto. At this point, the multiple section pile would be lifted up until the counterweighted sector gear is actuated to ro-

tate clockwise to disengage the pile 26. The pile 26 would then be lowered further through the tank shell 12 and would be relatched through the now uppermost section. Depending upon the number of sections of which each of the piles 26 is fabricated, this procedure could be repeated a number of times to preinstall each pile 26.

If the piles 26 are inserted at an intermediate site of 100 or so feet of water depth, the storage tank structure 10 could first be submerged to the bottom and then the handling vessel floated over the storage tank structure 10 to insert the piles 26. As the storage tank structure 10 is later rebuoyed and floated to the surface, the piles 26 would be locked in place.

Although the present invention has been described in connection with details of specific embodiments thereof, it is to be understood that such details are not intended to limit the scope of the invention. The terms and expressions employed are used in a descriptive and not a limiting sense and there is no intention of excluding such equivalents, in the invention described, as fall within the scope of the claims. Now having described the apparatus and methods herein disclosed, reference should be had to the claims which follow.

What is claimed is:

1. A submersible storage tank structure adapted to be installed far beneath the surface of a body of water comprising: an open bottom tank shell; a pipe, fixed in and extending above the roof of said tank shell, providing at least a portion of a means of fluid communication between the interior of said tank shell and the upper end of said pipe above the surface of a body of water through the interior of said pipe; a first valve means in said means of fluid communication for controlling said fluid communication between said interior of said tank shell and said upper end of said pipe whereby when said first valve means is closed during the lowering of said storage tank structure beneath the surface of a body of water, as the liquid level in said means of fluid communication reaches said first valve means, substantially all air is excluded from the interiors of said tank shell and said pipe beneath said first valve means; and a second valve means for re-establishing fluid communication between said interior of said tank shell and said upper end of said pipe when said first valve means is closed whereby fluid communication is re-established between said interior of said tank shell and said upper end of said pipe above the surface of a body of water, through said pipe, when said storage tank structure is at the depth at which it is to be installed beneath the surface of a body of water.

2. A storage tank structure as recited in claim 1 wherein said first valve means is selectively controlled; a means for remotely controlling said first valve means comprising at least in part, a positive mechanical connection, whereby said first valve means is substantially unaffected by fluid pressure within said interiors of said tank shell and said pipe; and said second valve means is a pressure controlled valve means actuated by a predetermined differential pressure across said second valve means.

3. A storage tank structure as recited in claim 1 wherein said first valve means comprises a poppet valve having a valve stem being provided with a threaded portion, said valve stem extending upward through said interior of said pipe from the head of said valve; an internally threaded element in engagement with said threaded portion of said valve stem; means for fixing said threaded element in said pipe while allowing fluid communication thereacross, a valve seat fixed in said pipe adjacent the head of said poppet valve whereby said first valve means is closed by rotating said valve stem to axially displace said valve head into contact with said fixed valve seat; said second valve means comprising at least one port extending through said valve head of said first valve means; and pressure actuated means for controlling the opening of said at least one port of said second valve means whereby said second valve means remains unaffected by fluid pressure until said first

valve means is closed and a fluid pressure is applied to one of the opposing sides of said valve head of said poppet valve to create a differential pressure across said valve head.

4. A method for installing a bottom-supported storage tank structure far beneath the surface of a body of water at an offshore site comprising the following steps:

- (a) floating said storage tank structure on a plurality of buoyant compartments with an open bottom tank shell of said storage tank structure above said surface of said body of water;
- (b) transporting said storage tank structure to said offshore site;
- (c) at said offshore site, reducing the buoyancy of said buoyant compartments until the lower end of said open bottom tank shell is beneath said surface of said body of water;
- (d) at least partially filling said tank shell with a lighter-than-water liquid while providing fluid communication between the interior of said tank shell, at the upper end thereof, and a point above said surface of said body of water, enough of said lighter-than-water liquid being directed into said tank shell to provide said storage tank structure with a slight negative buoyancy when said fluid communication is interrupted and said upper end of said tank shell is effectively sealed with substantially all of the air excluded therefrom and said buoyant compartments are completely flooded;
- (e) subsequent to step (d), completely flooding said buoyant compartments;
- (f) maintaining fluid communication between said interior of said tank shell and a point above said surface of said body of water while lowering said storage tank further into said body of water under the control of a buoyant surface support means until all air is excluded from said interior of said tank shell through said fluid communication means;
- (g) interrupting fluid communication between said interior of said tank shell and a point above said surface of said body of water whereby when substantially all air has been excluded from said tank shell said lighter-than-water liquid partially buoyantly supports said storage tank structure;
- (h) continuing the lowering of said storage tank structure to the installation depth;
- (i) re-establishing fluid communication between said interior of said tank shell, at said upper end thereof, and a point above said surface of said body of water to force the lighter-than-water liquid out through said fluid communication means by the flooding of said interior of said tank shell through said open bottom thereof; and
- (j) anchoring the substantially completely flooded storage tank structure in the formations underlying said marine bottom.

5. A method for installing a bottom-supported storage tank structure far beneath the surface of a body of water at an offshore site as recited in claim 4 wherein the apparatus for providing said fluid communication is at least in part the interior of a pipe extending upward from said upper end of said tank shell, said interior of said pipe being continuously above said surface of said body of water and in controlled fluid communication with said interior of said tank shell comprising the following additional step:

- (k) making up said pipe of pipe joints as said storage tank is lowered through said body of water so that the upper end of said pipe is always above the surface of said body of water.

6. A method for installing a bottom-supported storage tank structure far beneath the surface of a body of water at an offshore site as recited in claim 5 wherein there is first and second valve means within said pipe for controlling fluid communication between said interior of said

tank shell and said upper end of said pipe above said surface of said body of water comprising the following additional steps:

- (l) mechanically closing said first valve means to interrupt fluid communication subsequent to all air being excluded from beneath said first valve means; and
 - (m) applying pressure through said upper end of said pipe, as the storage tank structure attains said installation depth, to actuate said second valve means to re-establish fluid communication between said interior of said tank shell of said storage tank structure and said upper end of said pipe above said surface of said body of water.
7. A method for installing a bottom-supported storage tank structure far beneath the surface of a body of water at an offshore site as recited in claim 4 wherein buoyantly supporting said storage tank structure in said body of water when said lower end of said open bottom tank shell is beneath said surface of said body of water, comprises the following additional steps:
- (n) mounting a pressure cap on the upper open end of said pipe above said surface of said body of water to trap air in said interior of said tank shell, said pressure cap having an air bleeder valve, a liquid inlet valve, and means extending through said pressure cap for interrupting fluid communication between said interior of said tank shell and a point above said surface of said body of water; and
 - (o) prior to step (d), connecting a source of lighter-than-water liquid to said inlet valve so that air can be controllably bled from said interior of said tank shell as said tank shell is at least partially filled with lighter-than-water liquid.
8. A method for installing a bottom-supported storage tank structure far beneath the surface of a body of water at an offshore site as recited in claim 4 wherein there are vertical jackets extending completely through said tank shell and means in the lower ends of each of said jackets for sealing against piles inserted in said jackets comprising the following step:
- (p) preinstalling piles in said jackets, prior to reducing the buoyancy of said buoyant compartments, to permit the annuli between said jackets and said piles to provide a buoyant force when said lower end of said open bottom tank shell is beneath said surface of said body of water.
9. Apparatus for anchoring a submersible structure far beneath the surface of a body of water with piles set in formations underlying a marine bottom comprising: a plurality of open-ended vertical jackets fixed to the body of said submersible structure; latch means for releasably supporting a pile in each of said jackets, said latching means being releasable, by a prescribed substantial upward movement of a pile within the respective jacket, to permit subsequent unrestricted downward movement of a released pile therewithin, said latching means comprises a rotatable gear means journaled adjacent an end of said jacket, said gear means having a first peripheral toothed portion for meshing with a vertical rack of a pile supported in said jacket as a pile is lowered in said jacket; a second peripheral portion of said rotatable gear means, at a first end of said toothed peripheral portion, for coacting with the surface of a pile being lowered in said jacket, said gear means being adapted to be rotated by contact between said first peripheral toothed portion of said gear means and a rack of a pile moving down through said jacket to rotate said second peripheral portion against the surface of a pile while said first peripheral toothed portion is still in engagement with a rack of a pile, the coaction of the surface of a pile moving down through said jacket and said second portion of said gear means preventing the further rotation of said gear means for providing for the support of a pile in said jacket; a third peripheral portion of said gear means at the second end of

said peripheral toothed portion spaced from contact with the surface of a pile in said jacket when opposite the surface of a pile in said jacket; and an overcenter means, in conjunction with said gear means, adapted to further rotate said gear means to a position in which said third peripheral portion of said gear means is permanently opposite the surface of a pile in said jacket, subsequent to said gear means being rotated by a previously supported pile moving upward in said jacket until said toothed portion of said gear means is rotated out of mesh with the rack of an upwardly moving pile in said jacket and said third peripheral portion of said gear means is opposite the surface of a pile in said jacket.

10. Apparatus for anchoring a submersible structure far beneath the surface of a body of water with piles set in formations underlying a marine bottom comprising: a plurality of open-ended vertical jackets fixed to the body of said submersible structure; latch means for releasably supporting a pile in each of said jackets, said latching means being releasable, by a prescribed substantial upward movement of a pile within the respective jacket, to permit subsequent unrestricted downward movement of a released pile therewithin, said latching means comprises a rotatable sector gear journaled adjacent an end of said jacket, said sector gear having a toothed portion for meshing with a vertical rack of a pile supported in said jacket as a pile is lowered in said jacket; a planar portion on the periphery of said sector gear at one end of said toothed portion for coacting with the surface of a pile being lowered in said jacket, said sector gear being adapted to be rotated by contact between said toothed portion of said sector gear and the rack of a pile moving down through said jacket, the coaction of the surface of a pile moving down through said jacket and said planar portion of said sector gear means rotated into contact therewith preventing further rotation of said sector gear and providing for the support of a pile in said jacket by still meshing teeth of said sector gear and the rack of a pile in said jacket; and a counterweight fixed to said sector gear in a position so as to rotate said sector gear to a permanent position in which the toothed portion of said sector gear is out of mesh with the rack of a pile in said jacket so that said sector gear cannot contact a pile moving back down through said jacket, subsequent to said sector gear being rotated by a previously supported pile moving upward in said jacket until said toothed section of said sector gear is no longer in mesh with the rack of an upwardly moving pile in said jacket.

11. Apparatus for anchoring a submersible structure far beneath the surface of a body of water with piles set in formations underlying a marine bottom comprising: a plurality of open-ended vertical jackets fixed to the body of said submersible structure; latch means for releasably supporting a pile in each of said jackets, said latching means being releasable, by a prescribed substantial upward movement of a pile within the respective jacket, to permit subsequent unrestricted downward movement of a released pile therewithin, said latching means comprises a plurality of spaced radial lugs, fixed to the outer surface of said jacket and extending axially beyond an end thereof, said plurality of spaced radial lugs being adapted to drive off a retainer ring from around a plurality of spaced expendable stops, axially fixed to a pile supported in said jacket by an upper and outer portion of each expendable stop abutting the upper end of said jacket, the plurality of expendable stops on a pile in said jacket bridging the hollow interior of said jacket to hold the plurality of expendable stops to a pile in said jacket.

12. A submersible structure adapted to be installed far beneath the surface of a body of water and anchored by piles set in the formations underlying a marine bottom comprising a plurality of spaced, open-ended, vertical jackets fixed to a main body of said submersible structure; a preinstalled pile supported in each of said plurality of jackets, each of said preinstalled piles extending

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through said jackets and substantially beneath said body of said submersible structure; and latching means for releasably supporting each of said piles in a respective jacket, each of said latching means being provided with a pile releasing means responsive to a prescribed substantial upward movement of the respective pile with respect to said respective jacket whereby said piles are adapted to be released as said body of said submersible structure settles down onto a marine bottom so that said piles can be driven down into the formations underlying the marine bottom.

13. A submersible structure adapted to be installed far beneath the surface of a body of water and anchored by piles set in formations underlying a marine bottom as recited in claim 12 wherein said latching means comprises a sector gear; means for journaling said sector gear adjacent the upper end of said jacket, said sector gear having a toothed portion and an adjacent planar portion; a rack on said pile; said planar portion of said sector gear abutting the surface of said pile above said rack on said pile in said jacket to prevent rotation of said sector gear under the downward weight bias of said pile while said toothed portion of said sector gear meshes with said rack to support vertically said pile within said jacket; and a counterweight fixed to said sector gear so as to continue the rotation of said sector gear, to a position in which said toothed portion is permanently out of mesh with said rack on said pile, subsequent to a rotation of said sector gear caused by the upward movement of said pile with respect to said jacket.

14. A submersible structure adapted to be installed far beneath the surface of a body of water and anchored by piles set in the formations underlying a marine bottom as recited in claim 12 wherein said latching means comprises a plurality of expendable stops axially located on said pile, each of said expendable stops having an upper and outer section extending over the upper end of said jacket for supporting said pile against the downward weight bias of said pile; a constant width portion on each of said expendable stops, said constant width sections bridging the interior of said jacket for holding said expendable stops to said pile; a first means for axially locating said expendable stops in a first direction and supporting the weight of said pile by said expendable stops including an upper larger diameter portion and a lower smaller diameter portion of said pile, the upper ends of each of said expendable stops abutting an annular face defining the junction of said upper and lower portions of said pile; and a second means fixed to said pile beneath said expendable stops for locating said expendable stops in a second direction and for permitting said expendable stops to rotate about the lower ends thereof subsequent to the upward movement of said pile with respect to said jacket until said each of said expendable stops are substantially entirely above said upper end of said jacket.

15. A submersible structure adapted to be installed far beneath the surface of a body of water and anchored by piles set in formations underlying a marine bottom as recited in claim 14 wherein there is an annular knock-off ring fixed in the lower end of said jacket to locate said smaller diameter portion of said pile and designed to be disengaged from the inner wall of said jacket as said annular knock-off ring is abutted by said larger diameter upper portion of said pile as said pile moves down, with respect to said submersible structure to anchor said submersible structure.

16. A submersible structure adapted to be installed far beneath the surface of a body of water and anchored by piles set in formations underlying a marine bottom as recited in claim 14 where the constant width section of each of said expendable stops is of a prescribed length to permit said pile to oscillate vertically over a considerable distance without releasing said pile; and each expendable stop further having a lower wedge-shaped section

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forming a conical guide for centering said pile as said pile is lowered into said jacket for releasable support therein.

17. A submersible structure adapted to be installed far beneath the surface of a body of water and anchored by piles set in formations underlying a marine bottom as recited in claim 14 wherein there is a plurality of spaced radial lugs fixed to said jacket and extending thereabove, said radial lugs being positioned between said expendable stops on said pile for driving a retaining ring from around said upper and outer sections of said expendable stops as said pile is lowered into said jacket.

18. A pile for being releasably supported in an open-ended vertical jacket of a submersible structure adapted to be installed far beneath the surface of a body of water and anchored by piles set in formations underlying a marine bottom comprising an upper diameter portion and a lower smaller diameter portion of said pile; an annular face defining the junction of said upper and lower portions of said pile; a plurality of expendable stops axially positioned on said smaller diameter lower portion of said pile between said annular face and outwardly extending means fixed to said lower smaller diameter portion of said pile, each of said expendable stops having an upper and outer section; a constant width intermediate section and a lower wedge-shaped section, said upper and outer sections abutting said annular face, said expendable stops being held to said pile by a removable retaining ring fixed around said upper and outer portions of said expendable stops prior to said pile being preinstalled in a jacket.

19. A method for installing a submersible structure far beneath the surface of a body of water at an offshore site wherein there are a plurality of vertical open-ended jackets fixed to said submersible structure and means for releasably supporting a pile in each of said jackets so that a prescribed substantial upward movement of said piles with respect to said jackets releases said piles for the unrestricted downward movement thereof comprising the following steps in the sequence recited:

- (a) preinstalling a pile in each of said plurality of vertical jackets with said piles extending out of the lower ends of said jackets and beneath the lowermost portion of said submersible structure;
 - (b) providing said submersible structure, with said piles preinstalled, with a slight negative buoyancy for ease in lowering said submersible structure to a marine bottom;
 - (c) lowering said submersible structure, with said piles preinstalled, to said marine bottom from said surface of said body of water;
 - (d) receiving a signal, at said surface of said body of water, of said submersible structure being just above said marine bottom, said signal indicating that said submersible structure is oscillating vertically just above said marine bottom, said oscillations being due to first, a transference of the weight of said piles to said marine bottom as said piles, extending beneath said submersible structure, come in contact with said marine bottom causing said submersible structure to attain a positive buoyancy and rise, and second, the transference of said weight of said piles back to said submersible structure as the submersible structure rises to a point above which said piles no longer are in contact with said marine bottom;
 - (e) reducing the buoyancy of said submersible structure, in response to receiving said signal; to lower said submersible structure into positive contact with said marine bottom causing said preinstalled piles to move upward far enough with respect to said jackets to be permanently released;
 - (f) setting said released piles in said formations underlying said marine bottom through said jackets; and
 - (g) connecting said set piles to said jackets to anchor said submersible structure.
20. A storage tank structure anchored in the forma-

tions underlying a marine bottom far beneath the surface of a body of water at an offshore site comprising an open bottom cylindrical tank shell having a substantially horizontal roof; a vertical tether pipe fixed in said roof of said tank shell and extending above said surface of said body of water to provide fluid communication between the interior of said tank shell and the upper end of said tether pipe; and means for spacing said tank shell above said marine bottom to provide fluid communication between the lower open end of said tank shell and said body of water, said means for spacing said tank shell above said marine bottom being a plurality of compartments for buoyantly supporting said storage tank structure on said surface of said body of water during transportation to said offshore site and for providing substantial surface area for supporting said storage tank structure on said marine bottom during installation.

21. A storage tank structure anchored in formations underlying a marine bottom far beneath the surface of a body of water as recited in claim 20 comprising a plurality of vertical open-ended jackets fixed with respect to said storage tank structure, at least some of said plurality of vertical jackets extending through said roof and completely through said interior of said tank shell; and a pile extending through each of said jackets and permanently connected thereto, said piles having their upper ends adjacent the upper ends of said jackets and their lower ends set in said formations underlying said marine bottom to anchor said storage tank structure.

22. A storage tank structure anchored in formations underlying a marine bottom far beneath the surface of a body of water as recited in claim 20 comprising a buoyant means fixed to said upper end of said tether pipe to support said tether pipe in said body of water and to support at least a deck above said surface of said body of water.

23. A flotation unit for lowering a submersible structure, having negative buoyancy, far beneath the surface of a body of water by means of a pipe string connected to a structure comprising a flotation chamber having a central vertical opening therethrough, a lower set of releasable pipe gripping jaws fixedly positioned centrally above said flotation chamber; a plurality of vertical tubular columns fixedly spaced around said opening through said flotation chamber; a vertically reciprocable piston rod slidably mounted in each of said columns; and an upper set of releasable pipe gripping jaws mounted above the upper ends of said columns in a framework interconnecting said piston rods above said columns.

24. A method for installing a submersible structure far beneath the surface of a body of water at an offshore site utilizing a flotation unit as recited in claim 23 comprising the following steps:

- (a) assembling said flotation unit on said submersible structure with a vertical pipe connected to said submersible structure extending through said vertical opening of said flotation unit and through said upper and lower sets of releasable pipe gripping jaws, said pipe extending above said flotation unit at least far enough to be still within said upper set of jaws when said piston rods are raised up to their upper limit of upward vertical travel in said columns with said upper set of releasable pipe gripping jaws released;
- (b) gripping said pipe with said lower set of releasable jaws;
- (c) decreasing the buoyancy of said submersible structure until a negative buoyancy is attained and said submersible structure is supported, beneath said surface of said body of water, by said flotation unit floating on said surface of said body of water;
- (d) raising said piston rods to their upper limit of vertical travel in said columns with said upper set of releasable pipe gripping jaws released from said pipe;
- (e) gripping said pipe with said upper set of releasable pipe gripping jaws;

- (f) releasing said lower set of releasable pipe gripping jaws;
- (g) lowering said piston rods to their lower limit of vertical travel in said columns to lower incrementally said submersible structure;
- (h) adding enough pipe sections to said vertical pipe to extend above said upper set of releasable pipe gripping jaws when said piston rods are again raised to their upper limit of vertical travel in said columns;
- (i) gripping said pipe again with said lower set of releasable pipe gripping jaws;
- (j) releasing said upper set of releasable pipe gripping jaws; and
- (k) repeating steps (d) through (j), in that order, to lower incrementally said submersible structure until said submersible structure at least approaches said marine bottom.

25. A method for installing a submersible structure far beneath the surface of a body of water at an offshore site utilizing a flotation unit as recited in claim 24 including the following additional steps:

- (l) subsequent to step (k) permanently fixing said flotation unit in position to said pipe;
- (m) removing said piston rods, said framework, and said upper set of releasable pipe gripping jaws from said flotation unit;
- (n) decreasing further the buoyancy of said submersible structure to settle said submersible structure on said marine bottom with said flotation chamber of said flotation unit being beneath said surface of said body of water and said columns extending above said surface of said body of water; and
- (o) erecting an abovesurface deck atop said columns above said surface of said body of water.

26. A method for installing a submersible structure far beneath the surface of a body of water at an offshore site utilizing a flotation unit as recited in claim 24 including the following additional steps:

- (p) subsequent to step (k), incrementally lowering said submersible structure until said submersible structure settles fully on said marine bottom by repeating steps (d) through (j) as many times as is necessary and terminating with step (f);
- (q) anchoring said submersible structure in said formations underlying said marine bottom;
- (r) driving said flotation chamber beneath said surface of said body of water by raising said piston rods with respect to said columns with said upper set of releasable pipe gripping jaws gripping said pipe and said lower set of releasable pipe gripping jaws released from said pipe;
- (s) subsequent to step (r), permanently fixing said flotation unit to said pipe with said flotation chamber beneath said surface of said body of water and said columns extending above said surface of said body of water;
- (t) releasing said set of upper releasable jaws from said pipe;
- (u) removing said piston rods, said framework, and said upper set of releasable pipe gripping jaws from said flotation unit; and
- (v) erecting an abovesurface deck atop said columns above said surface of said body of water.

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