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Adler et al. [45] **Sept. 4, 1973**

[54] **LOADING TERMINAL FOR TANKERS OR OTHER LARGE SHIPS WITH FLOWABLE CARGO**

[75] Inventors: **Cyrus Adler**, New York, N.Y.; **Lewis Schneider**, Springfield, N.J.

[73] Assignee: **Cyrus Adler**, New York, N.Y.

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[21] Appl. No.: **12,995**

[52] **U.S. Cl.** **141/388,** 61/46, 137/236, 141/279

[51] **Int. Cl.** **B65b 1/04**

[58] **Field of Search** 141/387, 388, 279, 141/284; 137/236, 615; 9/8; 114/0.5; 166/0.5; 61/46

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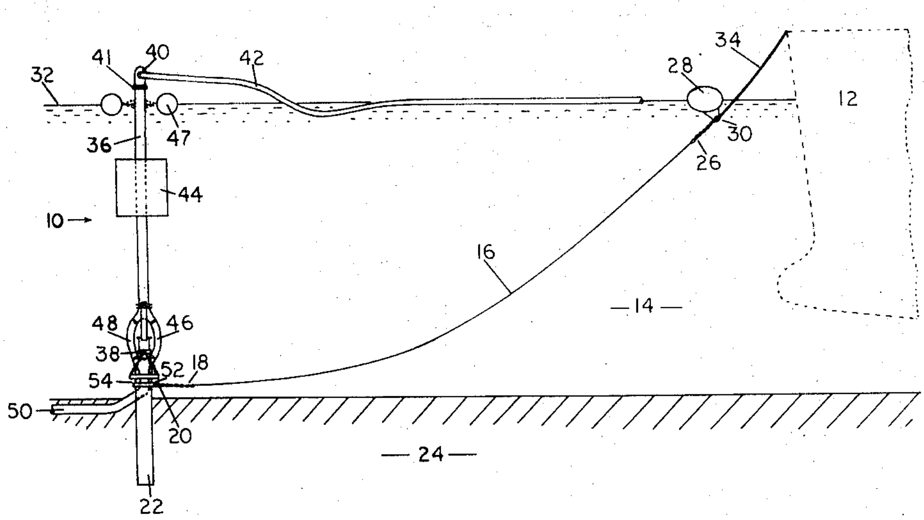
Primary Examiner—Bell, Jr., Houston S.
Attorney—Ryder, McAulay & Hefter

[57] **ABSTRACT**

An offshore mooring terminal for transferring liquid or flowable cargo between a ship and an onshore station. The ship is connected to the mooring terminal by a single mooring line connected at one end to a swiveling anchor located at the sea bottom. A buoyant riser column is attached at its lower end to the anchor by an articulate joint which permits the riser column to pitch and roll with the waves. The upper end of the riser column extends above or near the surface of the sea. The riser column provides a conduit for the fluid and includes a rotary joint at its upper end to receive the floating hoses running to the ship, and a connection to a submarine pipeline at its lower end for carrying the fluid shoreward or to other destinations as may be required. The swiveling anchor device to which the mooring line is secured allows the ship to rotate about the mooring terminal as it swings in the current.

20 Claims, 8 Drawing Figures



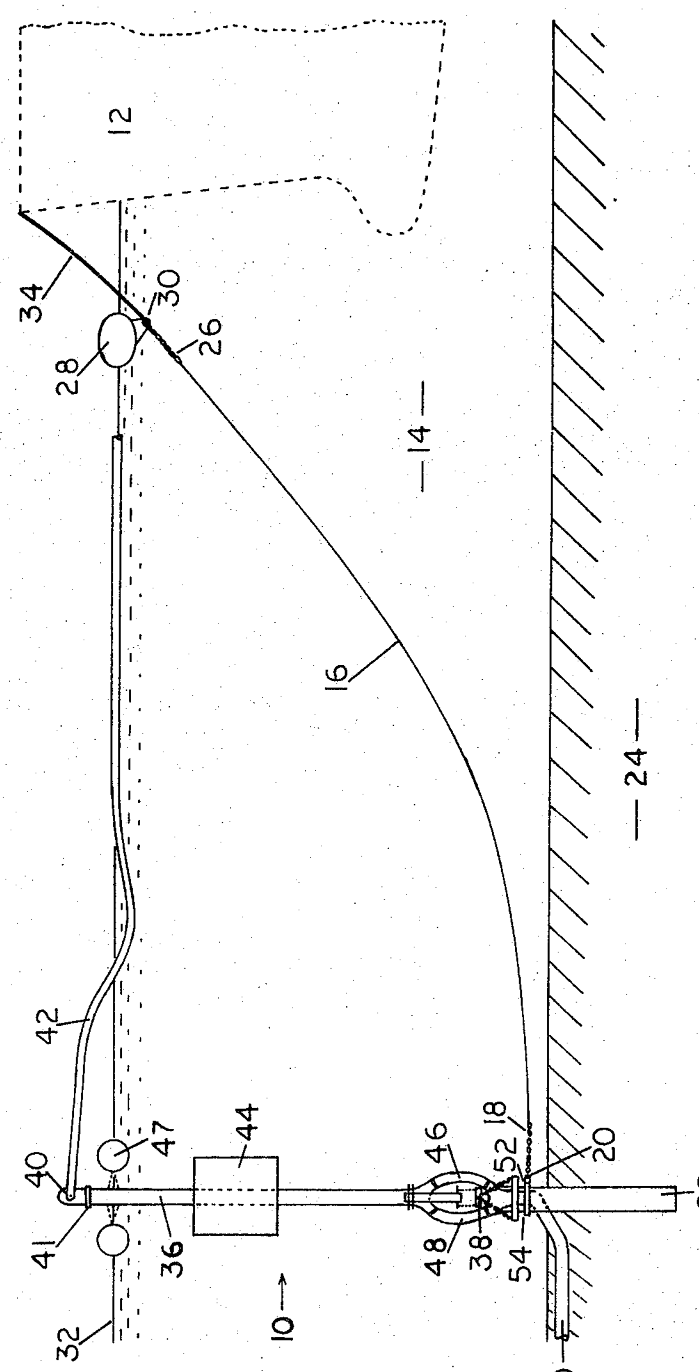


FIG. I

CYRUS ADLER
LEWIS SCHNEIDER INVENTORS

BY
Kenyon & Kenyon Reilly Carr & Chapin
ATTORNEYS

FIG. 4

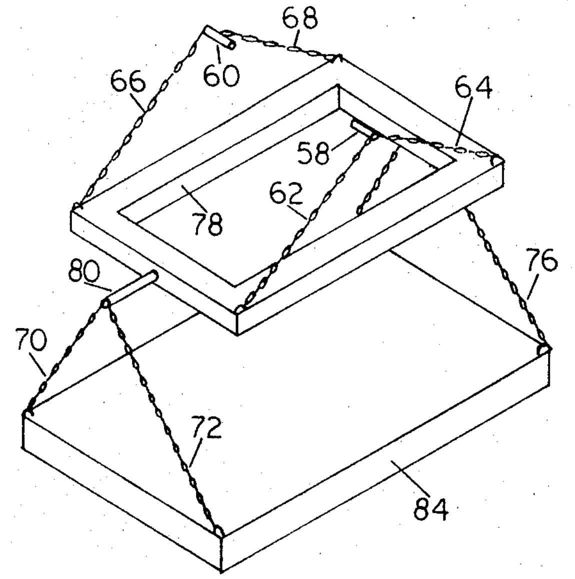
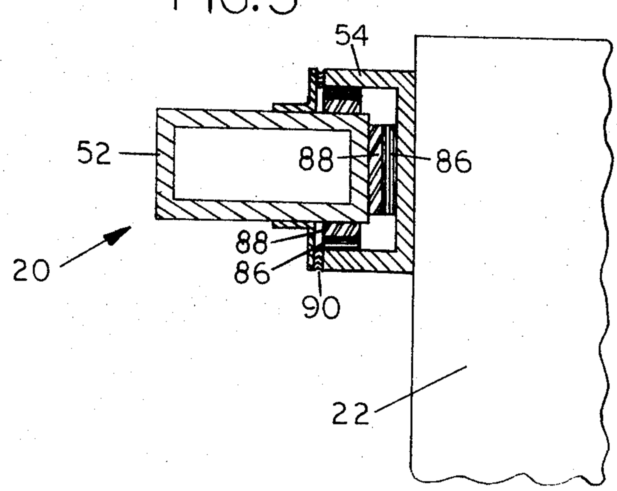


FIG. 5



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Kenyon & Kenyon Reilly Carr & Chapin

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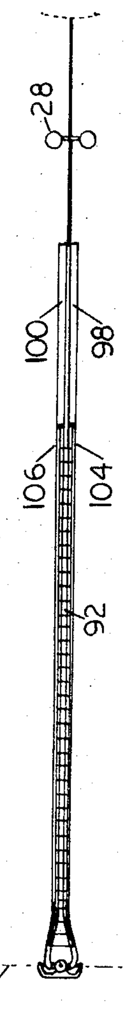

FIG. 7

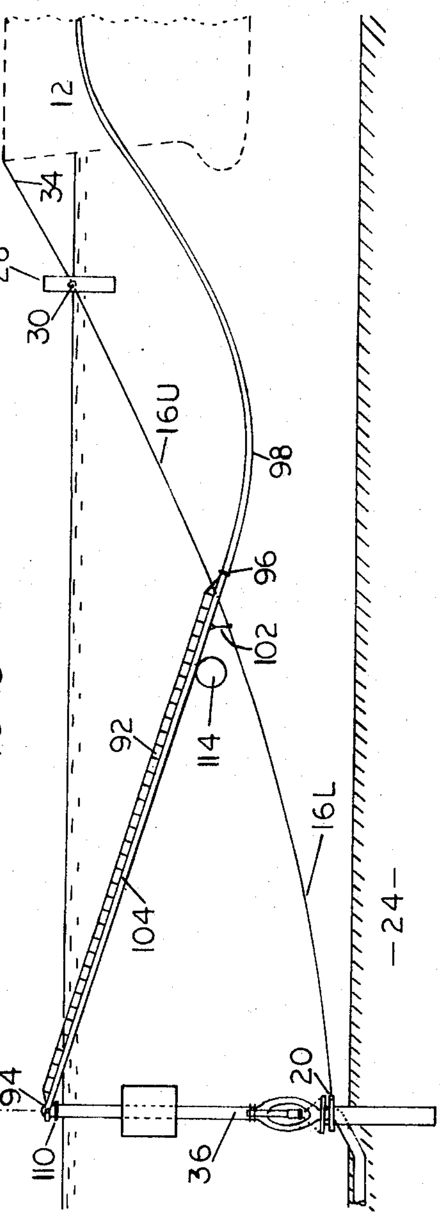

FIG. 6

CYRUS ADLER
LEWIS SCHNEIDER INVENTORS

BY
Kenyon & Kenyon Reilly Carr & Chapin
ATTORNEYS

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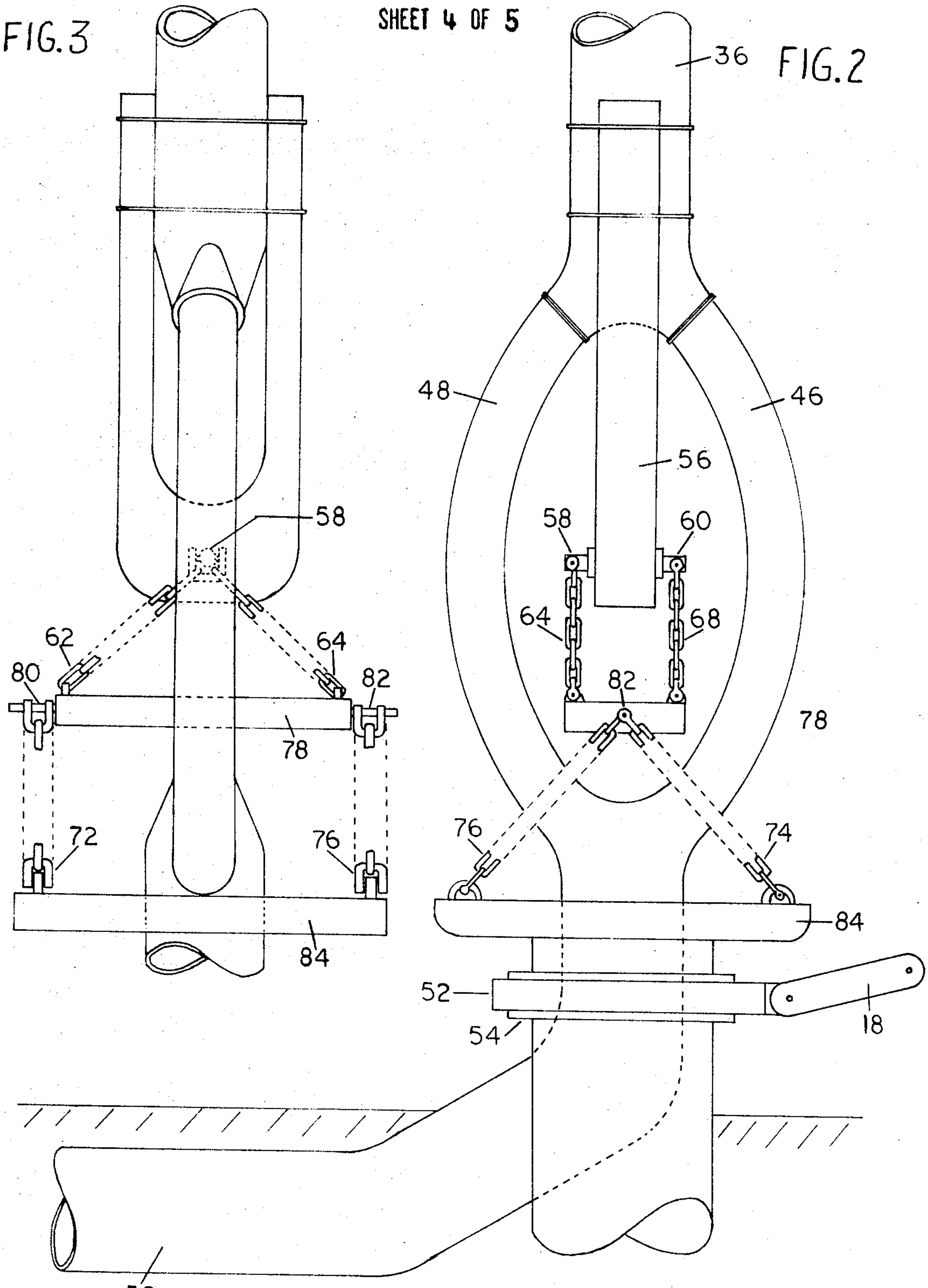
FIG. 3

FIG. 2



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LEWIS SCHNEIDER

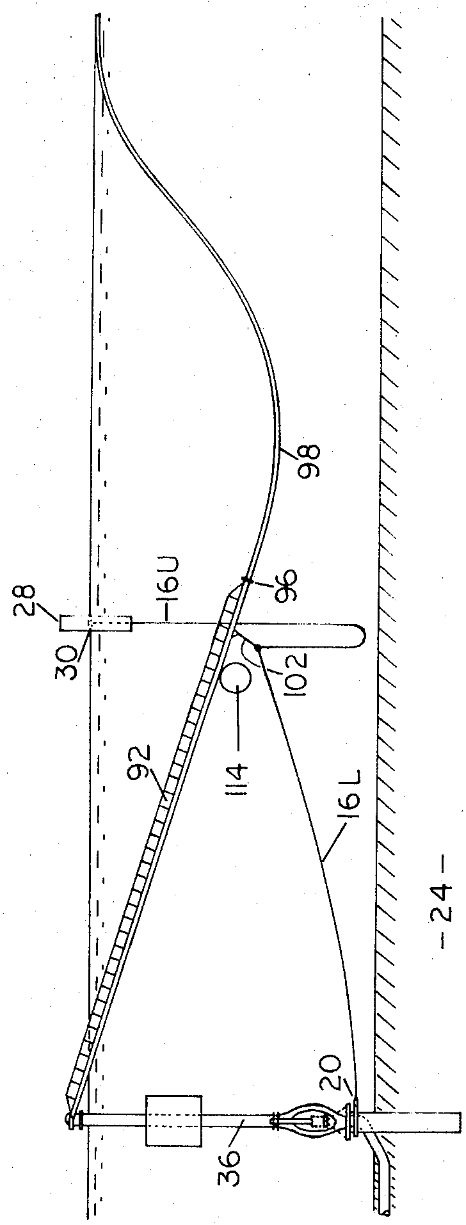
INVENTORS

BY

Kenyon & Kenyon Reilly Carr & Chapin

ATTORNEYS

FIG. 8



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LEWIS SCHNEIDER

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BY

Kenyon & Kenyon Reilly Carr & Chapin

ATTORNEYS

LOADING TERMINAL FOR TANKERS OR OTHER LARGE SHIPS WITH FLOWABLE CARGO

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an offshore mooring terminal, and more particularly to a single point mooring terminal for the loading or discharge of liquid or flowable cargo onto or from tankers or other large ships.

2. Description of the Prior Art

Economic factors in industries, such as the petroleum industry, combined with the geographic disposition of petroleum resources and world markets have led to the increased utilization of very large tankers for the transportation of crude petroleum and products. The unavailability of harbors with sufficient draft or berthing facilities to allow entry of such large ships at the crude oil sources and refinery and market locations has led to the use of offshore terminals.

One conventional approach to such a terminal is the single point mooring buoy whereby the ship is connected to an anchored floating buoy by a bow hawser. The hawser anchorage is free to swivel on the buoy in a manner which permits the ship to rotate about the buoy and generally face bow-on to the wind and current, thus tending to minimize the mooring forces on the anchorage. The system includes a length of floating hose between the ship and buoy, and a flexible hose connected between the buoy and the submarine pipeline running to the shore. A rotary fluid joint is provided on the top of the buoy to allow the floating hose to swivel in response to the movement of the ship as it swings about the mooring point. Also, the lower portion of the buoy is connected to the buoy anchorage by means of a plurality of long chains extending to the sea bottom.

The above-described prior art system is large and expensive. A principal disadvantage is that the large dynamic forces acting on the ship from the action of wind, wave and current are directly transmitted to the buoy by the mooring line attached to the top of the buoy. In turn, a buoy of substantial size is required to accommodate these large forces and the buoy must be constrained by large anchor chains. Furthermore, the static buoyancy of the buoy is relatively great, so that the chains are constantly subjected to high tension whether a ship is moored or not; resulting in abrasive wear on the chain lengths as the buoy responds to wave action. Since the cost of the chain is a large percent (in the order of one-third) of the total initial cost of the conventional buoy system, such abrasive action necessitating replacement of the chain can produce a substantial addition to life cycle costs.

Also, in the prior art mooring system referred to above where a plurality of chains connect a mooring tower or buoy to the anchors, the mooring tower or buoy is held relatively rigid, thereby permitting very little roll of the buoy in response to wind, waves and currents. Such a rigid connection of the buoy creates high stresses in the buoy and the supporting anchor chains, since the buoy is unable to substantially comply and roll with the waves and currents. In addition, in most mooring systems flexible hoses are employed to connect the submarine pipeline near the bottom of the sea in fluid communication with the fluid conduit connectors at the bottom of the buoy. Consequently, a large degree of twisting movement of the buoy will unduly

stress the hoses, often requiring replacement by procedures which are both time-consuming and expensive.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a single point mooring terminal which substantially eliminates the large dynamic forces ordinarily transmitted from a ship to a mooring buoy.

It is another object to provide a mooring terminal having structural elements which are relatively small in size and weight and yet has a high structural efficiency in accommodating the dynamic forces acting on a ship from the action of wind, wave and current.

It is another object to provide a mooring terminal which is relatively small in size and develops relatively small static buoyancy forces, so that the anchor means for the mooring terminal are not constantly subject to high static tension forces.

It is another object of the invention to provide a mooring terminal which is relatively small in size, does not require frequent replacement of parts, and is easily maintainable.

It is another object to provide a mooring terminal in which the buoy member readily complies and rolls with the waves and currents without developing high stresses on the mooring terminal.

It is still another object to provide a mooring terminal in which the buoy member readily complies and rolls upon accidental collisions or bumping by sea vessels, without damage to the mooring terminal.

It is a further object to provide a mooring terminal which does not permit a significant twisting movement of the buoy member.

These and other objects, which will become apparent from the detailed disclosure and claims to follow are achieved by the present invention which provides a single point mooring terminal for transferring fluid between a ship and an onshore station. The ship is connected to the mooring terminal by a mooring line anchored directly to the foundation through a swivel connection on the anchor located at the sea bottom. A buoyant riser column extends substantially from above the surface of the sea down to the anchor to which it is connected by an articulate joint. The riser column provides a conduit for the fluid and includes a rotary joint at its upper end to receive the floating hoses running to the ship, and a fluid coupling to a submarine pipe line at its lower end. The swivel connection between the mooring line and the anchor allows the ship to rotate about the mooring terminal. Also, the articulate joint permits the riser column to pitch and roll with the waves and currents while preventing any significant twisting movement of the riser column.

In one modification, a rigid boom structure is connected at one end to the rotary joint at the upper end of the riser column, in place of a portion of the floating hoses. The outboard end of the boom includes a connector for joining the floating hoses leading to the ship. A connection between the boom and a central portion of the mooring line prevents the mooring line from dragging along the sea bottom.

It is to be understood that, as used herein, the term "fluid" is intended to mean any liquid, gas or fluid slurry with solid particles suspended therein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation view of the mooring terminal connected to a ship, illustrative of the invention;

FIGS. 2, 3 and 4, respectively, are front, side and perspective views of the articulate joint employed in the mooring terminal shown in FIG. 1;

FIG. 5 shows a detailed cross-sectional view of the swivel connection between the mooring line and the anchor;

FIG. 6 is a side elevation view of the mooring terminal connected to a ship, illustrating a modification incorporating the rigid boom structure;

FIG. 7 is a plan view of the system shown in FIG. 6; and

FIG. 8 is a side elevation view of the mooring terminal shown in FIG. 6, in the position it assumes when a ship is not connected to the mooring line or under light current conditions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown the single point mooring terminal 10 of the invention connected to a ship 12 located offshore in a sea 14. Mooring terminal 10 generally includes a mooring chain or line 16 connected at its lower end 18 to a swivel connection 20 on the anchor 22 located at the sea bottom 24. The upper end 26 of the mooring line 16 is connected to an auxiliary floating buoy 28 by means of a fitting 30 provided on such buoy 28. When a ship is not anchored or moored to the mooring terminal 10, the auxiliary buoy 28 maintains the upper end 26 of line 16 at the sea surface 32, so as to be readily accessible for connection to a ship's hawser 34. Mooring terminal 10 also includes a riser column 36 attached at its lower end to the anchor 22 by an articulate joint 38. The upper end of riser column 36 extends above the sea surface 32 to a point where a horizontal rotary swivel joint 40 connects a floating hose 42 to the manifold of the swivel joint 40. Also, a vertical swivel joint 41 permits free rotation of the hose 42 about the vertical axis of the riser column 36.

The riser column 36 is a substantially rigid member, made of a material, such as steel, which provides a conduit for the fluid via one or more pipes, not shown, extending throughout its length. Riser column 36 preferably has a cylindrically shaped external surface in order to maintain the drag forces at a minimum, while it may internally comprise either one pipe, a cluster of parallel pipes or coaxial pipes depending on the specific requirements. A buoyancy chamber 44 is provided for the riser column 36 and designed to maintain the riser column 36 in a state of positive buoyancy at all times so that the riser column 36 tends to remain in an essentially upright position under the action of sea currents and waves. Buoyancy chamber 44 can, for example, be designed to limit the pitch and roll angle of the riser column 36 to 15 degrees. If desired, a floating ring buoy 47 can be connected so as to extend around the upper end of the riser column 36. The floating ring buoy 47 acts as a fender to protect the riser column 36 from small craft and debris, and also serves as a working platform and a support for the inboard end of the floating hose 42.

Fluid is transferred from a ship tank through the floating hose 42 to the manifold of the rotary swivel joint 40 where it then passes down through the conduits in the riser column 36. It is noted that more than one floating hose 42 can be employed, if desired. The lower end of the riser column 36 terminates in a Y feeding into two short flexible hoses 46 and 48 which are thence connected in a second Y leading into a submarine pipe line 50 at the sea bottom 24 for carrying the fluid shoreward or to other destinations as may be required. Of course, the fluid can be passed through the system in the opposite direction to that described above. It is to be pointed out that while this specific flexible hose arrangement is shown as the preferred embodiment, other suitable hose arrangements can be employed.

The swivel connection 20 for the mooring line 18 generally comprises a bearing ring around a vertical axis of rotation. In the specific embodiment shown, a ring girder 52 extends annularly around the lower end of the mooring terminal 10 and is slidably mounted in a fixed bearing frame 54 attached to the anchor 22. Also, anchor 22 is shown as a large diameter caisson sunk into the sea bottom 24 sufficiently to sustain the shear and uplift forces on the anchor foundation 22. However, alternate arrangements not shown, using clusters of concrete pipe or piles or drilled-in anchorages may be utilized depending on the actual sea bottom conditions at a particular site. As the direction of the wind and current varies, a tangential component of force will be developed at the swivel connection 20 causing the ring girder 52 to swivel on its bearings about a vertical axis. This swivel movement allows the ship to rotate about the mooring terminal 10 as it swings in the current. It is noted that the large dynamic forces acting on the ship are not directly transmitted to the riser column 36 by the mooring line 16, since such mooring line 16 is not attached to the anchor 22 through the riser column 36, but rather is directly attached via the swivel connection 20 to the anchor 22. Therefore, the articulated riser column 36 is subjected only to the forces acting upon itself and the floating hose 42.

In this fashion, since the ship forces are carried directly to the anchor 22 rather than through an intermediary buoy structure such as the riser column 36, and since the large structure, in the form of the ring girder 52 and mounting frame 54, is located at the sea bottom 24 rather than at the surface 32 where it would be subjected to the full intensity of wind and wave action, a great economy in the size and the weight of the required structural elements is achieved. Further details of the swivel connection 20 will be discussed hereinafter, in reference to FIG. 5.

Referring to FIGS. 2, 3 and 4 are shown, respectively, the front, side and perspective views of the articulate joint 38. Specifically, the lower end 56 of the riser column 36 is fitted with a pair of trunnions 58 and 60 joining such riser column 36 to a chain linkage arrangement comprising chain links 62–76. Upper chain links 62 and 64 form a swivel connection with trunnion pin 58 and, similarly, upper chain links 66 and 68 form a swivel connection with trunnion pin 60. The other ends of each of chain links 62–68 are connected to the respective corners of a rigid frame structure 78. An additional pair of trunnion or hinge pins 80 and 82 are fixedly attached to the frame structure 78, and provide the swivel pins for the lower chain links 70 and 72, and 74 and 76, respectively. The lower ends of each of chain links 70–76 are attached respectively to a fixed top plate 84 on the anchor 22. The kinematics of the chain linkage arrangement permits the lower end of the riser column 36 to pivot about two mutually perpendicular horizontal axes, but does not permit rotation of the riser column 36 about a vertical axis. This latter feature prevents the flexible hoses 46 and 48 from being subjected to twist action which, as mentioned previously, can result in shortening the useful life of such hoses. It is to be pointed out that the chain linkage arrangement can also be made using a single rigid link in place of each chain link 62–76, with each rigid link extending between a trunnion pin 58 or 60 and the frame structure 78, or extending between a trunnion pin 80 or 82 and the anchor top plate 84.

The articulate joint 38, with its chain link arrangement thereby allows the riser column 36 to pitch and roll in response to wave and current action while preventing any significant twisting movement by the riser column 36. In this manner, the development of high stresses on the mooring terminal 10 is avoided. In this connection, it is noted that other articulate joint arrangements can also be employed, such as a single universal joint or a spherical joint designed to provide two degrees of freedom without twisting. However, one major advantage of the articulate joint 38 shown and described is that it is not a mechanical joint and, therefore, is relatively free from the sealing, corrosion and bearing problems ordinarily accompanying a mechanical joint.

Referring to FIG. 5, there is shown in greater detail the swivel connection 20 for attaching the mooring line 16 to the anchor 22. Specifically, the lower end 18 of line 16 is fixedly attached to a point on the ring girder 52 which, in turn, is slidably supported in the fixed bearing frame 54. Frame 54 is affixed to the top of the anchor 22 and provides a circular track on which the ring girder 52 travels. An annular bearing surface is provided along the bearing frame 54 by thrust and radial race pads 86 made of a material, such a phenolic, which presents a bearing surface for the ring girder 52 as it rides in a circular path about a vertical axis in response to the movement of the ship 12. Also, stainless steel races 88 are welded to the ring girder 52 at locations which cause them to bear on the surfaces of pads 86. While the bearing ring will operate under direct exposure to sea water, it can be packed in grease and a suitable seal 90 used to prevent water from entering into the bearing areas. The swivel connection 20 is designed to provide a high degree of reliability and to operate over a long period of time, such as 10 years minimum, without requiring maintenance.

One possible disadvantage of employing the flexible floating hose 42 as shown in FIG. 1 is that under conditions of ebb or light current the catenary shape of the mooring line 16 is foreshortened, causing the portion of mooring line 16 near the lower extremity to slacken and lie on the sea bottom 24. Subsequently, as a ship is moored to the terminal 10 and changes its position in response to the direction of the current and/or wind, this lower portion of the mooring line 16 will tend to drag over the sea bottom 24. If the sea bottom 24 provides rough surfaces due to rock or coral projections, the mooring line 16 may become snagged, and consequently, will not freely follow the traverse of the ship. In addition, a rough sea bottom can account for a large portion of wear on the mooring line. Therefore, it is desirable to maintain the mooring line in a position where it is always clear of the sea bottom 24 and not subject to abrasion from being dragged thereon and cannot be snagged by projections on or near the sea bottom 24.

Referring to FIGS. 6 and 7, there is shown a modification of the invention which includes the use of a rigid boom structure 92 connected at its inboard end to a rotary joint 94 at the upper end of the riser column 36. It is noted that where the parts of the mooring terminal shown in FIG. 6 and 7 are the same as the corresponding parts of the mooring terminal 10 shown in FIGS. 1–5, the identical numerals will be used in FIGS. 6 and 7 to identify such parts. The outboard end of the boom 92 includes a connector 96 for joining one or more floating hoses 98 and 100 leading to the ship 12. The mooring line catenary 16 is constituted by a lower portion 16L and an upper portion 16U which are supported from the boom structure 92 by means of a hanger 102 at their point of juncture. As shown, the boom structure 92 is preferably a space truss with the relatively large diameter pipe sections 104 and 106 comprising the bottom chord, also serving as conduits for the transfer of fluid. As such, the employment of a substantial length of pipe sections 104 and 106 serves to eliminate the need for a substantial length of relatively costly floating hose. It is to be understood that the boom structure 92 can be made of pipes, bars, beams, or combinations thereof, which form a rigid structure.

The rotary joint 94 comprises a bearing joint which will enable the boom 92 to rotate freely about a horizontal axis 108. An additional rotary joint 110 permits the boom 92 to freely pivot about the vertical axis 112 of the mooring terminal 10. The rotary joint 110 and swivel connection 20, respectively, permit the boom 92 and the mooring line 16 to freely pivot about the vertical axis 112. The weight of the boom 92 and part of the weight of the mooring line 16 are supported by buoyance means 114 attached to the boom 92. As noted previously, the auxiliary buoy 28 supports the upper end of the mooring line 16 and provides an attachment point 30 for the ship's hawser 34.

Ordinarily, when a ship is not connected to the mooring terminal 10 or when light current conditions exist, the system will assume a configuration as shown in FIG. 8. Here, any slack in the mooring line 16 will be taken up by the hanger connection extending down from the boom 92, so that the mooring line 16 does not drop to the sea bottom 24. Alternately, when the ship 12 is attached to the mooring terminal with its tanks connected to the floating hoses 98 and 100, and the current and wind drag are at the maximum design values, the system will assume a configuration as shown in FIG. 6. Therefore, when the ship 12 is not attached to the mooring terminal 10 the equilibrium forces on the boom 92 are such that the boom 92 suspends the mooring line 16 above the sea bottom 24. Also, it is noted that the floating hoses 98 and 100 will always tend to float on the sea surface 32.

As an example of the size of the system to which the present invention can be designed around, a mooring terminal can be anchored at a 100-foot sea depth with a 100,000 to 300,000 DWT (dead weight ton) ship moored to this terminal from a distance of over 300 feet. A single mooring line is sufficient to accommodate the pitch and heave of the ship without developing high dynamic stresses on the line. A 200-foot boom is attached to a pair of 2-foot diameter swivel joints at the upper end of the riser column above the surface of the sea. The hoses and fluid conduits deliver oil at the rate of 140,000 barrels per hour.

Although the above description is directed to the preferred embodiment of the invention, it is noted that other variations and modifications will be apparent to those skilled in the art and, therefore, may be made without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. An offshore marine terminal for transferring fluids between a ship and an underwater pipe line comprising:

a. an anchoring structure fastened to the sea floor with a vertical conduit through its in-water section which connects to an underwater pipeline, and

b. a ring-swivel supported on a bearing around that part of the anchoring structure which extends above the sea bottom, said swivel being free to rotate 360° around a vertical axis through the anchoring structure, and

c. a buoyant riser column connected at its lower end through a joint to the anchor structure and providing a conduit means through which fluid can be transferred vertically, said joint between the anchor structure and the riser column acticulated to allow the riser column to pivot about any horizontal axis at the top of the anchoring structure, and

d. a flexible fluid coupling connecting the pipe through the anchor structure and the conduit in the riser column, and

e. a fluid swivel for the transfer of fluid connected to the upper end of said riser column above the water line for ease of maintenance and prevention of oil leaks, and

f. a rigid boom, hinged at its upper end to the said fluid swivel at the top end of said riser column, and provided with a buoyancy chamber or chambers at its lower end, and

g. a howser for holding the ship in place, and

h. a mooring line connected at its lower end to the said ring swivel on the anchor structure and connected at its upper end to the lower end of said boom and also to said hawser which holds the ship in place, and

i. said rigid boom connected at its lower, buoyant end to the upper end of the mooring line and to the lower end of the hawser that holds the ship moored, said rigid boom also carrying a conduit which is in fluid communication with swivel joint, and

j. a flexible coupling conduit connected between the conduit at the lower end of the rigid boom and the moored ship.

2. Apparatus as recited in claim **1,** wherein said articulate joint connecting said riser column to said anchoring structure includes a pair of trunnion pins connecting the lower end of said riser column to a linkage arrangement attached to said anchoring structure, said linkage arrangement comprising a set of upper links pivotally connected at their upper ends to said trunnion pins and attached at their lower ends to the four corners of a rigid frame structure, an additional pair of trunnion pins extending from two opposite sides of said rigid frame structure, and a set of lower links pivotally connected at their upper ends to said additional pair of trunnion pins and attached at their lower ends to the anchor structure, whereby said two pairs of trunnion pins are arranged to provide two mutually perpendicular horizontal axes so that said riser column can pivot about said axes.

3. Apparatus as recited in claim **1,** wherein said articulate joint comprises a single universal joint.

4. Apparatus as recited in claim **1,** wherein said articulate joint comprises a spherical ball joint having two degrees of motion, without twisting motion.

5. Apparatus as recited in claim **1,** wherein there is connected to the upper end of said riser column a floating ring buoy.

6. Apparatus as recited in claim **1,** wherein there is provided a buoyancy chamber positioned near the upper half of said riser column to maintain said riser column in a state of positive buoyancy.

7. Apparatus as recited in claim **1,** wherein said fluid swivel coupling means omprises a rotary swivel joint at the upper end of said riser column, the manifold of said rotary swivel joint communicating with a ship-to-riser conduit.

8. Apparatus as recited in claim **1,** wherein said second coupling means for connecting the lower end of said riser column in fluid communication with a submarine pipe line comprises a flexible connection.

9. Apparatus as recited in claim **8,** wherein said flexible connection comprises a conduit in the lower end of said riser column terminating in a Y-configuration which connects with two flexible hoses, said flexible hoses being connected at their other ends to a further Y-configuration leading onto said submarine pipe line.

10. Apparatus as recited in claim **9,** wherein said riser column is attached at its lower end to said anchoring structure by an articulate joint to permit said riser column to rotate about two mutually perpendicular horizontal axes while not permitting rotation about a vertical axis, thereby preventing said flexible hoses from twisting substantially.

11. Apparatus as recited in claim **1,** wherein the lower end of said mooring line is connected to said anchoring means by a swivel connection comprising a bearing ring extending around a vertical axis of rotation.

12. Apparatus as recited in claim **11,** wherein said swivel connection comprises a ring girder slidably supported on bearings in a fixed bearing frame encircling the lower portion of said apparatus and attached to the anchoring structure, whereby movements of said mooring line are accommodated by a swivel motion of said ring girder on its bearings about a vertical axis.

13. Apparatus as recited in claim **12,** wherein said bearings comprise thrust and radial pads attached to said fixed bearing frame, and stainless steel races attached to said ring girder so that said stainless steel races bear on said pads.

14. Apparatus as recited in claim **1,** wherein the conduit means for the passage of fluids between the ship and said first coupling means includes a rigid boom structure rotatably connected at its inboard end to the upper end of said riser column for rotation about both a horizontal and a vertical axis.

15. Apparatus as recited in claim **14,** wherein said fluid swivel comprises a pair of swivel joints having their manifold in fluid communication with the conduits in said rigid boom structure, said swivel joints permitting the boom structure to rotate freely about both a horizontal and a vertical axis.

16. Apparatus as recited in claim **14,** wherein said mooring line includes an upper length of line and a lower length of line, with the point between said upper and said lower lengths being connected to said rigid boom structure to provide a support for said mooring line.

17. Apparatus as recited in claim **14,** wherein said rigid boom structure is a space truss including tubular members as said conduit means.

18. Apparatus as recited in claim **14,** wherein said rigid boom structure and said mooring line are provided with buoyancy means.

19. Apparatus as recited in claim **18,** wherein said buoyancy means includes a first buoy connected to the rigid boom structure.

20. Apparatus as recited in claim **19,** wherein said buoyancy means includes a second buoy attached to the upper end of the mooring line and adapted to also provide an attachment point for the ship's hawser.

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