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(54) A MOORING SYSTEM

(71) We, EXXON RESEARCH AND ENGINEERING COMPANY, a Corporation duly organised and existing under the laws of the State of Delaware, United States of America, of Linden, New Jersey, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which is is to be performed, to be particularly described in and by the following statement:-

In many situations it is desirable permanently to moor vessels in the ocean, such as storage vessels to receive and store crude oil from an offshore oil field. Such storage vessels are usually extensively modified tankers or barges. In mild environments the storage vessel may be moored by bow hawsers to a single anchor leg mooring or other conventional mooring system. However, storage vessels are frequently located far off shore in severe environments, and, because the storage vessel must remain moored even in storms, high mooring forces are imposed on the mooring system. If the storage vessel is to remain permanently moored the mooring system must be designed to withstand the highest forces imposed by the most severe environment at the site. To lessen corrosion and wear, it is desirable to have mechanical components, such as mooring and cargo swivels, located so that they will not be subjected to continuous salt water immersion or alternate wetting and drying action which may cause failure of seals and bearings. Because the mooring is permanent it is further desirable to locate swivel seals and bearings where they can be conveniently inspected and maintained.

Several suitable permanent moorings for storage vessels have been of the single anchor leg mooring design, for example see U.S. Patent Nos. 3,641,602 and 3,614,869. Other permanent moorings for storage vessels have been of the catenary anchor leg design, for example see U.S. Patent Nos. 3,538,880 and 3,823,432. However, in both types of such moorings a buoy, located at the water surface, is subjected to high wave forces which increase peak mooring forces. In the single anchor leg mooring the mooring swivel and fluid swivels located beneath the water surface must be removed and brought to the surface for maintenance. In the catenary anchor leg mooring, the anchor system is very expensive, especially in deep water, and the underwater cargo system requires frequent maintenance.

The present invention relates to a mooring system and more particularly to a system for permanent mooring for a vessel such as a storage vessel. According to the present invention a system for mooring and the handling of cargo comprises a vessel floating on the surface of a body of water, a tension carrying mooring leg having a main axis normally having a substantially vertical orientation and connected at one end to the bottom of said body of water, rigid structural means having a fixed and constant length and attached to said vessel for spacing said mooring leg from said vessel, means for enabling said vessel to swing about said mooring leg, tension exerting means mounted on said vessel capable of exerting tension on the upper end of the mooring leg so as to restore it to a substantially vertical position when said mooring leg deflects therefrom and cargo handling means for the transfer of cargo between the vessel and a location outside the vessel. The rigid structural means, e.g. a yoke, is constantly forced upward by suitable means, such as counterweights, springs, or winches, conected to said means and located on the vessel. In the present invention, preferably a mooring swivel and fluid swivel are used and these are preferably situated relatively high above the water surface, so that they will not be subjected to salt water immersion or any alternate wetting and drying action. This not only prevents failure of seals and bearings but also facilitates inspection and maintenance in contrast to underwater swivels.

The present invention can readily be contrasted with a conventional single anchor leg mooring system which relies principally on net buoyancy of a buoy for restoring elasticity. Damping of the motion of the counterweight, and thus of the yoke and the complete mooring system, can be accomplished by controlling the amount of liquid introduced into a tank or appropriate chamber housing the counterweight. The use of a yoke (the rigid structural means) will restrain the permanently moored storage vessel against sway and yaw relative to the mooring and will also prevent it from surging forward on a slack line. The absence of a buoy at the water surface in the present system will reduce forces on the mooring system.

The invention is now described with reference to the drawings in which:

Figure 1 illustrates a riser (mooring leg) and yoke mooring system according to the present invention, with the riser in an undeflected vertical position.

Figure 2 illustrates a riser and yoke mooring system according to the present invention, substantially like that of Figure 1, except with the riser in a deflected position as a result of high mooring forces.

Figure 3 is an enlarged top plan view of the riser and yoke mooring system of Figure 1.

Figure 4 is an enlarged side view of the riser and yoke mooring system of Figure 1.

Figure 5 is a cross-sectional view taken substantially on the line 5-5 of Figure 3.

Figure 6 is a cross-sectional view taken substantially on the line 6-6 of Figure 3.

Figure 7 is an alternative embodiment of the present invention.

Figure 8 is another alternative embodiment of the present invention.

Referring now to the drawings, there is shown in Figure 1 a storage vessel generally designated 10 which is permanently moored to the sea floor 18 by a mooring system comprising a yoke 20, a riser 12 and a base 16. The vessel shown is a modified tanker. The base is conventionally secured by virtue of its mass or by means of piles (not shown) to the sea floor 18. The riser 12 is pivotally attached to the base 16 through a conventional universal joint 14 which permits the riser to pivot in any vertical plane. The free end of the riser extends above the surface of the sea.

The yoke 20 is pivoted at one end on pins 34 located on opposite sides of the vessel and on an axis transverse to the centerline of the tanker. The yoke is thus free to pivot in a plane vertical with respect to the vessel and containing the vessel centerline, but is restrained against pivoting in a plane horizontal with respect to the vessel. The free end of the yoke extends over and forward of the bow of the tanker and is connected to the upper end of the riser through a mooring swivel 56 and a gimbaled mooring table 50.

The mooring table 50 is pivoted at the free end of the yoke 20 on horizontal pins 48 having their axis parallel to the axis of the yoke pivot pins 34. The mooring swivel 56 is housed in a mooring ring 52 which is pivoted on pins 54 on an axis in the plane of the mooring table 50 and in a plane vertical with respect to the vessel and passing through the centerline of the vessel. The mooring ring 52 is thus free to gimbal, that is it is free to tilt in any direction with respect to the yoke 20.

The mooring swivel 56, designed to withstand substantial axial thrust, is housed between the mooring ring 52 and the top of the riser 12, and is coaxial with the centerline of the riser. The mooring table 50 is thus free to rotate around the riser 12. This permits the yoke 20 and the vessel 10 to swing completely around the riser 12 and thus swing freely about the mooring base 16.

The outer end of the yoke 20 is lifted upward by a cable 38 running to a counterweight 24 located in a tank or chamber 26 in the hull of the vessel 10. Cable 38 is guided over a sheave 42 mounted on posts 44 and over sheave 40 located over the center of chamber 26. The lifting action imparted on the yoke 20 by the counterweight 24 exerts tension on the riser 12. This tensioning action is analogous to the tension applied by the buoy to the anchor leg of a conventional single anchor leg mooring. When environmental forces cause the vessel 10 to move from the neutral position, as shown in Figure 1, the riser 12 pivots from its normal vertical orientation about the base universal joint 14 into a position such as shown in Figure 2. Deflection of the riser from a vertical position causes the yoke 20 to dip down, thus lifting the counterweight 24. The horizontal component of tensile force in the riser in the deflected position exerts a restoring force tending to draw the vessel back to the neutral position.

In a typical installation, with the base installed in 360 ft. of water and with the riser extending 100 ft. above the water in the undeflected position, the mooring table will drop from 100 ft. to 40 ft. above the water when the moored vessel moves 230 ft. from the neutral position. At this position, the riser is deflected 30° from the vertical and the horizontal restoring force is half of the tension force in the riser. If the cable 38 forms an angle of approximately 60 degrees with the yoke in this deflected position, and is attached at a point near the outer end of the yoke, then the horizontal restoring force will be approximately half the weight of the counterweight 24 in the position just described.

The counterweight 24 may be partially filled with a liquid 28, such as water or drilling mud. The mass of the counterweight may be changed by pumping liquid to or from the counterweight by a conventional pump 32 connected to the counterweight through a hose 30.

Liquid cargo may be transferred between the vessel 10 and an underwater pipeline 60 by a system generally comprising hose 62 between the pipeline and piping 64 housed within the riser 12, as shown in Figure 1, or attached externally to the riser 12. A fluid swivel 66 mounted on the mooring ring 52 and connected to riser piping 64 as shown in Figure 4, allows cargo to flow while the vessel rotates about the riser 12. Cargo piping 70 on the yoke is connected through hose 68 to the fluid swivel 66 and through hose 72 to piping 74 onboard the vessel. These flexible hose connections allow relative pivoting between the mooring table, the yoke, and the vessel.

In Figure 7 an alternative embodiment of the present invention is shown in which a mooring swivel 80 designed to withstand substantial axial thrust is housed near the outer end of the yoke 20 and with its axis substantially perpendicular to the plane of the yoke. The riser 12 is pivotally attached to the mooring swivel 80 through the universal joint 82 which permits the yoke 20 and the vessel 10 to swing completely around the riser 12 and thus swing freely about the mooring base 16.

The outer end of the yoke 20 is lifted upward by means such as cable 38 running over sheave 42 mounted on posts 44, under sheave 40 mounted on the deck of the vessel 10 and connected to a resilient system which comprises a shaft 84 projecting from a cylinder 86. Cylinder 86 is firmly mounted to the deck of the vessel. Shaft 84 enters cylinder 86 through a seal 88, and is attached to a piston 90 in sealed sliding contact with the interior of the cylinder, which divides the cylinder into a first and a second chamber of variable volume. When the first chamber 92 of the cylinder 86 is filled with a pressurized gas or liquid, the piston 90 and shaft 84 are forced to the right (see Figure 7), thus exerting tension in cable 38, lifting yoke 20 upward and exerting tension on the riser 12. As explained above with reference to the preferred embodiment of Figures 1-6, this tensioning of the riser 12 tends to restore the riser and the moored vessel 10 to a neutral position whenever it is disturbed by environmental forces. The pressure within the chamber 92 may be varied through an external pump 94 connected to the chamber through piping 96 to control tension in the cable 38 and in the riser 12, thus changing the characteristics of the mooring system to suit best the environmental conditions.

An external tank 100 may be joined to the piping through a valved orifice 106. Changes in pressure within the chamber 92, caused by changes in the tension in riser 12, will force gas or liquid to flow between the chamber and the tank 100. This flow of liquid or gas will be restricted as it flows through the orifice 106, thus damping motion of the vessel on the mooring system. The damping action can be varied by changing the size of the orifice 106. Damping may be exerted on the mooring system described with reference to Figure 1 to 6 of the drawings as the preferred embodiment by placing a liquid 102, such as oil or water, within the counterweight chamber 26. This damping action may be enhanced by making the clearance between the walls of the chamber 26 and the counterweight 24 small. This dampening action may be varied by providing piping or conduit 104, between the upper and lower portions of the chamber on opposite sides of the counterweight 24, as shown in Figure 1, and by controlling the opening of a valved orifice 106, within this piping to regulate flow therethrough.

Again referring to Figure 7, the piping 64 within the riser 12 communicates with a conduit formed within a load carrying center shaft (not shown) mounted at the top of the riser and directly below the universal joint 82. This load carrying center shaft is surrounded by a fluid swivel housing 110 mounted on upper and lower fluid swivel joints 112 and 114, which comprises a fluid swivel assembly such as described in U.S. Patent 3,606,397. Cargo flows through the piping 64 to the swivel housing 110 and then through flexible hose 116 to cargo piping 70 on the yoke 20. If desired, the piping 64 can be situated externally of the riser 12, being secured adjacent to its outer surface.

In Figure 8 another alternative embodiment of the present invention is shown in which a rigid frame structure 120 is mounted on the rigid yoke 20. A cable 122 runs from a winch 124 mounted on the deck of the vessel 10 to the top of the rigid frame 120. Tension applied by the winch 124 through the cable 122 causes rigid frame 120 and rigid yoke 20 to pivot about the yoke pivot pins 34, thus lifting the outer end of the yoke 20 and exerting tension on the riser 12. As explained above with reference to the preferred embodiment described with reference to Figure 1 to 6 of the drawing, this tensioning of the riser 12 tends to restore the riser and the moored vessel 10 to a neutral position whenever it is disturbed by environmental forces.

Winch 124 may be of the constant tension type, which exerts a constant tension in the cable 122 while allowing cable to be reeled out or reeled in. Alternatively, the cable 122 may be of an elastic material, such as nylon, which will elongate under tension. If the cable 122 is of an elastic material, the end of the cable may be fastened to a strong point on the deck of the vessel 10, instead of to the winch 124.

WHAT WE CLAIM IS;

1. A system for mooring and the handling of cargo, comprising a vessel floating on the surface of a body of water, a tension carrying mooring leg having a main axis normally having a substantially vertical orientation and connected at one end to the bottom of said body of water, rigid structural means having a fixed and constant length and attached to said vessel for spacing said mooring leg from said vessel, means for enabling said vessel to swing about said mooring leg, tension exerting means mounted on said vessel capable of exerting tension on the upper end of the mooring leg so as to restore it to a substantially vertical position when said mooring leg deflects therefrom and cargo handling means for the transfer of cargo between the vessel and a location outside the vessel.

2. A system according to claim 1 which includes pivotal means between said mooring leg and said bottom of the body of water.

3. A system according to either of claims 1 and 2 which includes a mooring swivel located between said mooring leg and said rigid structural means.

4. A system according to claim 3 wherein the mooring swivel is mounted on said mooring leg for permitting relatively free swinging movement of said vessel about a mooring point, said mooring swivel being located above the surface of said body of water.

5. A system according to any one of the preceding claims wherein said rigid structural means is connected to said mooring leg through a gimbal.

6. A system according to any one of the preceding claims wherein the cargo handling means includes a cargo swivel operably connected with a conduit and a further cargo conduit on said rigid structural means.

7. A system according to claim 6 wherein the cargo swivel is rotatably mounted with respect to said mooring leg.

8. A system according to either of claims 6 and 7 wherein the cargo swivel is situated above the surface of said body of water.

9. A system according to any one of the preceding claims wherein said rigid structural means is pivotally connected near an end of said vessel so as to pivot in a plane vertical with respect to the vessel and containing the vessel centreline.

10. A system according to any one of the preceding claims wherein said tension exerting means comprises a counterweight.

11. A system according to claim 10 wherein said counterweight is connected to said rigid structural means by at least one cable.

12. A system according to either of claims 10 and 11 which includes a chamber on said vessel housing said counterweight.

13. A system according to claim 12 wherein said chamber is at least partially filled with a liquid.

14. A system according to either of claims 12 and 13 wherein said counterweight is in substantial sealed sliding relationship with the sides of said chamber and there is at least one passage connecting upper and lower portions of said chamber between one side of said counterweight and the opposite side of said counterweight.

15. A system according to claim 14 which includes an orifice in said passage.

16. A system according to claim 15 which includes means for varying the flow of fluid through said orifice.

17. A system according to any one of claims 10 to 16 which includes means for varying the mass of said counterweight.

18. A system according to any one of claims 1 to 9 wherein said tension exerting means comprises a flexible tension member connected to the rigid structural means and to a shaft connected to a piston in sealed sliding contact with a pressurized cylinder.

19. A system according to claim 18 which includes a pump for varying the pressure within said cylinder.

20. A system according to either of claims 18 and 19 which includes a tank connected to said cylinder through at least one passage.

21. A system according to claim 20 which includes an orifice in said passage.

22. A system according to claim 21 which includes means for varying the opening of said orifice.

23. A system according to any one of the preceding claims wherein said rigid structural means is connected at the bow of said vessel and extends forward thereof above the water surface to said mooring leg.

24. A system according to any one of the preceding claims wherein the tension exerting means is connected to the mooring leg through the rigid structural means.

25. A system according to any one of the preceding claims wherein the vessel is spaced radially from the main axis of the mooring leg.

26. A system for mooring and the handling of cargo according to claim 1 substan-

tially as hereinbefore described with reference to the drawings.

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1563619 COMPLETE SPECIFICATION

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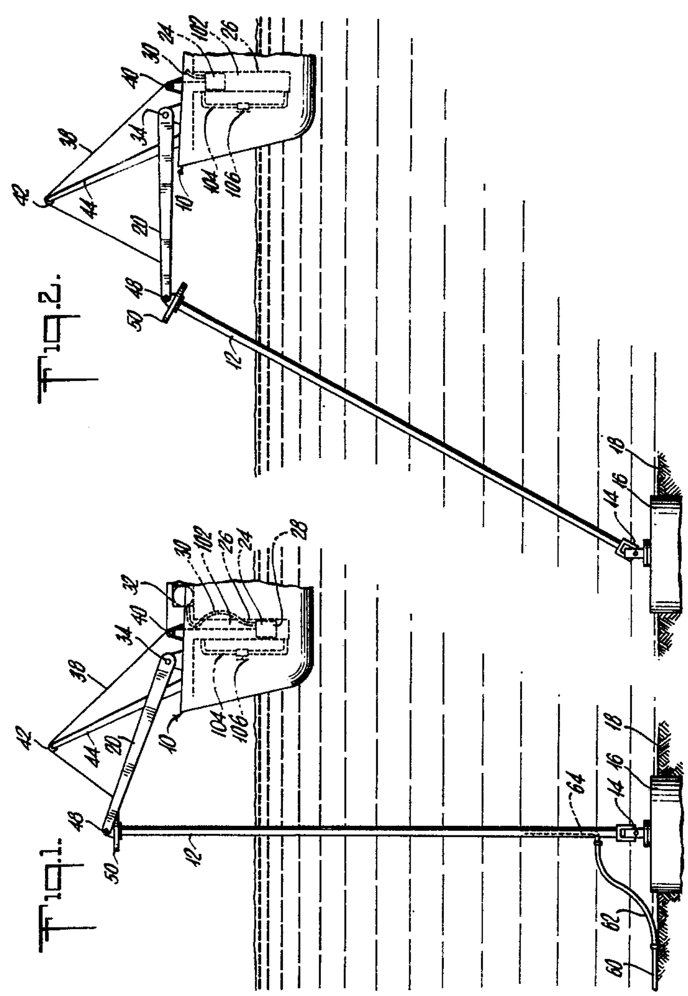
Sheet 1



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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

Fig. 3.

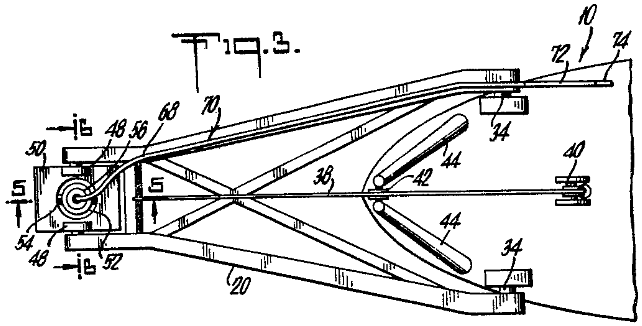


Fig. 5.

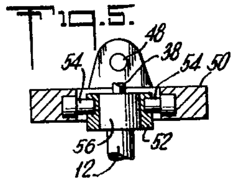


Fig. 6.

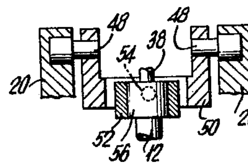
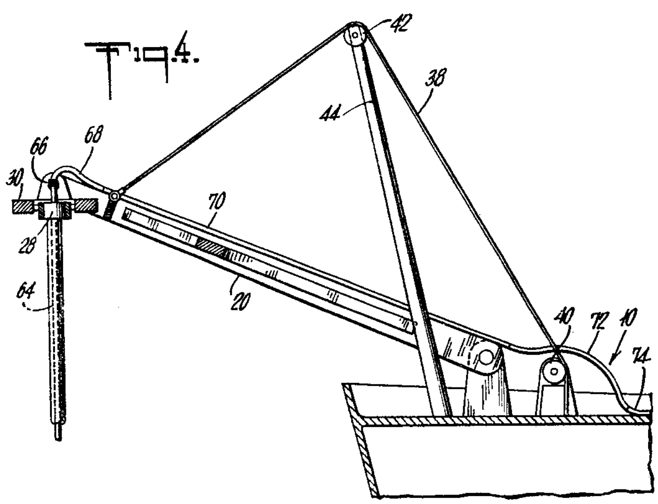


Fig. 4.



1563619 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

Fig.7.

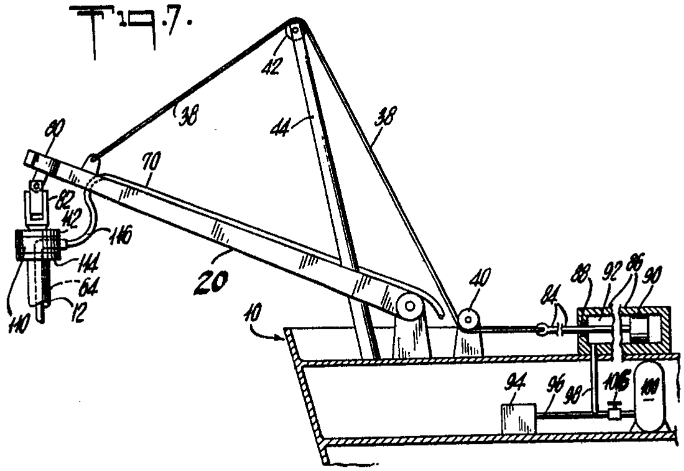


Fig.8.