July 7, 1970 W. F. MANNING 3,519,034

SUBMERGED STORAGE AND FLOATING TERMINAL LOADING ASSEMBLY

Filed Nov. 15, 1966

FIG. 1

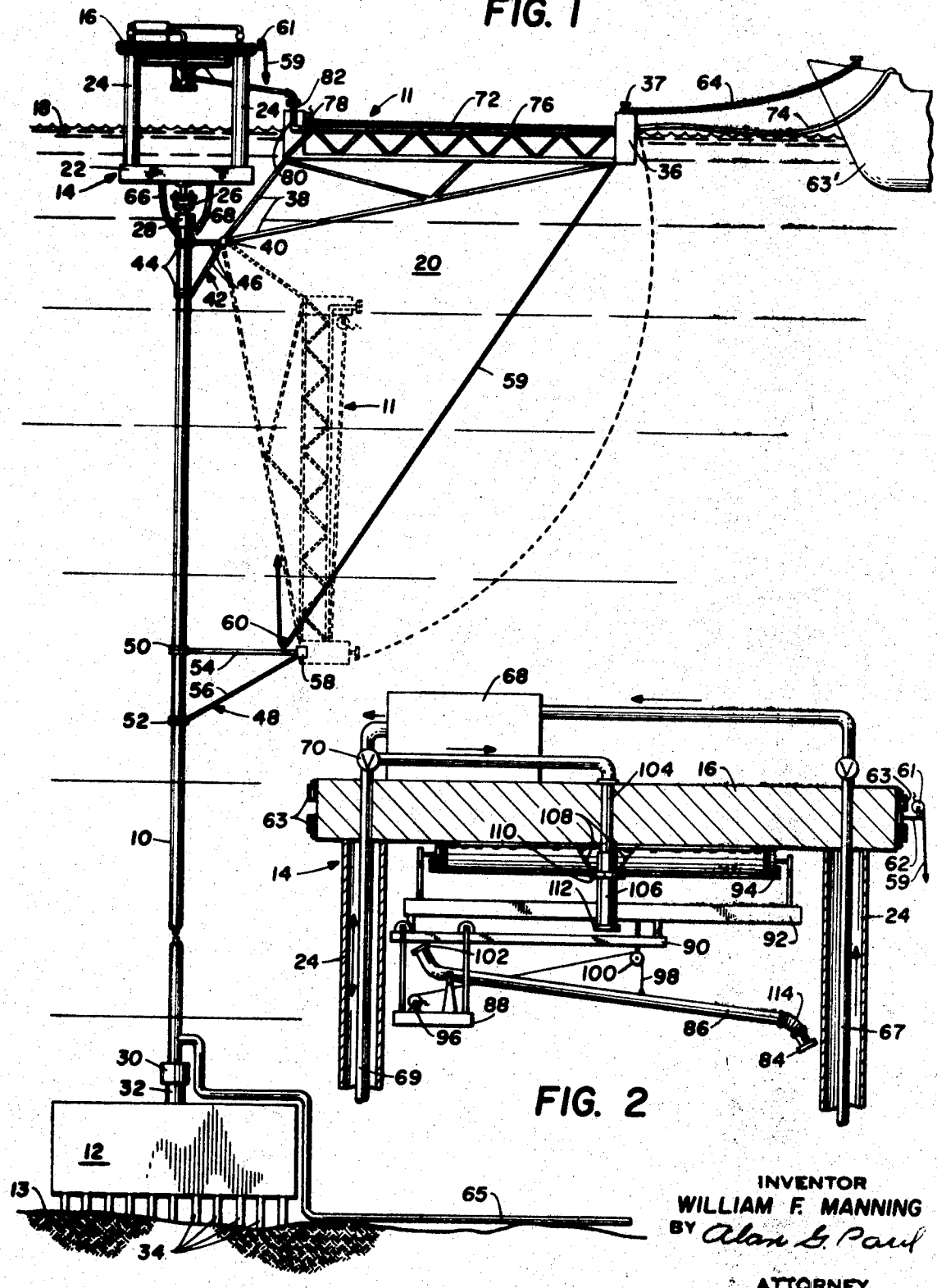


FIG. 2

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SUBMERGED STORAGE AND FLOATING TERMINAL LOADING ASSEMBLY

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ABSTRACT OF THE DISCLOSURE

An anchored, offshore apparatus for storing material below the surface of a body of water and for transporting the material from the storage area to a point adjacent the surface. The apparatus comprises an open-bottom storage tank anchored in a submerged position. A rigid-walled tether pipe is attached to the tank and extends substantially vertically upward therefrom. A floating terminal having a deck thereon is attached to the upper end of the tether pipe and serves to support the pipe in its vertical position. Material is transferred through the tether pipe between the tank and the terminal.

The present invention relates to an improved offshore structure for the mooring and loading of vessels, particularly with crude oil and liquefied gas accumulated in a submerged storage tank. More particularly, the invention is concerned with the surface and near-surface apparatus of a subsea producing system, commonly called a "single point mooring system," wherein a vessel such as a tanker may be moored in the most advantageous direction, dictated by the wind and waves, during loading.

Present developments in the offshore oil and gas industry indicate that drilling and production efforts will be extended to underwater areas, such as the outer fringes of the continental shelves and the continental slopes (defined as areas where the water depth is over six hundred feet and less than six thousand feet). At these depths, particularly where the subaqueous wellheads can be widely spaced, submarine production systems are presently considered the most practical method of producing hydrocarbons trapped in the subaqueous formations. Submerged storage tanks, able to accommodate at least ten days' supply of accumulated fluid hydrocarbons, are an integral part of the system. With wellheads, production satellites, gathering systems, and production storage, all being supported on the ocean bottom, perhaps six hundred feet or more below the surface, some means is necessary for transporting the accumulated hydrocarbons from these depths to a tanker which periodically visits the area. A single point mooring system is considered the most advantageous means for accomplishing this result. Such a system generally consists of a surface unit, means for anchoring the surface unit, and at least one fluid passage between the surface unit and submerged storage facilities. The surface unit is provided with a central floating terminal and a loading and mooring means connected between the central floating terminal and the tanker. The loading and mooring means is designed to pivot around the terminal so that the tank may be moored in the most advantageous direction at the time, which would usually be with the bow of the tanker pointed into the wind and waves.

A single point mooring system is also advantageous in areas where good harbors are not available or where the harbors are so extremely crowded that there is a considerable advantage in being able to load and unload offshore. Furthermore, tankers utilizing offshore loading facilities need not wait for a high tide to enter a harbor which is the case in many areas of the world. In this

instance the single point mooring system could be connected to either onshore or offshore storage facilities.

Accordingly, it is an aspect of the present invention to provide a stable offshore floating terminal, connected to a point adjacent the ocean bottom, for mooring a tanker thereto and transporting fluids between bottom storage facilities and the tanker.

It is another aspect of the present invention to provide an improved means for connecting the floating terminal to storage facilities located at the marine bottom.

It is a further aspect of the present invention to provide a novel boom or support means extending part way between the floating terminal and the tanker to facilitate the tanker being moored at a safe distance from the terminal while being in fluid communication therewith.

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

FIG. 1 is a schematic elevational view of the novel single point mooring system of the present invention; and

FIG. 2 is an enlarged view of the portion of the floating terminal illustrating an arrangement for providing fluid communication between apparatus on the floating terminal and a tanker, through a rotatably and pivotally mounted boom, that can be extended outwardly from the terminal in any direction.

Now looking at FIG. 1, the single point mooring system of the present invention consists of a substantially vertical rigid-walled tether pipe **10** bridging the body of water between a submerged facility, comprising at least an open bottom storage tank **12**, located on the marine bottom **13**, and a surface unit comprising a buoyant central floating terminal **14** universally fixed to the upper end of the tether pipe **10**, and a loading boom **11** rotatably and pivotally mounted on the tether pipe **10** and selectively connected to the terminal **14**. The floating terminal **14** is a wave transparent structure consisting of a deck **16** supported, above the surface **18** of a body of water **20** on buoyant horizontal submerged floats **22**, by four buoyant peripheral vertical columns **24**. The upper end of the tether pipe **10** is connected by a collet connector **28** to the lower end of a universal joint **26**, depending centrally from the floating terminal **14** at approximately the center of buoyancy thereof. The floating terminal **14** provides support for an above-surface deck, for mounting equipment, as well as a buoyant support for the tether pipe **10**. The universal joint **26** allows the deck **16** to hold a constant orientation even though the upper end of the tether pipe **10** is displaced from over the fixed lower end thereof. The tether pipe **10** is anchored at its lower end by a collet connector **30** fastened to the upper end of a short, upstanding stub pipe **32** extending from the upper end of the storage tank **12** which is firmly fixed in the formation underlying the marine bottom **13** by piles **34**. As shown, the flexibility of the tether pipe **10** will compensate for any movement of the floating terminal **14** from directly over the storage tank **12**. Since such an arrangement is only practical in very deep water, the flexibility of the tether pipe **10** being proportional to its length, a universal connection between storage tank **12** and the tether pipe **10** is normally advisable. Such a connection is shown in the present inventor's similarly titled copending application Ser. No. 589,434, filed on Oct. 25, 1966.

The loading boom **11**, consisting of an open framework of braces, has, at its outer end, a flotation tank **36** which floats partially above the surface **18** of the body of water **20** when the boom **11** is in the position shown in full lines in FIG. 1. The flotation tank **36** is large enough for the landing of personnel and has an upstand-

ing mooring bollard **37** fixed on its upper planar surface. The outer end of the boom **11** is buoyantly supported by the tank **36**, the inner end of the boom being pivotally supported on the tether pipe **10** by a triangular configuration of struts **38** depending from the boom **11** and connected at an apex, spaced below the boom, by a knee-action pin joint **40**, to a subsurface swivel **42** journaled on the tether pipe **10**, near the upper end thereof. The swivel **42** consists of a pair of spaced rotatable collars **44** mounting the arrangement on the tether pipe **10**, and a pair of interconnecting struts **46** extending therefrom and converging at the pin joint **40**. Another swivel **48**, journaled lower down on the tether pipe **10**, consists of a pair of spaced rotatable collars **50** and **52** journaled on the tether pipe **10** with a horizontal beam **54** extending outward from the upper collar **50** and being supported by a diagonal strut **56** fixed to the lower collar **52** at its inner end. On the outer end of the beam **54** is a seat **58**, for supporting the outer end of the boom **11**, or the flotation tank **36** thereof, when the boom is stored beneath the surface **18** when not in use as shown in phantom.

When the boom **11** is unrestrained it tends to rise to the surface **18** due to the buoyancy of the flotation tank **36**. To store the broom **11** beneath the surface **18** of the body of water **20**, a handling line **59** is connected from the lower end of the flotation tank **36**, through a pulley **60** spaced out from the tether pipe **10** on the horizontal beam **54** of the swivel **48** and hence, up substantially parallel to the tether pipe **10** to the edge of the deck **16** of the terminal **14** where a power winch, shown schematically at **61**, is mounted on a trolley **62** between the C rails of a circular track **63** running along the perimeter of the deck **16**. Reeling up the handling line **59** draws the outer end of the boom **11** down, pivoting it about the pin joint **40**, beneath the surface **18**, until the flotation tank **36** at the outer end of the loading boom **11** is located in the seat **58** on the swivel **48**. By this arrangement the loading boom **11** is located far beneath the surface **18** of the body of water **20** when not in use so that it cannot be damaged during storms and will not itself present a surface for wind and waves to act upon, and therefore permitting only minimal surface wind and wave forces to be applied to the tether pipe **10** through the above-surface components of the terminal **14** when the system is not in use.

When the present mooring and loading system is to be utilized in conjunction with a subaqueous oil field, a long distance from shore, the fluid, to be delivered periodically to a tanker **63'** moored by a line **64** to the bollard **37**, is conducted to the storage and loading facilities by a number of subsea pipelines **65** (one shown), each connected with a plurality of subsea wellheads through a subsea gathering station (not shown). The tether pipe **10** provides fluid communication between the subsea pipeline **65** and the floating terminal **14**. The tether pipe **10**, for purposes of this illustration, is constructed as a double-walled conduit, forming concentric flow passageways, with the subsea pipelines **65** being connected to the annulus of the tether pipe **10** through the outer wall thereof just above the collet connector **30**.

Crude oil and/or gas is transferred from the upper end of the tether pipe **10** to the deck **16** of the floating terminal **14** through the hollow interior of at least one of the supporting columns **24** and the submerged floats **22**, the universal joint **26** being bypassed by a flexible line **66** connected to the annulus of the tether pipe **10**. The crude oil may be carried directly within the hollow interiors of the columns **24** in the floats **22** or may be contained within a closed conduit **67**, as shown in FIG. 2, carried within these components. The specific system under discussion, being designed for the production of oil, dictates that the produced fluid is directed through processing equipment **68** (schematically shown in FIG. 2), including a separator on the deck **16**, the oil being separated from any included gas and water and the pressure being reduced to atmospheric. The resulting gas can then be flared, or, if economical, it can be stored. The separated oil is then conducted back down to the bottom of the floating terminal directly through certain of the hollow buoyant columns **24** and the submerged floats **22**, or by enclosed conduits **69**, through a two-way, three-position valve **70** (also shown in FIG. 2). A path of fluid communication is provided from the floating terminal **14** to a storage area within the storage tank **12** through the central passage in the tether pipe **10** and a flexible tube **68** bridging the universal joint **26**. The oil is conducted down through the center of the tether pipe **10**, passing through the collet **30**, and into the storage tank **12**. Any suspended solids will settle out through the open bottom of the tank **12**. Included water will also separate out from the oil.

When the tanker **63'** arrives to receive the oil stored in the tank **12**, the connection between the processing equipment **68** on the deck **16** of the floating terminal **14** and the storage tank **12** on the marine bottom **13** is broken, and the storage tank **12**, through the tether pipe **10**, is then connected to the tanker loading apparatus, to be discussed later. As shown in the embodiment of FIG. 2, the valve **70** is repositioned to direct the oil from the upper end of the fluid conduit **69** into the loading apparatus, while blocking the outlet of the processing equipment **68**. The differential head, of the sea water outside and the oil inside the open bottom of the storage tank **12**, provides an adequate supply of oil on the suction side of pumps (not shown) mounted in the floating terminal **14** for water that is greater than about four hundred fifty feet, the pumps on the terminal **14** providing high pressure for quickly loading the tanker **63'**. For depths of less than approximately four hundred fifty feet, subsurface pumps will also be included in a submerged portion of the floating terminal **14**. Pumps that may be used for transferring oil from the bottom storage tank **12** to the terminal **14** are well known in the art and are illustrated in more detail in the British Pat. No. 1,023,085, published Mar. 16, 1966.

The boom **11**, constituting a portion of the above-mentioned tanker loading apparatus, serves the double purpose of supporting a fluid transferring conduit along its length and providing means at its other end for mooring the tanker **63'** at any point on the circumference of a circle around the tether pipe **10**. A hollow conduit **72** extending the length of the boom **11** contains the oil being transferred from the inner to the outer end of the boom **11** while functioning as the backbone for the framework making up the boom itself. At the outer end of the boom **11**, the conduit **72** extends through the flotation tank **36** and is connected to the inner end of a buoyant loading hose **74**. A hose retrieving line **76** is connected between the outer free end of the buoyant loading hose **74** and a schematically illustrated winch **78** mounted at the inner end of the boom **11**. Prior to storing the boom **11**, the winch **78** (which would probably be power driven) would be actuated to reel up the retrieving line **76**, wrapping the buoyant loading hose **74** back around boom **11** to keep it from becoming entangled in the water during storage.

There is no permanent fluid connection between the rotatable and pivotable boom **11** and the stationary terminal **14**. The inner end of the boom **11** terminates in a standpipe section **80**. A flange **82** on the upper end thereof is designed to mate, when the boom **11** is in the solid line position of FIG. 1, with a complementary flange **84** formed on the outer end of a transition arm **86** (FIG. 2) suspended beneath the platform **16** of the floating terminal **14**. Since the boom **11** must be able to rotate approximately 360° around the tether pipe **10**, the transition arm **86** must also be able to rotate 360°. To avoid a collision with one of the four support columns **24** of the terminal **14** during rotation, the transition arm **86** must also be retractable completely under the platform

14 and so it is pivotally mounted on a reciprocatable underhung carriage 88 suspended from a track comprising a pair of parallel rails 90 on a turntable 92 rotatable on a circular rail 94 located centrally to the underside of the platform 16. The pivoting of the transition arm 86 is controlled by a winch 96 mounted on the carriage 88 by a line 98 connected therebetween and entrained over a pulley 100 fixed, between the rails 90, on the turntable 92. As shown in FIG. 2, the carriage 88 is as far over to the left as allowed by the rails 90, within the support columns 24. This permits the right end of the transition arm 86 to be also within the support columns 24 so that the turntable 92 may be rotated to line the transition arm up with the boom 11. Once the boom has been rotated to a position where it is in line between the tanker 63' and the tether pipe 10, the turntable 92 is rotated into the same position. The carriage 88 is then moved in on the rails 90 until it is centrally located beneath the platform 16. The transition arm 86 in this position extends out beyond the platform support columns 24 as shown in FIG. 1. As the carriage 88 moves in on the rails 90, the distance between the winch 96 and the pulley 100 shortens, causing the transition arm 86 to drop down toward the boom 11.

When the carriage 88 reaches the center of the platform 16 on the rails 90 and is locked in place, the winch 96 is actuated to continue the lowering of the outer end of the transition arm 86 until the flange 84 thereof mates with the flange 82 on the inner end of the standpipe 80 of the conduit 72. Personnel on the inner end of the boom 11 bolt the flanges together to form a fluidtight seal. With the flanges 82 and 84 bolted, a flange 102, on the inner end of the transition arm 86, is now in a horizontal plane directly beneath the terminus of a fluid conduit 104 selectively connected to the storage tank 12 through the valve 70 and having its downstream end depending centrally through the platform 16 to a point just above the transition arm 86, when the transition arm 86 is in the position shown in FIG. 1. The terminal portion 106 of the conduit 104 is a rotatable slip coupling biased upwardly out of connection with the transition arm 86 by a pair of springs 108 connected between the underneath of the platform 16, on opposite sides of the conduit 104, and a thrust or throw-out bearing 110 for allowing the terminal portion to rotate while being biased upward. By applying a downward force on the terminal portion 106, a terminal flange 112 on the end thereof may be lowered into conjunction with the flange 102 on the inner end of the transition arm and personnel in the carriage 88 can bolt the flanges 112 and 102 together to form also a fluidtight seal. The terminal portion 106 would be of a flexible pressure resistant material to compensate for any misalignment of the conduit 104 and the transition arm 86. A flexible section 114 at the other end of the transition arm 86 compensates for the individual movement on the terminal 14 and the boom 11 caused by surface wave action. With such an arrangement the oil flowing up from the storage tank 12 through the line 69, within one of the support columns 24, is directed through the two-position, three-way valve 70 into the line 104, down through the transition arm 86, and into the fluid conduit 72 of the boom 11, the oil being conducted through the loading hose 74 and into the tanker 63.

The turntable 92 should not be rigidly locked in position in the circular track 94 so that any slight movement of the boom 11 caused by shifting in the position of the tanker 63, moored thereto, will cause the turntable to rotate slightly on the rails rather than causing a distortion of the transition arm 86. The rotation of the boom 11 will also cause the winch trolley 62 to roll along its track to realign the winch with respect to the boom 11 due to the interconnecting handling line 59.

The wind and wave forces acting on the surface components of the system, such as the floating terminal 14 and the boom 11 when it is in the loading position, as well as the tanker 63 when moored thereto, will cause the upper portion of the system to be laterally displaced and, in so doing, will force the tether pipe 10 out of the vertical position shown in FIG. 1. The tether pipe would either bend, due to its inherent flexibility, or it would pivot around a lower universal joint just above the collet connector 30, if such a joint were included (as previously described). The movement of the tether pipe 10 away from its vertical position is opposed by the upwardly directed forces resulting from the submerged buoyant floats 22 and the buoyant support columns 24 of the terminal 14. Since the tether pipe 10 is of constant length, the terminal 14 will be drawn down further into the water by its lateral displacement. As the terminal 14 is drawn down, the additional submergence of the support columns 24 results in an increasing buoyant force tending to restore the tether pipe to its vertical position. The magnitude of the restorative force will be determined by the combined buoyancy of the floats 22 and the support columns 24. Therefore, these buoyant elements are designed to produce a buoyant force much greater than that necessary to support the terminal 14 and the equipment thereon. If, in a particular instance, a small terminal 14 is to be used, having buoyant sections only large enough to support the equipment, one or more cylindrical buoyancy tanks can be mounted concentrically on the upper portion of the tether pipe 10 between the two swivels 42 and 48, or the swivel 42 and pivot joint 40 can be redesigned to be lower on the tether pipe 10 and the cylindrical buoyancy tank can be mounted between the swivel 42 and the collet connector 28. The closer to the top of the tether pipe 10 that the buoyancy tank is mounted, the greater the resultant couple acting to right the tether pipe 10. Without a buoyancy tank on the tether pipe 10, it would be necessary to provide auxiliary support for the tether pipe 10 any time the terminal 14 was removed for repairs.

The single point mooring system of the present invention could serve other functions in conjunction with a subsea production system. Electrical generators, and the prime power source therefor, would be located on the deck 16 of the terminal 14 for supplying necessary power to the pumps and controls of the storage tank 12 and the bottom-mounted satellite gathering system and therethrough to the subsea wellheads. The tether pipe 10 would support the interconnecting power lines as well as electrical readout and command lines for the subsea system. These various lines would be supported along the outside of the tether pipe 10, bridging the swivel 26 by flexible lines, if the loading boom 11 is not allowed to rotate more than one revolution, or rotatable electrical connections may be formed within the swivel 26.

What is claimed is:

1. A subsea material producing system comprising:
- a storage tank anchored in formations underlying a marine bottom beneath the surface of a body of water at an offshore site;
- a tether pipe attached to said storage tank and extending substantially vertical to a point at least adjacent said surface of said body of water;
- a floating terminal for mooring a vessel thereto and for loading produced material onto the vessel;
- means for fastening said floating terminal to the upper end of said tether pipe to locate said floating terminal at said offshore site, said floating terminal maintaining said tether pipe in its substantial vertical position in said body of water;
- means for fluid communication between said storage tank and said floating terminal, said communication means being at least in part supported by said tether pipe for directing material from said storage tank to said floating terminal; and
- means for conducting said material from said floating terminal to a vessel moored thereto.

2. An offshore structure as recited in claim 1 wherein means for buoyantly supporting said floating terminal extend through said surface of said body of water whereby the further said upper end of said tether pipe is displaced from directly above said fixed lower end of said tether pipe, the deeper said terminal is drawn down into said body of water, further submerging said buoyant means and creating a larger restorative buoyant force tending to move said floating terminal back over said lower fixed end of said tether pipe.

3. An offshore structure as recited in claim 2 wherein said tether pipe is fastened to said floating terminal at substantially the center of buoyancy thereof.

4. An offshore structure as recited in claim 2 wherein said floating terminal has a portion thereof normally positioned above the surface of the body of water and wherein said buoyant means of said floating terminal comprises at least one horizontal submerged float and at least one vertical column extending between said submerged float and said above-surface portion of said floating terminal to produce a substantially wave transparent structure.

5. A subsea material producing system comprising a storage tank anchored in formations underlying a marine bottom beneath a body of water at an offshore site; a rigid-walled tether pipe having the lower end thereof fixed with respect to said marine bottom, said tether pipe extending substantially vertically to at least a point near said surface of said body of water; a floating terminal having at least an above-surface deck, said tether pipe being fastened to said terminal to locate said floating terminal at said offshore site; a first fluid communication means, at least supported by said tether pipe, for conducting material from at least one pipe line extending across said marine bottom to said above-surface deck of said floating terminal; and a second fluid communication means, at least supported by said tether pipe, for conducting material from said deck of said floating terminal to a storage area within said storage tank anchored far beneath said surface of said body of water.

6. A subsea material producing system as recited in claim 5 wherein the lower end of said storage tank is in open communication with said body of water adjacent said marine bottom.

7. A subsea material producing system as recited in claim 5 wherein at least one of said first and second fluid communication means comprises an axial passageway within the rigid outer wall of said tether pipe.

8. A subsea material producing system as recited in claim 5 wherein said first and second fluid communication means comprises said tether pipe formed of a concentric double-walled conduit to provide a central fluid passageway and an annular fluid passageway extending the length of said tether pipe.

9. A subsea material producing system as recited in claim 8 wherein said pipe line, extending across said marine bottom, is in fluid communication with said annular passageway of said tether pipe, and said storage area of said storage tank is in fluid communication with the central passageway of said tether pipe.

10. A subsea material producing system as recited in claim 5 wherein said first and second fluid communication means extend from said upper end of said tether pipe to said above-surface deck of said floating terminal through at least one column supporting said terminal deck above said surface of said body of water on at least one submerged float, said floating terminal forming a wave transparent structure.

11. A subsea material producing system comprising:

a storage tank anchored in formations underlying a marine bottom beneath the surface of a body of water at an offshore site;

a tether pipe extending from a fixed point at least adjacent said marine bottom to a point at least adjacent said surface of said body of water;

a floating terminal for mooring a vessel thereto for loading material onto the vessel;

means for fastening said floating terminal to said tether pipe to locate said floating terminal at said offshore site;

first means for fluid communication between a storage area within said storage tank and said floating terminal, said first means being at least in part supported by said tether pipe and adapted to allow flow of material between said tank and said terminal;

means for conducting material from said floating terminal to a vessel when moored thereto;

a pipe line extending at least in part across said marine bottom and adapted to be connected at one end to a material producing source; and

second means attached to the other end of said pipe line for fluid communication between said pipe line and said floating terminal, said second means being at least in part supported by said tether pipe and adapted to allow flow of material from said pipe line to said floating terminal.

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9—8; 114—.5; 137—236; 166—.5