June 29, 1965 G. T. RICHARDSON ETAL 3,191,201

MOORING SYSTEM

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FIG. 1.

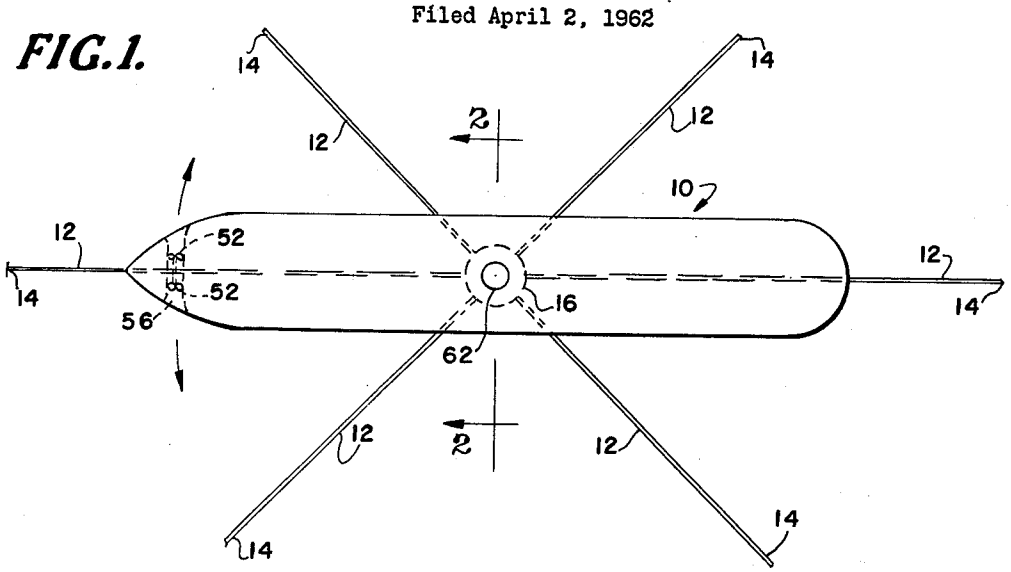
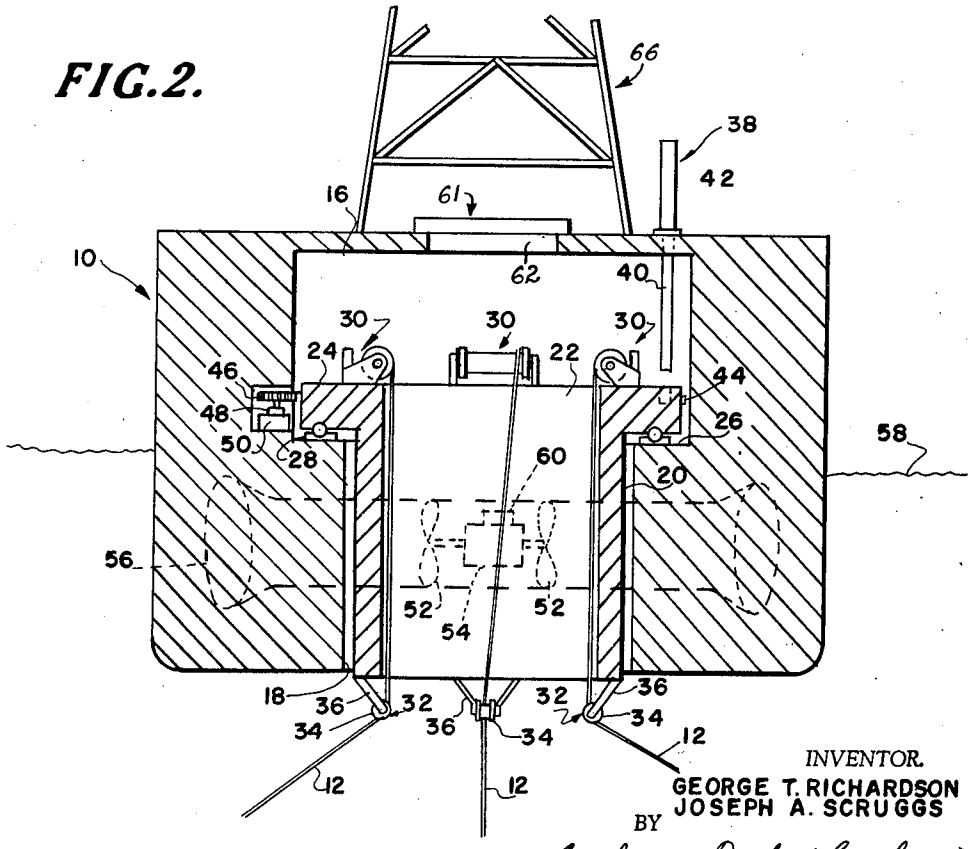


FIG. 2.



INVENTOR.
GEORGE T. RICHARDSON
JOSEPH A. SCRUGGS

BY

Cushman, Darby & Cushman

ATTORNEYS

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MOORING SYSTEM

George T. Richardson, Baton Rouge, La., and Joseph A. Scruggs, Fort Lauderdale, Fla., assignor to The Offshore Company, Baton Rouge, La., a corporation of Delaware

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The present invention relates to the offshore mooring of floating structures and in particular to a novel deep water mooring system which anchors the floating structure over a fixed point on the underwater bottom and minimizes movement of the structure due to wind, waves and tide.

In the field of off-shore oil well drilling, it is usually desirable, where possible, to conduct the drilling operations from a platform which is supported by a steel framework from the underwater bottom. A variety of structures for this purpose have been proposed and used including those which are permanently secured to the bottom and those which are selectively submersible so as to be later removed from location. Obviously in deep water, for example over 100 feet, such supports become very expensive and complex due to the major portion of the mass being supported at the upper end of a relatively limber structure. This type of structure is comparable to an inverted pendulum and is quite susceptible to earthquake damages.

In deep water, therefore, floating structures such as floating platforms or floating drilling ships have been proposed and used to support the drilling equipment. Obviously, the difficulties in drilling from floating structures are those of maintaining the structure in a fixed position under the influence of wind, waves and tide. Conventionally, laterally extending anchor lines are utilized to restrain motion of the structure, but these lines have not been completely satisfactory in providing adequate resistance to movement, particularly movement at right angles to the drill string. It is obvious that vertical movement of a floating support structure can be compensated for by a number of simple mechanical expedients but that horizontal movement or vertically twisting movement of the structure as a result of pitch, roll and yaw can be tolerated only in very small amounts.

Conventional systems for the deep water mooring of floating structures for supporting drilling equipment are described more in detail in, for example, Patent Nos. 2,512,783, 2,986,888 and 2,987,892. In each of these arrangements, a plurality of mooring buoys are laterally spaced from the floating structure and are anchored to the bottom with suitable anchors and lines. The structure, generally in the center of the spaced buoys, is moored fore and aft to the ring of buoys by means of cables. If the structure is a ship, its bow is generally placed in the center of the buoys. While this arrangement holds the ship over a fixed point and reduces pitch, yaw and roll caused by wind and wave action, it has not been found completely satisfactory. One disadvantage lies in the difficulty in orienting the ship with respect to wind and waves. Usually it will be desirable to point the bow of the ship into the wind to maintain roll of the ship at a minimum. With a given lateral anchor type of mooring the adjusting of ship direction, or orientation, is limited to something less than 180 degrees depending on the number and arrangement of lateral mooring lines and in addition is time consuming to effect. This is a serious disadvantage when the ship is being used for drilling operations because drilling must be discontinued during changes in orientation with serious loss of time. Since the movement of the ship in a direction transverse to the drill string should be kept at a minimum during a drilling operation, any

but slight changes in wave and wind direction should be corrected for by orienting the ship.

Broadly, the present invention overcomes this disadvantage of difficult orientation by providing a floating support structure with a vertical well extending through the bottom of the ship and having therein a rotatable member to which anchored mooring cables may be secured. The floating structure is positioned with the rotatable member over the desired fixed point and the mooring cables from a desired pattern are secured to the rotatable element from below thus fixing the same against rotation. The ship can then be rotated easily and rapidly 360 degrees to any desired position without changing any of the mooring cables. Thus not only can small changes in wind direction be continually compensated for but also by maintaining the proper orientation at all times, the force of the wind on the ship and the corresponding stress in the mooring lines can be kept at a minimum.

Accordingly, it is a primary object of the present invention to provide a floatable structure with means for mooring the same over a fixed point on a subsurface bottom and for reducing movement of the structure due to wind and waves.

It is a further object of the invention to accomplish the above object by providing for ready orientation of the floatable structure 360 degrees about the fixed point thereby reducing wind and wave action on the structure which cause movement of the structure and large stresses in the mooring lines.

It is a further object of the invention to provide a floatable structure having a vertical well extending through the bottom thereof and a rotatable member in the well to which anchored mooring lines can be secured from below.

It is a still further object to provide a method of mooring a floating structure above a fixed point on the subsurface bottom and of maintaining the motion of the structure and the stresses in the mooring system at a minimum by permitting the structure to be readily oriented 360 degrees about the fixed point.

These and other objects and advantages will become apparent from a reading of the following detailed description of a preferred embodiment of the invention when taken in conjunction with the drawings in which:

FIGURE 1 is a schematic top plan view of a ship constructed in accordance with the principles of the present invention; and

FIGURE 2 is a sectional view on the line 2—2 of FIGURE 1.

Referring to the drawings, a floating ship **10** provided with the mooring system of the present invention is seen to be moored by six mooring cables **12** each of which is suitably anchored at one end to the underwater bottom by an anchor **14**. As shown, the anchors **14** are laterally spaced from the ship **10** in a generally circular pattern. In practice, the number spacing and pattern of anchors and cables **12** will vary depending on the depth of the water, the character of the bottom and the weather conditions to be resisted.

According to the principles of the invention, the ship **10**, which may be for example a ship designed for conducting oil well drilling operations, is provided with a well **16** which is open at its lower end **18** through the bottom of the ship. Into the well is loosely fitted a rotatable sleeve **20** to which the mooring cables **12** may be secured. As shown, the sleeve **20** is a cylindrical member having a central bore **22** coaxial with the well **18** and an outer annular flange **24** by means of which the sleeve is mounted within the well **16**. The well is provided with an inwardly and upwardly extending annular shoulder **26** on which are mounted suitable bearings illustrated schematically at **28** for supporting the flange

24 from below. In practice, the well 16 and the sleeve 20 may be constructed of any desired diameters to suit the purpose of the moored ship. The bearings 28 must resist the imposed forces and their type and size will vary depending on the weight of the sleeve 20 and the expected forces exerted during a mooring operation. The clearance between the exterior of the sleeve 20 and the sides of the well is generous so as to permit easy relative rotation between ship and sleeve.

According to further principles of the invention, the mooring cables 12 extend upwardly from their anchors 14 toward the sleeve 20 and are secured thereto from below to effect mooring of the ship. As shown, mooring equipment, such as a windlass 30 for each cable 12 is rigidly mounted to the upper surface of flange 24 on the sleeve. The cables 12 lead downwardly through the bore of the sleeve over a suitable arrangement of fairlead devices, illustrated at 32, and thence out beneath the ship to the desired spread pattern determined by the location of anchors 14. The fairlead devices 32 may conveniently be pulleys 34 mounted on the lower end of the sleeve by means of brackets 36 in a position to prevent the cables from chafing on the sleeve or ship and to guide the cables on to the windlasses.

While the mounting of the mooring equipment on top of the flange 24 and the passage of the cables 12 through a single coaxial bore 22 in the sleeve is a preferred construction, it is apparent that other arrangements are also suitable. For example, the cables 12 could pass through separate passages and the large central bore 22 could be omitted in some mooring situations.

Preferably, also means are provided for releasably locking the sleeve 20 against rotation relative to the ship. As illustrated at 38, the locking means may include an axially slidable vertical locking bar 40 insertable into one or more cavities in the top of flange 24 and operable by a suitable mechanical or hydraulic actuator 42 fixed to the ship. In addition, power-operated means are provided for positively rotating the sleeve. As shown, the periphery of the flange 24 may be fitted with gear teeth 44 which mesh with the teeth on a drive gear 46 operated through a clutch 48 by a suitable motor 50.

As is apparent from the above description, the ship 10 is freely rotatable about the sleeve 20 when the latter is moored by the cables 12. When, as shown, the sleeve 20 is mounted in the center of the ship, the ship, weathervane fashion, will tend to point its bow into a wind. It is usually desirable, however, to provide power operated means to aid in orienting the ship especially if the sleeve is not centered in the ship. As shown, a pair of controllable pitch screw propellers 52 with associated drive 54 therefor are mounted in a passageway 56 extending transversely through the bow of the ship below the surface of the water. Alternatively, means for orienting the ship may be employed such as vertical axis omnidirectional thrust cycloidal propellers mounted in the bow or stern. The latter arrangement has the advantage that the propellers, while maintaining the desired orientation of the ship, can be adjusted to exert a forward thrust against the wind and thereby tend to equalize the forces on the mooring cables. The drive 54 for the orienting mechanism is preferably automatically controlled by a gyroscopic control device, illustrated at 60, whereby the heading of the ship, once it is established, will be maintained.

As indicated above, the ship 10 may be a drilling ship for conducting oil well drilling operations. The mooring system of the invention is particularly adapted to such operations because the sleeve 20 may be constructed of sufficient diameter to permit the drill string to be lowered through the bore 22. In this application of the invention, the support and drive for the drill string, including for example, a conventional Kelly joint and rotary table arrangement can be mounted on the ship above the upper end of the sleeve bore 22. Conveniently, an aperture 62 generally coaxial with and communicating with bore 22 may be provided in the deck of the ship whereby the drive 64 and support 66 for drilling string may be installed on the deck.

In operation of the mooring system, the floating ship is positioned so as to place the axis of rotation of the sleeve 20 over a preselected point on the subsurface bottom. This may be accomplished by leading the cables 12 from the windlasses 30 through the bore 22 of the sleeve to a suitable anchor pattern which has been established in a manner known in the art. Operation of the windlasses together or singly then tightens the cables 12 and adjusts the tension therein so that the sleeve 20 is effectively held in a fixed position directly above the preselected point. The ship, being freely rotatable about the sleeve, may then be oriented so as to minimize the effect of the forces of wind, waves and tide on the ship in terms of movement of the ship and stresses in the cables 12.

Usually the bow of the ship should be headed into the wind as this reduces motion of the ship, particularly roll. Additionally, the smaller area thus exposed to the wind and waves reduces the forces which are transmitted to the cables 12. When the sleeve 20 is located in the center of the ship, the action of the wind and waves will tend to head the ship into the wind after the fashion of a weather vane. More positive orienting forces may be applied by operation of the propellers 52 or by means of an auxiliary vessel and tow cable. Preferably, the ship will be provided with an inboard orienting mechanism such as propellers 52 so that the direction of the ship may be maintained by continuous operation of the mechanism. Conveniently, the orienting mechanism may be gyroscopically controlled by device 60 once the proper orientation has been established.

It will be understood that during the establishing and maintaining of the desired ship orientation the ship is freely rotatable with respect to sleeve 20. That is, during these operations, the clutch 48 is disengaged and the latch bar 40 is in its upper or unlatched position. Positive rotation or latching of the sleeve 20 normally will be employed when the system is not in actual use such as when the mooring machinery 30 requires repair or when the ship is being moved to a new operating site.

It is apparent from the above description that the present invention provides a mooring system that fixes a floating structure over a fixed point on the underwater bottom while permitting simple and rapid 360 degree orientation of the structure about the fixed point. The system is applicable to the mooring of any floating structure and is particularly applicable to floating drilling structures. In the latter application drilling operations may be conducted through the sleeve and need not be discontinued during changes in orientation of the structure because rotation of the structure about the sleeve does not produce movement transverse to the drill string. While a preferred embodiment of the invention has been described, modifications thereof are contemplated and the described details are not intended to be limiting except as they appear in the appended claims.

What is claimed is:

1. A floatable vessel from which drilling operations on a submerged bottom may be conducted comprising: an elongated hull having a streamlined bow to reduce resistance to movement of said hull through the water; a well extending vertically through said hull; a vertical hollow cylinder supported by said vessel mounted in said well for rotation about a vertical axis relative to said hull; and means secured to said cylinder for attaching at least one anchor line thereto, whereby when said cylinder is anchored to a submerged bottom said hull may be rotated about said cylinder and oriented in a direction to minimize wind and water forces on said hull and whereby marine-bottom drilling operations can be carried out from said vessel by operating downwardly through said cylinder.

2. The structure defined in claim 1 wherein the well is located substantially centrally of the hull, and including a plurality of said attaching means spaced about the cylinder, whereby a plurality of anchor lines can be streamed generally radially from the cylinder to thereby anchor the latter coaxially above a relatively fixed point on the marine bottom.

3. The structure defined in claim 1 including drilling apparatus mounted on said hull for operating downwardly through the cylinder.

4. The structure defined in claim 1 including water-reaction power-operated controllable thrust-producing means mounted to said hull in spaced relation to the well and arranged to produce thrust in a horizontal direction substantially tangentially of said vertical axis.

5. The structure defined in claim 4 wherein the thrust-producing means includes a tunnel extending substantially transversely through the bow of the hull and a reversible propeller arranged substantially coaxially in said tunnel.

6. The structure defined in claim 2 in which each attaching means includes a power-driven winch.

7. A floatable structure adapted to be anchored to a submerged bottom comprising: a floatable hull having a vertical recess which is open through the bottom of said hull; a vertical hollow mooring sleeve carried within said recess; bearing means between said hull and said mooring sleeve for supporting the weight of said sleeve on said hull and for permitting relative rotation between said sleeve and said hull about the vertical axis of said sleeve; and cable winding means secured to said sleeve for attaching at least one anchor line thereto and for hauling in on the anchor line.

8. A floatable structure as in claim 7 wherein said sleeve includes an outwardly extending annular flange which carries said cable winding means and wherein said bearing means is disposed between the lower surface of said flange and a portion of said hull.

9. A floatable structure as in claim 7 further comprising power means carried by said hull separate from said mooring sleeve for acting on the water to effect rotation of said hull about said mooring sleeve when the latter is anchored to a submerged bottom.

10. A floatable structure as in claim 8 further comprising guide means carried by said sleeve for guiding an anchor line to said cable winding means and for preventing contact of the anchor line with said sleeve.

11. A floatable structure which can be moored above a fixed point on a submerged bottom at which underwater operations are to be performed comprising: a floatable hull having a vertically extending recess the lower end of which opens through the bottom of the hull; a vertical sleeve within said recess through which underwater operations may be carried out from said hull, said sleeve having a bore of substantial diameter and an open lower end; means supporting said sleeve on said hull and for rotation relative to said hull about the axis of the sleeve; and means secured to said sleeve for attaching at least one anchor line thereto, whereby when said sleeve is anchored to a submerged bottom to prevent rotation of the sleeve said hull may be rotated about said sleeve and oriented in a direction to minimize wind and water forces on said hull and whereby underwater operations can be carried out from the hull on a submerged bottom by operating downwardly through said sleeve.

12. A floatable structure as in claim 11 wherein said means for attaching an anchor line to said sleeve includes cable winding means secured to said sleeve.

13. A floatable structure as in claim 11 further comprising an outwardly extending annular flange on said sleeve, said means for supporting said sleeve engaging the lower surface of said flange.

14. A floatable structure as in claim 11 further comprising an outwardly extending annular flange on said sleeve, said flange carrying a plurality of said anchor line attaching means in spaced apart relationship, each of said anchor line attaching means including cable winding means, and wherein said sleeve supporting means engages the lower surface of said flange.

15. A floatable structure as in claim 14 further comprising anchor line guide means corresponding to cable winding means and carried by said sleeve below said flange for guiding an anchor line to the respective cable winding means and for preventing contact of the line with the said sleeve.

16. A floatable structure as in claim 11 further comprising power means carried by said hull separate from said sleeve for acting on the water to effect rotation of said hull about said sleeve when the latter is anchored to a submerged bottom.

17. In combination with a structure floating in a body of water: a mooring member having a vertical axis and carried within a recess which is open through the bottom of the floating structure, said mooring member having a downwardly facing annular surface; bearing means between said annular surface and said floating structure for supporting said member on said structure and for permitting relative rotation between said member and said structure about said vertical axis; and means positioning said member above a fixed point on the submerged bottom and preventing rotational and horizontal movement of said member, said means including a plurality of anchor lines secured at their upper ends to said mooring member and extending downwardly and outwardly in generally radial direction with respect to said axis and anchor means securing the lower ends of said lines to the submerged bottom.

18. A floatable structure adapted to be anchored to a submerged bottom comprising: a floatable hull having a vertical recess which is open through the bottom of said hull; a mooring member having a vertical axis extending therethrough carried within said recess; bearing means between said hull and said mooring member supporting the weight of said member on said hull and permitting relative rotation between said member and said hull about said vertical axis; and means on said member for securing one end of an anchor line thereto whereby when an anchor line is secured to said member and passed downwardly to a submerged bottom said hull becomes anchored while simultaneously being rotatable about said member so as to reduce the effect of wind and wave action on said hull.

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FERGUS S. MIDDLETON, *Primary Examiner.*

MILTON BUCHLER, *Examiner.*