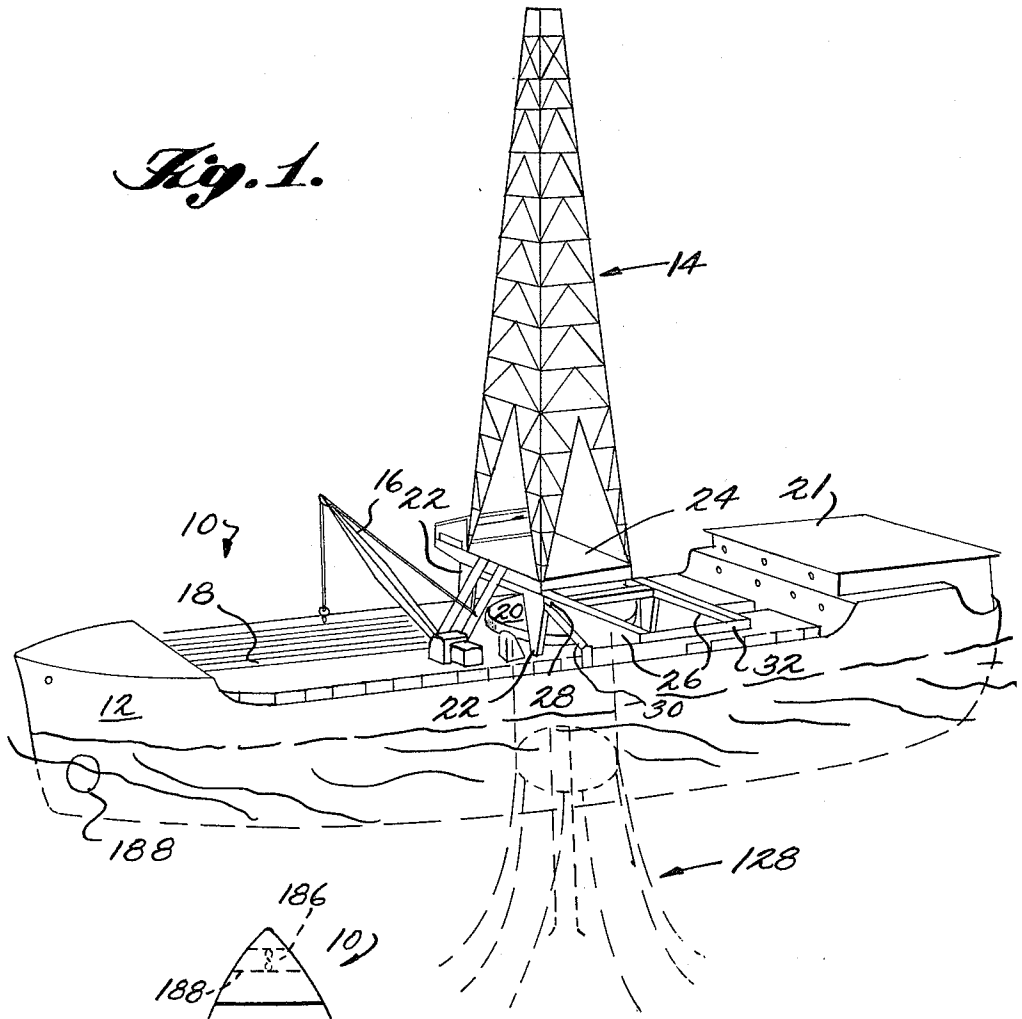
Oct. 18, 1966 G. T. RICHARDSON 3,279,404

FLOATING MOORING SYSTEM

Filed Dec. 20, 1963 5 Sheets-Sheet 1

Fig. 1.



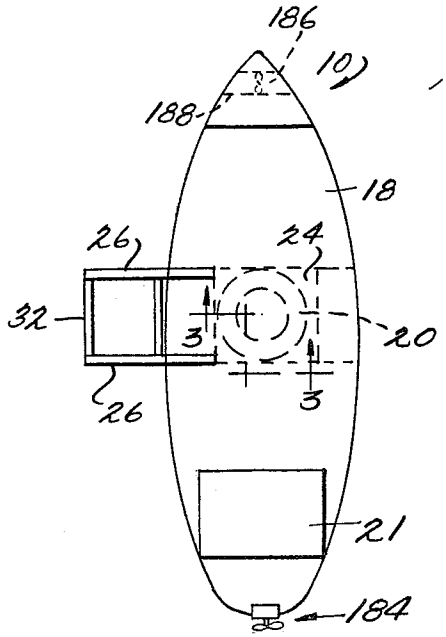


Fig. 2.

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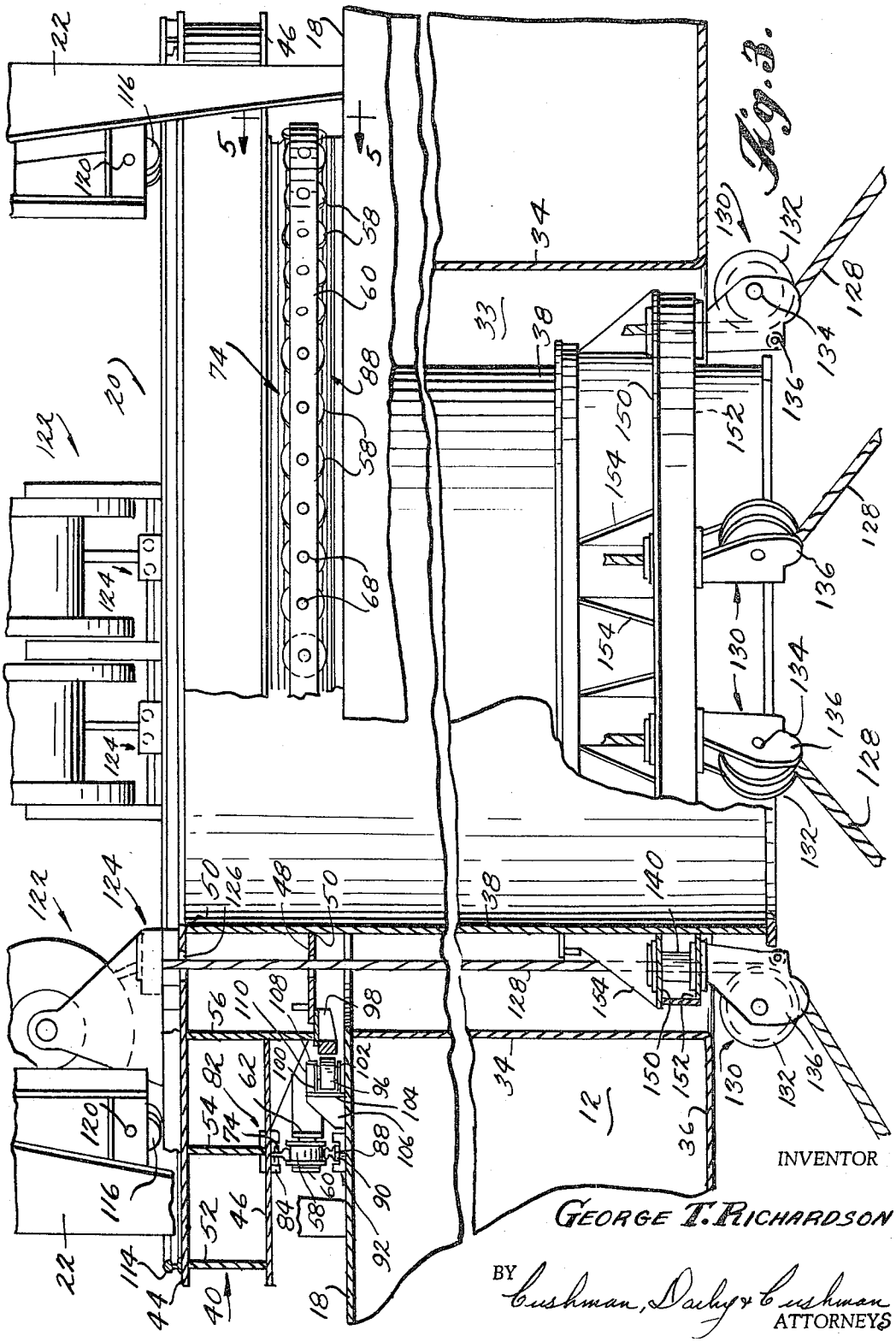

Fig. 3.

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FLOATING MOORING SYSTEM

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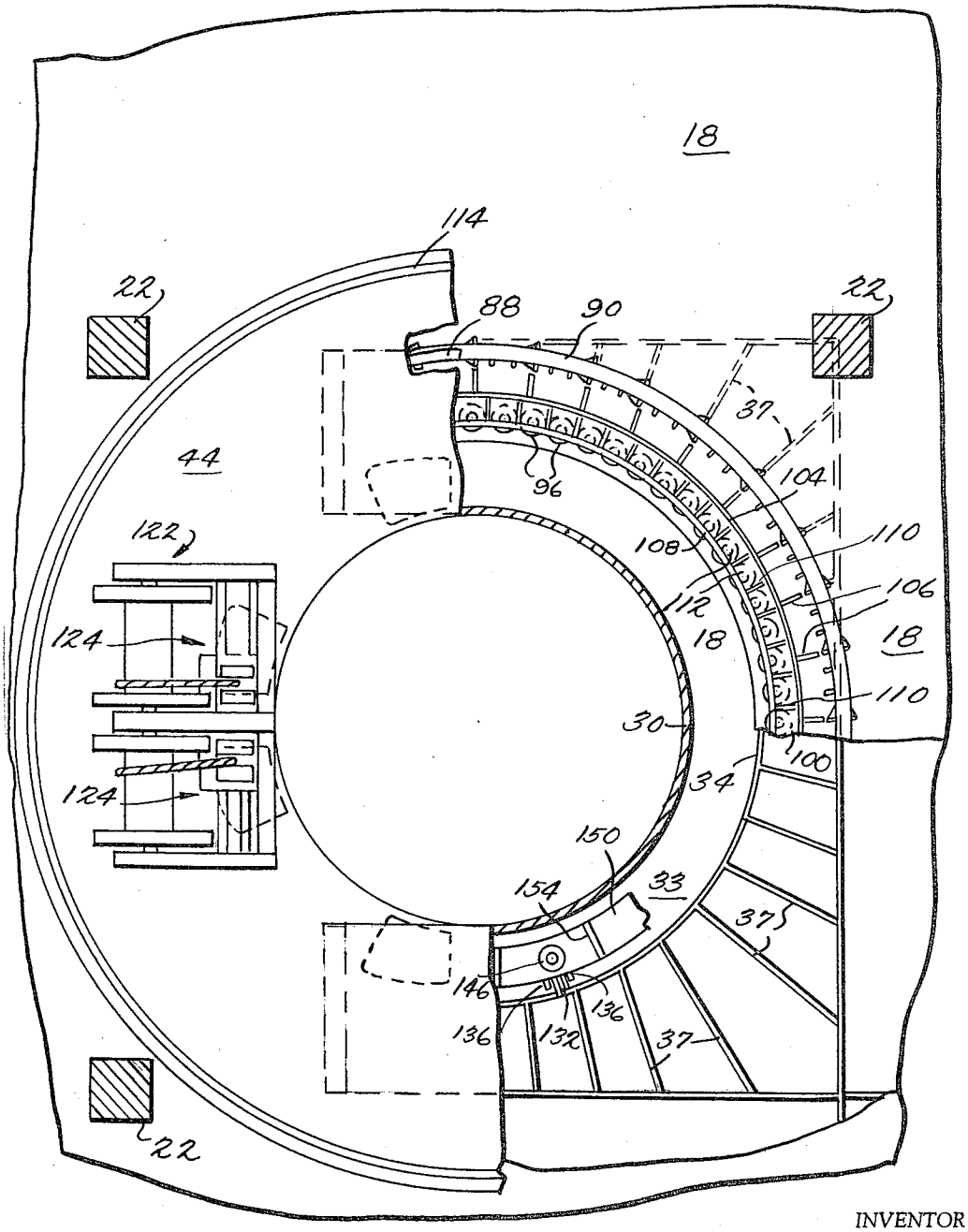

Fig. 4.

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Fig. 5.

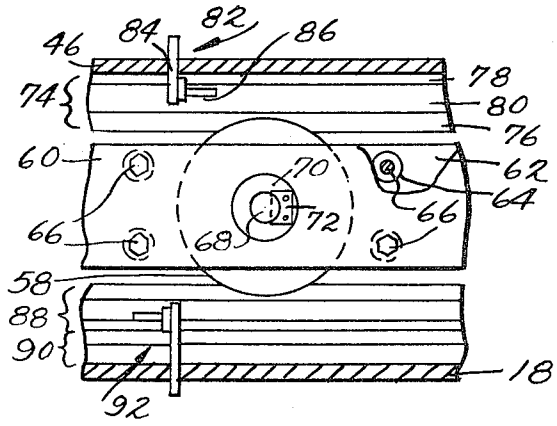

Fig. 6.

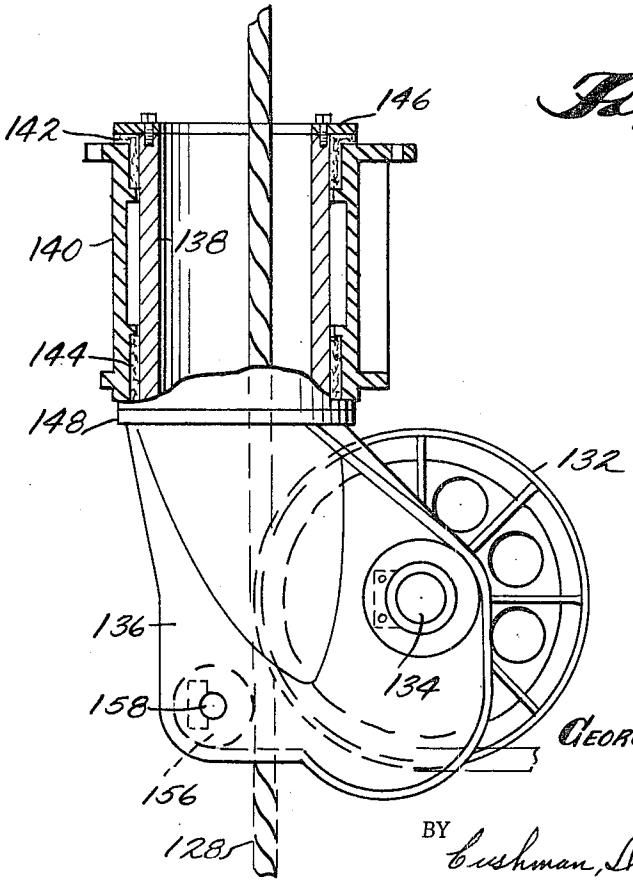

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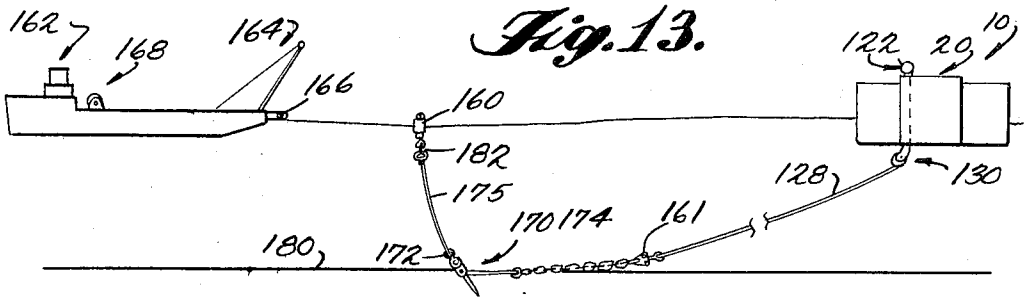
Fig. 13.



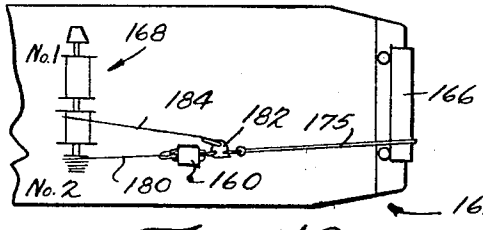


Fig. 12.

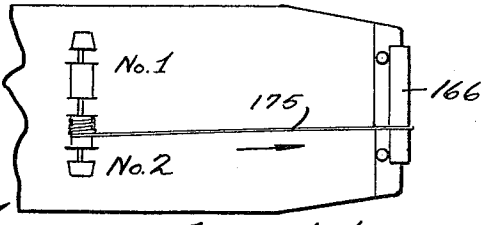


Fig. 11.

Fig. 10.

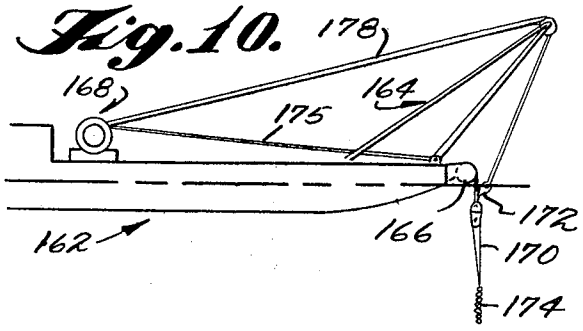


Fig. 9.

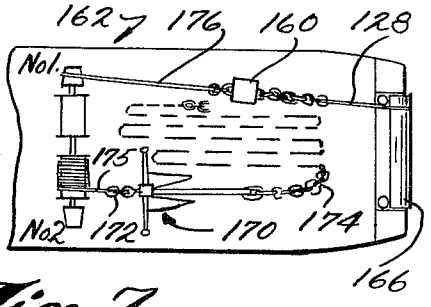


Fig. 8.

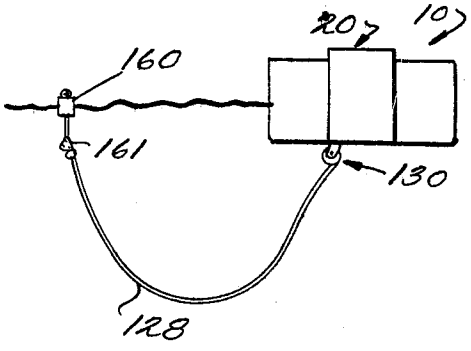
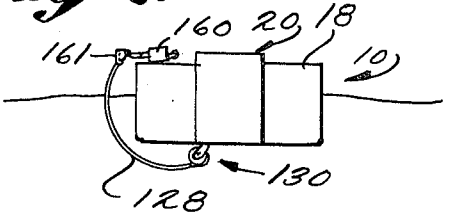


Fig. 7.



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United States Patent Office 3,279,404 Patented Oct. 18, 1966

3,279,404

FLOATING MOORING SYSTEM

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Filed Dec. 20, 1963, Ser. No. 332,225
9 Claims. (Cl. 114—0.5)

This invention relates to the mooring of a floating structure in a manner which permits orientation of the structure to minimize the effects of wind and water on the structure and in particular to the mooring of floating structures from which underwater operations are conducted.

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 structure for supporting drilling equipment are described more in detail in, for example, United States 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 arraangement 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.

In another type of mooring system, disclosed in United States Patent 2,699,321, a floating oil storage vessel is provided with a vertical well through which a rigid shaft structure extends into anchored engagement with the submerged bottom. The floating structure is not connected to the shaft and is thereby free to move both vertically and rotatably with respect to the shaft structure. Drilling is performed through the shaft structure from a drilling rig mounted on top of the shaft structure. While this mooring arrangement permits the floating vessel to be oriented with respect to the action of wind and water without moving the anchor means it requires a rigid structure extending to the submerged bottom and thus possesses the disadvantages of high cost, complexity and instability already referred to.

The primary object of the present invention is to overcome, to the large extent, the above-mentioned disadvantages inherent in the rigid, bottom-engaging type of support and in the conventional anchored type of support. Broadly, the invention accomplishes this object by providing a rigid mooring member which is supported and carried by a floating vessel in a vertical well through the vessel. The mooring member is restrained against vertical movement relative to the vessel, but is freely rotatable about its own vertical axis. In use, the mooring member is held in a fixed position above a desired point on the submerged bottom by attaching it to a plurality of generally radical mooring lines which extend downwardly and outwardly to anchor points on the bottom. The vessel is then rotated about the fixed mooring member by means by propeller-type thrusters at the ends of the vessel to a position in which wind and wave action on the vessel are at a minimum. Preferably, the mooring member has a vertical bore so that underwater operations of any nature, such as diving, salvage, drilling and well completion, can be conducted from the vessel through the bore. Equipment for performing these operations, such as a drilling rig, is mounted on the vessel above the mooring member.

A further object of the invention is to provide a floatable vessel with a vertical well, a mooring member carried by the vessel within the well and mounting means for the mooring member for permitting relative rotation between the member and the vessel about a vertical axis through the member so that the vessel may be readily oriented 360 degrees about the member.

It is a further object to provide a method of mooring a floating vessel of the above type by a novel combination of steps for establishing a pattern of mooring lines extending outwardly and downwardly from the mooring member.

The invention will be further understood from the following detailed description in conjunction with the drawings in which:

FIGURE 1 is a schematic prespective view of a drilling ship which embodies the principles of the present invention;

FIGURE 2 is a schematic top plan view, on a reduced scale, of the drilling ship of FIGURE 1;

FIGURE 3 is a fragmentary elevational view, taken generally along the line 3—3 of FIGURE 2 of the mooring member and its arrangement within the drilling ship;

FIGURE 4 is a top plan view, partly broken away, of the mooring member and its arrangement in the drilling ship;

FIGURE 5 is a fragmentary elevational view, on an enlarged scale, of part of the mounting arrangement for the mooring member looking in the direction of the arrows 5—5 in FIGURE 3;

FIGURE 6 is an elevational view on an enlarged scale and partly broken away, of one of the fairleads on the mooring member; and

FIGURES 7–13 are schematic views showing the steps of anchoring the ship of FIGURE 1.

Referring to FIGURES 1 and 2, there is shown a drilling ship **10** having an elongated hull **12** of conventional construction and carrying a derrick **14** and conventional hoisting equipment **16** for transferring supplies and equipment to and from the ship. The center portion **18** of the top deck is provided with various handling equipment and storage facilities (not shown) for pipe and other materials employed in under water drilling and well-completion operations. The stern portion of the top deck is provided with a landing platform **21** for helicopters.

A derrick support structure is mounted on the center deck portion **18** over a hollow, cylindrical mooring member **20** which is constructed and arranged according to the principles of the invention and which is illustrated in detail in FIGURES 3–6. The support structure, which also forms part of the mooring arrangement, includes four upright support columns **22** disposed at the corners of a square and firmly secured to the deck **18** of the ship **10**. The upper ends of the support columns **22** are secured to a horizontal support frame on top of which is slidably mounted a derrick platform **24** of conventional construction. The derrick **14** is secured to the derrick platform **22** and is movable therewith in a horizontal plane between a position over the mooring member **20** and a position over one side of the ship **10**.

To support the derrick **14** and derrick platform **22** over the side of the ship **10** there is provided a hinged cantilever structure which can be swung downward to jut over one side of the ship. As seen schematically in FIGURE 1, this structure includes a pair of spaced generally triangular support members **26** which are pivoted to two of the support columns **22** at **28** for rotation about a horizontal axis extending longitudinally of the ship **10**. In the position shown in FIGURE 1 the support members **26** have been rotated downwardly over one side of the ship into engagement with a pair of fixed upstanding frames **30** which are secured to the deck **18** of the ship. The upper edges of the members **26**, together with cross members **32** provide a flat supporting frame onto which the derrick platform **24** may be slid so as to be in a position to service well heads which are located above water level.

Referring now to FIGURES 3 and 4, the mooring member **20** which constitutes the primary feature of the invention, is shown in its operative position in a vertical well **33** which is located on the longitudinal axis of the ship **10**. The well **33**, which extends completely through the hull **12**, is defined by a vertical cylindrical side wall **34** joined at its upper end to the top deck **18** and at its lower end to the ship's bottom **36**. Intermediate its ends the wall **34** is joined to various framing members **37** (FIGURE 4) inside the hull **12**.

The mooring member **20** includes a vertical cylindrical sleeve **38** which extends completely through the well **33** in spaced relationship with the wall **34** and an outwardly extending upper flange portion **40** which overlies an annular portion of the deck **18** adjacent the well **33**. The flange portion **40** includes three horizontal vertically spaced annular plates **44**, **46** and **48** which are disposed around the upper portion of the sleeve **38**, the upper and lower plates **44** and **48** being secured to the sleeve **38** as by welds **50**. The intermediate plate **46** which has an internal diameter greater than the other two plates is suspended from the upper plate **44** by three concentric cylindrical plates **52**, **54** and **56**.

The mooring member **20** is mounted for rotation about its own axis and supported against downward movement by means of a plurality of circumferentially spaced double-flanged rollers **58** disposed between the flange **40** and the deck **18**. The rollers **58** are vertically mounted for rotation about horizontal axes within a cage formed of inner and outer vertical concentric plates **60** and **62** which are coaxial with the mooring sleeve **38**. As seen best in FIGURE 5, the plates **60** and **62** are held in concentric relationship by means of a plurality of spacer sleeves **64** radially disposed between the plates and a plurality of bolts **66** passing through the sleeves **64** and the plates.

Each roller **58** is journalled on a fixed axle **68** which extends in a radial direction through a hole in each plate **60**, **62**. An annular reinforcing plate **70** is welded to the exterior of each plate around each axle hole. The axles **68** are retained in place by means of rectangular keeper plates **72** bolted to the exterior of the reinforcing plates **70** and residing in slots in the peripheries of the axles **68**.

The tops of the vertical rollers **58** are engaged by a downwardly facing circular rail **74** which is fixed to the lower surface of the mooring member flange **40**. As seen in FIGURES 3 and 5, the rail **74** is secured to the intermediate horizontal plate **46** at a location intermediate its inner and outer edges. The rail **74** is generally I-shaped and consists of a running flange **76** engaging the rollers **58**, a base flange **78** and a web **80** integral with the flanges **76**, **78**. The base flange **78** is clamped to the plate **46** in any suitable manner as by means of a plurality of spaced brackets **82**. In the construction illustrated, each bracket **82** includes a vertical bracket plate **84** of generally inverted U-shape which extends through slots in the horizontal plate **46** and straddles the rail **74**. Each bracket plate **84** has welded thereto a T-shaped member **86** which tightly engages the web **80** and base flange **78** of the rail **74** to hold the same in place.

The vertical rollers **58** ride on top of a horizontal circular rail **88** which is fixed to the deck **18** in any suitable manner. As shown, the rail **88** rests on top of a support ring **90** which is T-shaped in cross section. The ring **90** is welded to the deck **18** and the rail **88** is clamped to the ring **90** by means of brackets **92** which are similar to the brackets **82** employed with the upper rail **74**.

Referring again to FIGURES 3 and 4, it will be seen that the mooring member **20** carries an outwardly facing circular rail **94** which engages a plurality of deck-supported horizontal rollers **96** in a manner to prevent lateral movement of the mooring member **20** relative to the hull **12**. The rail **94** is suspended from the lower plate **48** of the mooring member flange **40** by means of suitable brackets **98**. The horizontal rollers **96** are carried in a cage which includes upper and lower annular plates **100** and **102** welded along their outer edges to a vertical cylindrical plate **104**, which in turn is mounted on the deck **18** by means of a plurality of upstanding triangular bracket plates **106**. The inner edges of the annular plates **100**, **102** are welded to an inner cylindrical plate **108**, and radially disposed vertical reinforcing plates **110** are welded between the upper edges of the inner and outer cylindrical plates **104** and **108**. Each roller **96** is rotatable on a fixed vertical axle **112** which extends through holes in the annular plates **100**, **102** and which is held in place by keeper plates (not shown) in the same manner as the axles **68** for the rollers **58**.

The top plate **44** of the mooring member flange **40** carries a circular hold-down rail **114** which is secured to the upper surface of the plate **44** near its outer edge in any convenient manner. Each of the upstanding support columns **22** carries four spaced vertical hold-down rollers **116** which engage the top of the rail **114** and thereby prevent any upward movement of the mooring member **20**. The rollers **116** are mounted on fixed axles **120** which are secured in suitable cages in generally the same manner as are the axles **68** for the rollers **58**.

The top plate **44** of the mooring member flange **40** is also provided with four double-drum electrically operated anchor winches **122** which include a cable traversing

mechanism **124** synchronized with the winch drive. Each winch is secured to the plate **44** adjacent a pair of holes **126** through which anchor lines **128** from each drum pass downwardly between the sleeve **38** and the side wall **34** of the well **33**.

The lower end of the mooring member sleeve **38** is provided with eight equi-spaced fairleads **130**, one for guiding each anchor line **128**. Each fairlead **130** includes a flanged pulley wheel **132** mounted on a horizontal axle **134** between two vertical bracket plates **136**. As seen in FIGURES 3, 4 and 6, the vertical plates **136** are secured to the lower end of a sleeve assembly which permits the pulley wheel to swivel in a horizontal plane. The sleeve assembly includes an inner sleeve **138** rotatably mounted within an outer sleeve **140** by means of upper and lower bushing elements **142** and **144** and upper and lower end plates **146** and **148**.

The outer sleeve **140** is rigidly mounted between two annular plates **150** and **152** which are secured along their inner edges to the mooring member sleeve **38** near enough to its lower end that the pulley wheels **132** are disposed below the ship bottom **36**. A plurality of upstanding triangular plates **154** are welded to the top of the upper annular plate **150** and to the mooring member sleeve **38** to reinforce the fairlead mounting. The anchor line **128** for each fairlead **130** passes through the bore of the inner sleeve **138** and between the pulley wheel plates **136** where it engages the pulley wheel **132** along the portion of the periphery which faces the mooring member sleeve **38**. A small roller **156** mounted on a horizontal axle **158** between the plates **136** holds the anchor line **128** in engagement with the pulley wheel **132**.

FIGURES 7–13 illustrate schematically the procedures and equipment which are employed in running and setting anchors for the mooring member **20**. The eight anchor lines **128** which may be, for example, 2-inch diameter cable, remain threaded through the mooring member flange **40** and the fairleads **130**, once the assembly of the parts described above have been completed. When the lines **128** are not in use their free ends, usually with buoys **160** attached, are looped around the bottom of the ship **10** and carried on the deck **18** as seen in FIGURE 7. In this position, of course, almost the entire length of the lines **128** is carried on the drums of the winches **122**. For simplicity of illustration only, one anchor line **128** is shown in FIGURES 7–13, but it will be understood that all eight lines are handled in the same manner.

When the ship **10** has arrived at a site where it is to be moored, the free ends of the anchor lines **128**, with their buoys **160** attached by means of a shackle **161**, are taken from the deck **18** by means of the hoisting equipment **16** (FIGURE 1) and placed in the water, as seen in FIGURE 8. Each line **128** is then handled in sequence by a supply boat **162** in the manner illustrated in FIGURES 9–13. The deck of the supply boat carries an A-frame **164**, a horizontal stern roll **166**, and a double-drum winch **168**. An anchor **170**, having a shackle **172** and a short length of anchor chain **174** connected thereto, is also stowed on the deck of the supply boat **162**. The shackle **172** connects with the free end of a trip wire **175** which is carried on drum No. 2 of the winch **168**.

The supply boat **162** first picks up the buoy **160** and hauls it on deck, as seen in FIGURE 9. The supply boat winch **168** is provided with a cable **176** for this purpose. Next, a runner **178** from drum No. 1 of the winch **168** is attached to the anchor shackle **172** and by means of the A-frame **164** lifts the anchor **170** over the stern of the boat, as seen in FIGURE 10. At the same time the men on the boat **162** disconnect the buoy **160** from the shackle **161** and attach the free end of the anchor chain **174** thereto. When the anchor **170** is hanging free of the boat **162**, as seen in FIGURE 10, the runner **178** is disconnected from the shackle **172**. The anchor **170** is then lowered to the submerged bottom **180** by drum No. 2, the trip wire **175** and the stern roller **166**, as seen in FIGURE 11.

The end of the trip wire **175** opposite the anchor **170** carries a shackle **182** which, as seen in FIGURE 12, is connected by the men on the boat **162** to the buoy **160** when the trip wire **175** has been unwound from drum No. 2. This is accomplished in a manner known in the art with the aid of auxiliary runners **184** and **186** which are employed to hold the trip wire on board while the connection is made. The buoy **160** is then cast free of the boat **162**, as seen in FIGURE 13.

The running of seven more anchors, one for each of the other seven anchor lines **128** is carried out in sequence in the same manner as that just described. Usually, the anchors will be equally spaced along the circumference of a large circle of, for example, a diameter of 5000 feet. After all of the anchors have been placed, the winches **122** on the mooring member **20** in the ship **10** are operated to wind in their cables **128** to a predetermined tension. This positions the mooring member **20** at the center of the circle of anchors and restrains it against displacement in both horizontal and vertical planes.

In operation of the mooring system the hull **12** of the ship **10** is freely rotatable about the mooring member **20** which is held stationary by its anchor lines **128**. Pull on the lines **128** is measured by strain-gage recorders which receive signals from gages on pawls in the drive for the winches **122**. The mooring forces, as well as the ship motion, are minimized by keeping the ship **10** headed into the sea. This is accomplished with two electric propeller-type thrusters, one located at each end of the ship. The stern thruster, illustrated at **184** in FIGURE 2, occupies about the same position as an outboard motor. The bow thruster, illustrated at **186**, is located in a tranverse tunnel **188** through the bow.

The direction and speed of rotation of the thrusters **184** and **186** are controlled automatically from an instrument console which continuously receives direction signals from a gyroscope system. The console is designed to produce output signals which are proportional to the difference between the direction signals and an input signal which is set manually for a desired heading. The output signals govern the output of diesel-driven direct current generators located in the power plant room of the ship. The current from the generators is conducted to the motors of the thrusters **184** and **186**. The system also includes means for sensing and controlling rate of change of direction and feedbacks thus preventing the hull from overswinging or hunting.

A very flexible system is achieved by controlling the thruster motors by excitation of the generators, because the motors can then be run in either direction at any speed from zero to maximum. In addition, the stern thruster can be operated manually and rotated 360° about its vertical axis.

After the mooring member **20** has been anchored above a desired site, the thrusters **184** and **186** are operated to rotate the hull **12** of the ship **10** to a position in which the effects of wind and water on the ship are minimized. The automatic control system for the thrusters then maintains this heading which has been set on the control console. The system also includes instruments which measure the amount and direction of any lateral displacement of the mooring member **20** from the dead center position. When this displacement is not correctable by changing the heading of the hull **12**, the winches **122** may be operated to pull the mooring member **20** back to its original position. While the hull **12** is rotatable 360° about the mooring member **20** without being obstructed, the electric, air and any other lines leading to equipment which may be used on the member **20** will require unplugging and replugging about every 120° rotation.

When the mooring member **20** has been anchored at a location in the manner described above, drilling into

the submerged bottom **180** and other underwater operations may be conducted from the deck **18** of the ship **10** through the bore of the mooring member **20**. It will be appreciated that the draw works hook is suspended by the derrick **14** along the vertical axis of mooring member **20** so that the hull, which carries the derrick, may be rotated to any position without affecting alignment of the drilling and completion equipment with the well hole.

It will thus be appreciated that the invention provides a floating mooring system which accurately and positively locates a vessel above a predetermined submerged location and which permits the vessel to be oriented with respect to the wind and wave without disturbing the anchor pattern. The system is particularly applicable to floating drilling vessels because underwater operations conducted through the mooring member **20** need not be discontinued when the hull **12** is rotated. While a specific embodiment of the invention has been described and illustrated it is not intended that the details thereof be limiting except as they appear in the appended claims.

This application describes and claims an improvement on the apparatus of application Serial No. 184,466, filed April 2, 1962.

What is claimed is:

1. In combination with a floatable structure having a vertical well therein open through the bottom of said structure: a vertical cylindrical member supported by said structure within said well; first vertical roller means supporting said cylindrical member on said structure for rotation about the vertical axis of said cylindrical member; second vertical roller means restraining said cylindrical member from upward movement relative to said floatable structure and horizontal roller means restraining said cylindrical member from lateral movement relative to said floatable structure.

2. Apparatus as in claim **1** wherein each of said roller means includes a plurality of rollers disposed in a circular pattern and in engagement with a circular rail.

3. Apparatus as in claim **1** wherein said cylindrical member has a vertical bore for permitting underwater operations to be performed from said floatable structure through said bore.

4. Apparatus as in claim **1** wherein said cylindrical member has an outwardly extending horizontal flange which carries a first rail on its lower surface and a second rail on its upper surface, said rails engaging rollers supported by said floatable structure to thereby form said first and second roller means.

5. In combination with a floatable structure having a vertical well therein open through the bottom of said structure: a vertical hollow cylindrical member within said well in spaced relationship from the sides of the well; an outwardly extending horizontal flange on said member; means supporting said cylindrical member for rotation about its vertical axis relative to said floatable structure and preventing vertical and lateral displacement relative to said floatable structure, said means including first roller means below said flange restraining downward displacement of said cylindrical member, second roller means above said flange restraining upward displacement of said cylindrical member and third roller means laterally of said cylindrical member for restraining lateral displacement thereof; a plurality of mooring line winding means carried by said flange; mooring line guiding means carried by said member below and in substantial alignment with said winding means; and a plurality of mooring lines extending from said winding means through the space between said member and the sides of the well to said guiding means.

6. The method of mooring a structure floating in a body of water, said structure having a vertical well therein which comprises: mounting a vertical cylindrical member within said well for rotation about its vertical axis; attaching one end of a mooring line to said member and passing the other end downwardly through said well and up to the surface of the water; placing an anchor on a second floating structure and moving the latter into proximity with said other end of said mooring line attaching the anchor to said other end; lowering said anchor from said second floating structure to the submerged bottom; hauling in on said line from said member to thereby tension said line and restrain said member against movement; and rotating said floating structure about said member to a position at which wind and water forces on said structure are minimized.

7. Apparatus as in claim **5** wherein said first roller means includes a plurality of vertical rollers disposed in a circular pattern and journalled in a circular cage, the lower surface of said flange resting on top of said rollers and the lower surface of said rollers resting on a support surface carried by said floatable structure.

8. Apparatus as in claim **7** including a derrick-supporting platform disposed above said flange, said platform being supported by a plurality of legs extending upwardly from the deck of said floatable structure, said second roller means including rollers carried in fixed positions by said legs and engaging a circular supporting surface on the top of said flange.

9. Apparatus as in claim **7** wherein said winding means are carried on top of said flange, said flange being provided with a hole adjacent each of said winding means for the passage of one of said mooring lines.

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