FIG. 1.

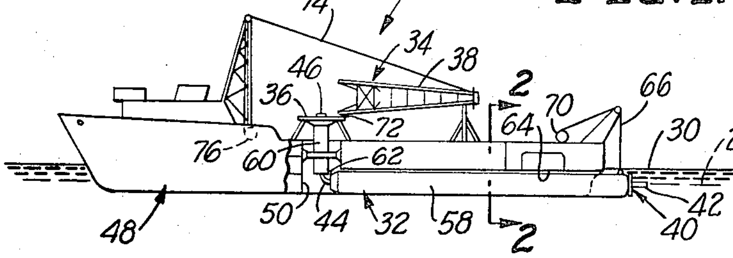


FIG. 2.

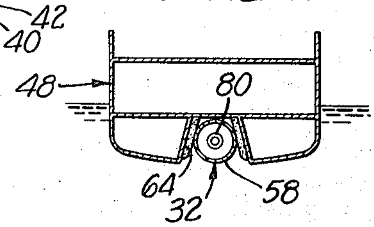
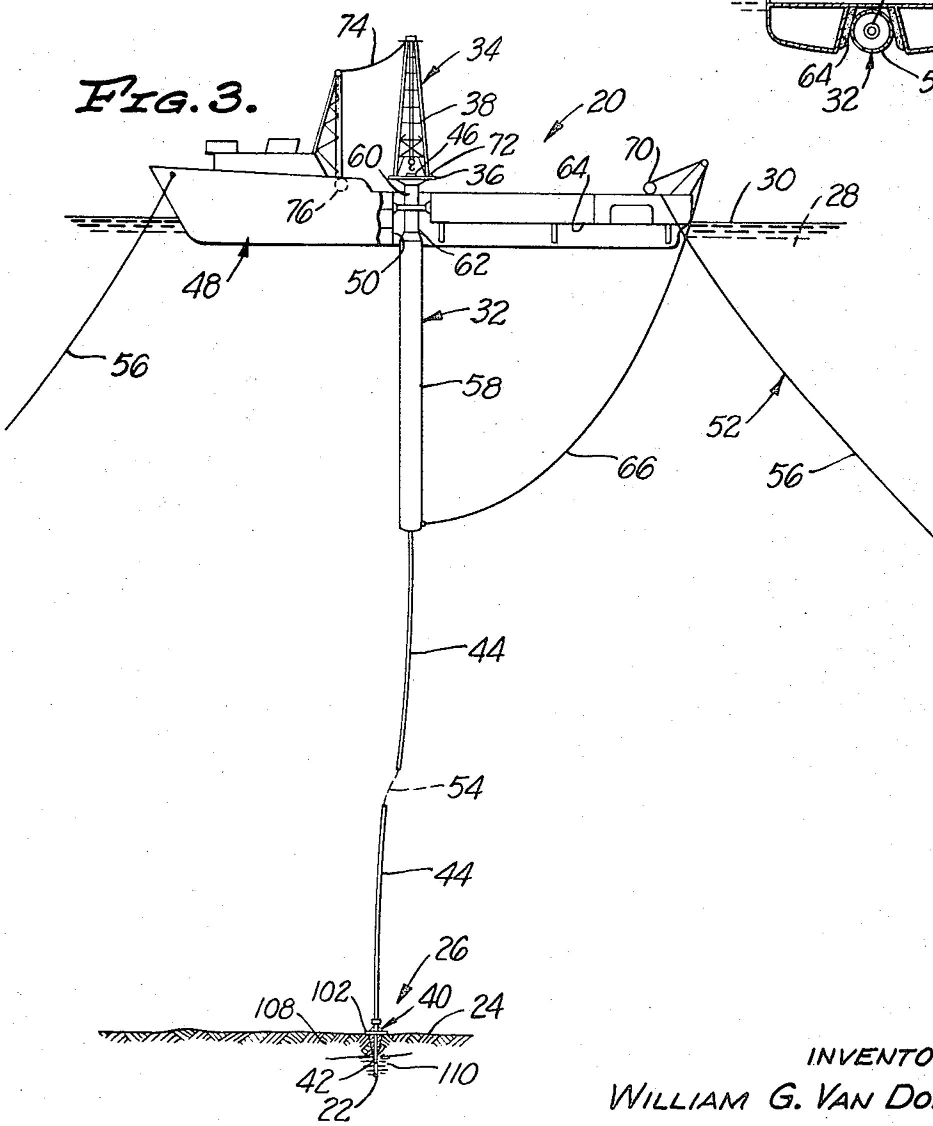


FIG. 3.



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OFFSHORE DRILLING SYSTEM

Filed July 18, 1966

FIG. 5.

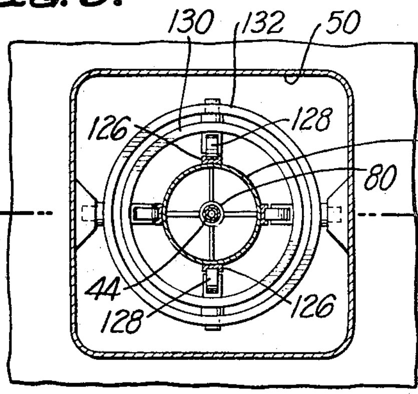

FIG. 6.

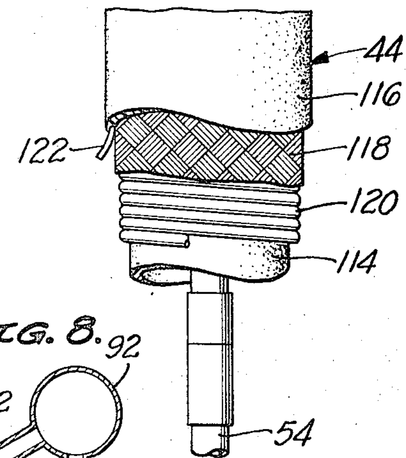

FIG. 8.

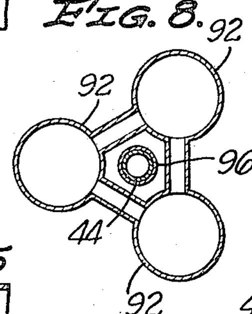

FIG. 4.

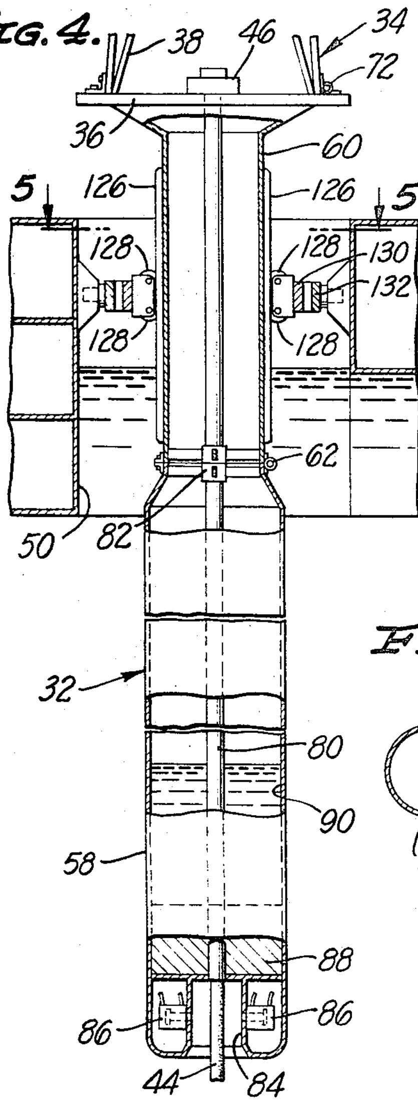

FIG. 7.

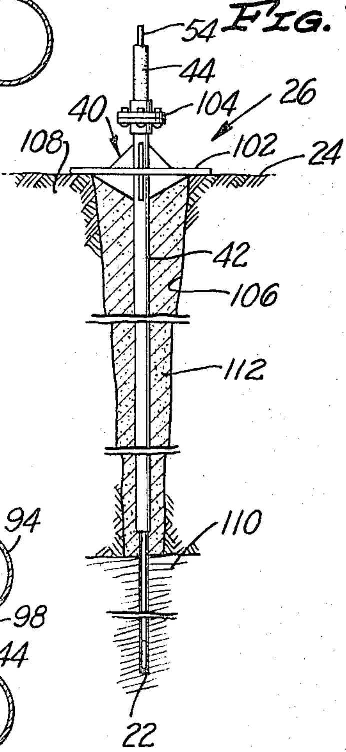

FIG. 9.

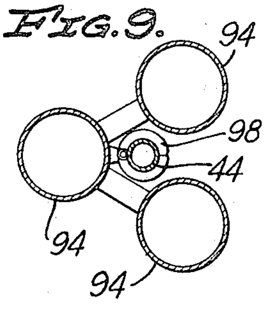

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FIG. 11.

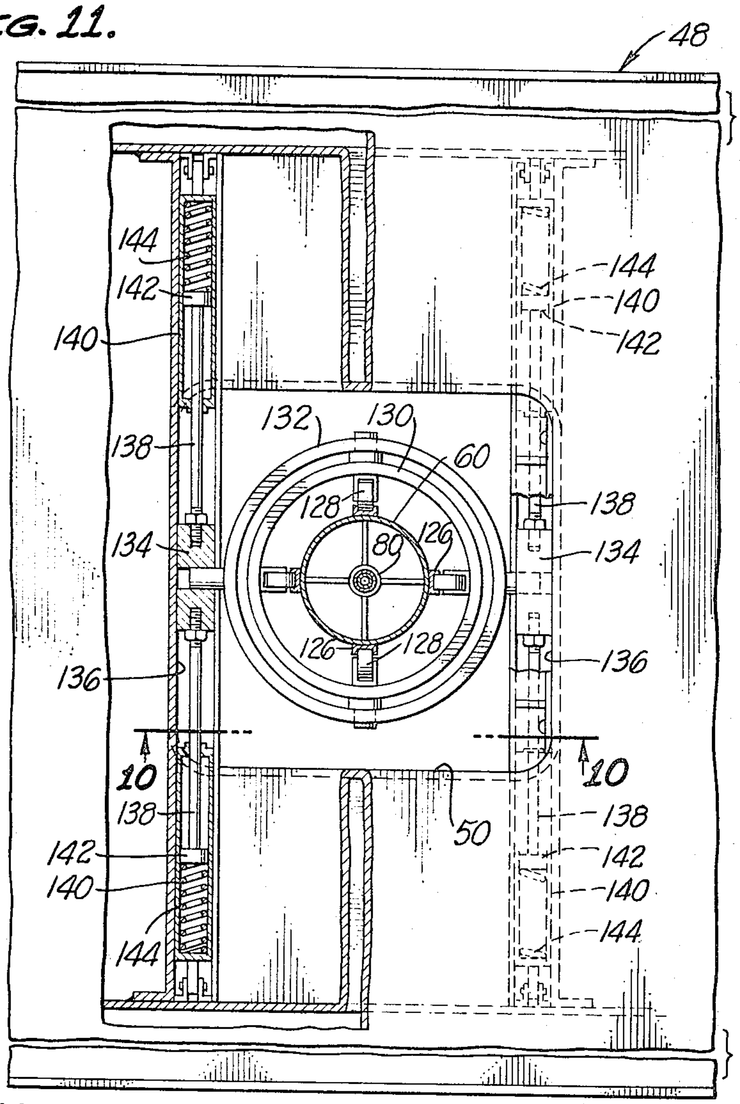

FIG. 10.

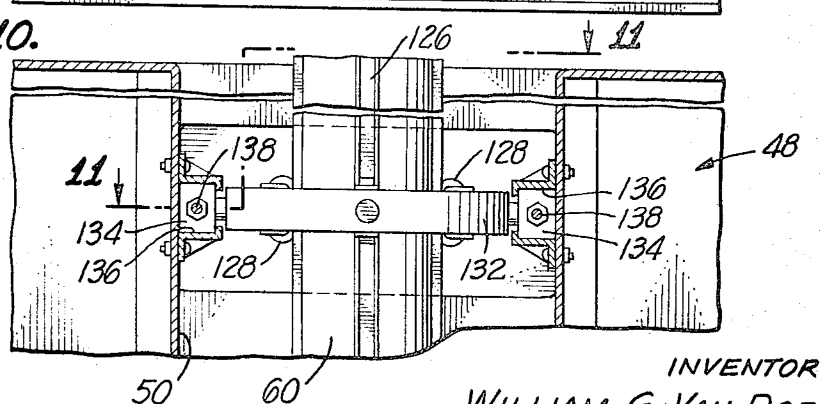

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FIG. 12.

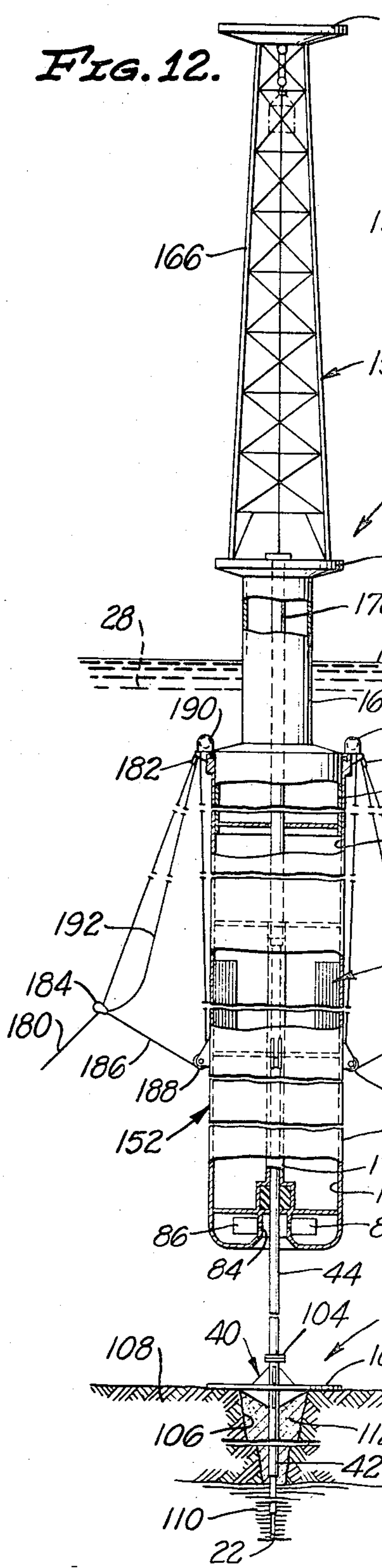


FIG. 14.

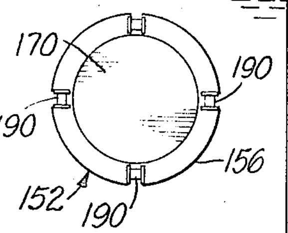
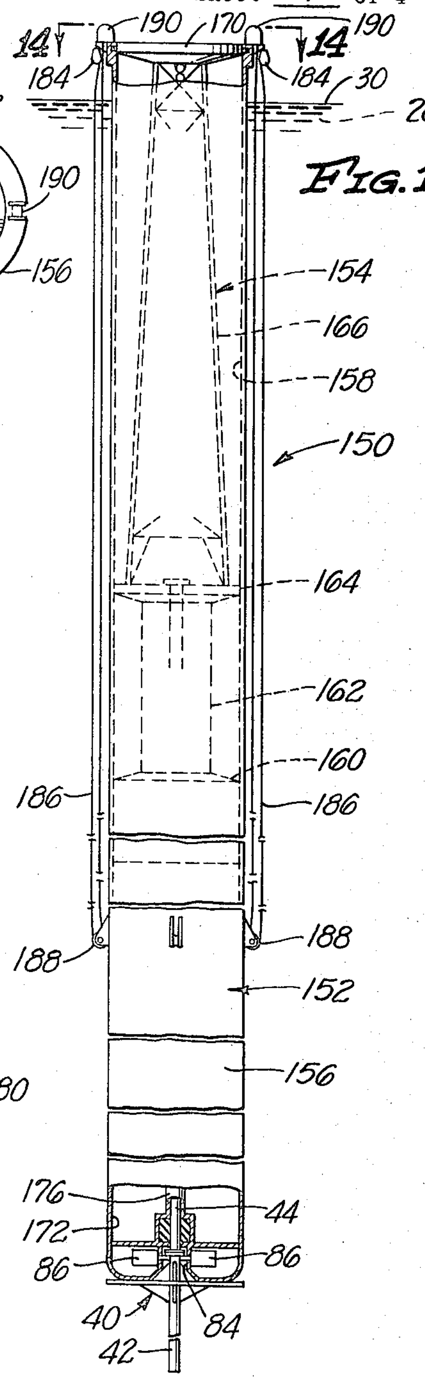


FIG. 13.



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3,419,090
Patented Dec. 31, 1968

3,419,090

OFFSHORE DRILLING SYSTEM

William G. Van Dorn, La Jolla, Calif., assignor of twenty-five percent to John G. Carter, ten percent to Ralph A. Bard, Jr., ten percent to Harold B. Smith, and five percent to William L. Klevans

Filed July 18, 1966, Ser. No. 565,848
21 Claims. (Cl. 175—7)

ABSTRACT OF THE DISCLOSURE

An offshore drilling system for drilling wells at submerged locations having a spar buoy arrangement easily transportable to and stabilized above a submerged location so as to be virtually unaffected by surface waves or swells, the spar buoy arrangement being operable by itself or in conjunction with a floating vessel or platform and connected to the submerged location through a flexible conductor tubing which accepts the equipment necessary for drilling into the submerged location.

The present invention relates in general to offshore drilling systems for drilling wells at submerged locations and, more particularly, to an offshore drilling system of the type wherein the various operations associated with drilling and completing the well are carried out from a floating base. An offshore drilling system of this type is normally used in water too deep for a stationary base of operations, such as an artificial island, a platform standing on the bottom, or the like. Although the floating drilling system of the present invention is preferably utilized for drilling and completing wells at such deep-water locations, it is not restricted thereto and is limited only by the water depth required to accommodate it, as will be apparent hereinafter.

The primary object of the present invention is to provide a floating drilling system which forms an extremely stable base for carrying out all operations associated with drilling and completing, and, if desired, producing, an offshore well. More particularly, the primary object of the invention is to provide a floating base of operations which is virtually unaffected by surface waves or swells.

The foregoing primary object of the invention is attained by providing, and a basic object of the invention is to provide, a stable base of operations comprising a free-floating, upright, spar buoy which projects above the mean water level sufficiently to clear the highest anticipated waves or swells, and which extends downwardly to a depth such that a substaintial portion, and preferably a major portion, of its length is submerged in water relatively unaffected by surface wave or swell action.

More specifically, a basic object of the invention is to provide a base of operations comprising an upright, free-floating, spar buoy of a length sufficient to provide it with a natural heaving period which is longer than the longest period of the waves or swells anticipated above the submerged drilling location.

By way of example, the spar buoy of the invention may have an over-all length of the order of two hundred to three hundred feet, or more, and may project above the mean water level a distance of the order of fifty feet, or more. The resulting long natural heaving period renders the spar buoy virtually insensitive to wave and

swell action. Even in the presence of fifteen to twenty foot waves, such a spar buoy will oscillate vertically only a few inches at most and will oscillate angularly not more than about three degrees.

The spar buoy of the invention may comprise a single upright buoy member, or it may comprise two or more smaller, upright buoy members spaced apart circumferentially about the upright axis of the spar buoy. If two or more buoy members are used, they may be parallel, or they may diverge downwardly. Preferably, the buoy members are of circular cross section, although other configurations may be used. In any event, the buoy member or members may have reduced cross sectional dimensions at and above and below the mean water level to minimize the effects of waves and swells.

An essential object of the invention is to provide a stable, floating drilling system which includes an upright, free-floating spar buoy of the foregoing nature and which includes a drilling rig carried by and coaxial with the spar buoy. A related object is to provide a drilling system of this character wherein the drilling rig includes a conventional drilling platform and derrick mounted on the upper end of and coaxial with the spar buoy, the latter maintaining the drilling platform and derrick above the highest waves and swells anticipated above the submerged well location.

An important object of the invention is to provide a floating drilling system of the foregoing nature which includes a drill shoe anchored to the bottom at the submerged well location and comprising a "surface" casing set in the earth at such location, and which includes a flexible conductor tubing interconnecting the lower end of the spar buoy and the surface casing of the drill shoe. The conductor tubing extends upwardly along the axis of the spar buoy to the drilling platform at the upper end thereof, although the portion of the conductor tubing between the drilling platform and the lower end of the spar buoy need not be flexible.

Another object is to adjust the buoyancy of the spar buoy so that it maintains the flexible conductor tubing in tension. With this construction, the conductor tubing elastically stabilizes the spar buoy and further minimizes its already-small vertical and angular oscillations. Another object of the invention in connection with the flexible conductor tubing is to achieve the desired flexibility by utilizing as the conductor tubing a metallically-reinforced nonmetallic hose. In some instances, however, the flexible conductor tubing may be a metallic tubing.

Another and important object of the invention is to utilize a flexible conductor tubing of a diameter sufficient to permit the passage therethrough of all equipment and well components necesary for drilling and completing, and, if desired, producing, the well. More particularly, the invention contemplates making the flexible conductor tubing large enough to permit the passage of such equipment as drill strings and bits, logging equipment, casings and liners, production tubing systems, wellhead installations, and the like. Thus, the flexible conductor tubing completely isolates the various operations to be performed in drilling, completing, and, if desired, producing, the well from the surrounding aqueous environment. Such isolation has various advantages, one being that it permits drilling with fresh water, thereby preventing any chemical reaction of sea water with the drilling mud, and, further, it permits conventional drilling mud recovery. Other advantages are that it prevents sea-water corrosion of the drill string, reduces drill-string tension by supporting that portion of the drill-string weight which is buoyed up by the drilling mud, prevents local bending of the drill string, prevents the lateral oscillations caused by the Magnus effect of water currents on a naked drill string rotating in open water, and the like.

Another object of the invention is to utilize the flexible conductor tubing as a means for lowering the drill shoe to the bottom, for jetting it into place in any sediment on the bottom, and for then cementing it in place. After the cement introduced through the flexible conductor tubing has set, the drill shoe, and its surface casing, are firmly anchored to the earth at the submerged well location so that drilling operations through the conductor tubing and the surface casing can be initiated.

An important advantage of the foregoing spar-buoy, drill-shoe and flexible-conductor-tubing combination is that, if the upper end of the spar buoy drifts laterally from a point directly above the submerged well location, the flexible conductor tubing assumes a curve having a very large radius, particularly at the junction of the flexible conductor tubing with the surface casing incorporated in the drill shoe. This avoids any sharp bends in the drill string between the drilling platform and the upper end of the hole being drilled, which is an important feature.

An important object of the invention is to provide a floating drilling system of the foregoing nature which includes means for limiting lateral displacement of the drilling platform from a position directly above the submerged well location. Preferably, the drilling platform is maintained within a circle having a radius equal to of the order to ten percent of the water depth so as to minimize bending of the drill string at the critical point where it enters the drill shoe. Lateral excursions of the drilling platform may be confined to this limited area by various mooring means, such as engine-driven propellers, elastic mooring lines connected directly or indirectly to the spar buoy, and the like.

The over-all effect of the foregoing structural features of the floating drilling system of the invention is to provide a very stable base of operations which renders the drilling rig virtually immune to wave and swell action, vertical and angular oscillations of the drilling rig being limited to but a few inches and less than about one degree, respectively, and which maintains the horizontal position of the drilling rig within acceptable limits. In this manner the present invention eliminates two of the most serious problems encountered with drilling systems which float on the surface, one being the tendency of the drill bit to alternately lose contact with and impact against the bottom of the hole as the system heaves vertically under the influence of wave or swell action, and the other being excessive bending of the drill string.

Still another important object of the invention is to provide a floating drilling system wherein the spar buoy is provided adjacent its lower end with at least one ballast compartment adapted to receive water ballast to maintain the spar buoy upright. A related object is to vary the amount of water ballast in the ballast compartment to compensate for variations in the weight supported by the spar buoy. For example, when drill string sections are added as drilling progresses, water is pumped from the ballast compartment in amounts sufficient to maintain the drilling platform at a substantially constant elevation above the mean water level.

Another object of the invention is to provide an offshore drilling system which includes a floating vessel, such as a ship, barge, or the like, connected to the spar buoy adjacent the upper end thereof, but below the drilling rig. With this construction, the floating vessel may be utilized to carry such things as engines for powering the drilling rig, drilling mud storage and recovery equipment, drill string storage, living quarters for the drilling crew or crews, and the like.

The spar buoy may be located alongside the floating vessel, or it may extend upwardly through a well therein. In either event, an important object of the invention is to interconnect the floating vessel and the spar buoy with connecting means which includes means providing for relative vertical movement of the floating vessel and the spar buoy to prevent transmission of upward and downward movement of the floating vessel to the spar buoy, which includes gimbal means for preventing transmission of pitching and rolling motions of the floating vessel to the spar buoy, and which includes means providing for relative lateral movement of the floating vessel and the spar buoy to minimize transmission to the spar buoy of lateral movement of the floating vessel, particularly lateral movement due to rolling thereof. A related object is to limit lateral excursions of the drilling rig from a point directly above the submerged well location by means of mooring lines connected to the floating vessel.

Still another object of the invention is to provide a spar buoy and floating vessel combination of the foregoing nature which includes means providing for upward pivotal movement of the spar buoy into a retracted position beneath the floating vessel, and preferably into a channel in the under side of the floating vessel, and which includes means providing for downward pivotal movement of the derrick into a retracted position above the floating vessel, the spar buoy and the derrick being retracted in this fashion for transport purposes to and from the drilling site.

Still another important object of the invention is to provide a floating drilling system wherein the spar buoy itself carries all of the equipment necessary for drilling a well through the conductor tubing and the drill shoe, no auxiliary floating vessel being necessary, except perhaps to tow the floating drilling system to and from the drilling site.

Another object is to provide a self-contained spar-buoy drilling system of the foregoing nature in which the drilling rig is retractable downwardly into the spar buoy for transport purposes, or to weather storms and/or unusually high waves or swells. A related object is to provide closure means at the upper end of the derrick for closing the upper end of the spar buoy when the drilling rig is retracted downwardly into the spar buoy. A related object is to provide a construction wherein such closure means is capable of serving as a helicopter landing platform in ferrying personnel to and from the drilling site.

Another object is to provide a self-contained spar-buoy drilling system wherein the mooring means for limiting lateral displacement of the spar buoy includes mooring lines connected directly thereto. Another object in this connection is to provide means for vertically adjusting the effective points of connection of the mooring lines to the spar buoy as required for maximum stability.

The foregoing objects, advantages, features and results of the present invention, together with various other objects, advantages, features and results thereof which will be evident to those skilled in the offshore drilling art in the light of this disclosure, may be achieved with the exemplary embodiments of the invention described in detail hereinafter and illustrated in the accompanying drawings, in which:

FIG. 1 is a side elevational view of one embodiment of the floating offshore drilling system of the invention in transport condition, part of the hull of a floating vessel constituting part of the drilling system being broken away to reveal hidden parts;

FIG. 2 is an enlarged sectional view taken as indicated by the arrowed line **2—2** of FIG. 1;

FIG. 3 is a view similar to FIG. 1, but showing the floating offshore drilling system of the invention in operating condition;

FIG. 4 is an enlarged, fragmentary vertical sectional view showing the relationship between the floating vessel and a spar buoy of the floating offshore drilling system of the invention, FIG. 4 being taken as indicated by the arrowed line **4—4** of FIG. 5;

FIG. 5 is a fragmentary horizontal sectional view taken as indicated by the arrowed line **5—5** of FIG. 4;

FIG. 6 is a fragmentary view, with parts broken away to reveal internal structure, of a preferred form of flexible conductor tubing for the floating offshore drilling system of the invention;

FIG. 7 is a fragmentary vertical sectional view illustrating a drill shoe of the floating offshore drilling system of the invention set in the earth at the desired submerged well location;

FIGS. 8 and 9 are horizontal sectional views through alternative spar buoys of the invention;

FIG. 10 is a fragmentary vertical sectional view similar to FIG. 4, but illustrating an alternative connecting means between the floating vessel and the spar buoy, FIG. 10 being taken as indicated by the arrowed line **10—10** of FIG. 11;

FIG. 11 is a fragmentary horizontal sectional view taken as indicated by the arrowed line **11—11** of FIG. 10;

FIG. 12 is a side elevational view, partially in section, showing another embodiment of the floating offshore drilling system of the invention wherein all components of the drilling system are carried by a spar buoy without any auxiliary floating vessel, a retractable drilling rig of this embodiment of the invention being shown in its extended, operative position;

FIG. 13 is a view similar to FIG. 12, but showing the drilling rig in its retracted position within the spar buoy; and

FIG. 14 is a top plan view taken as indicated by the arrowed line **14—14** of FIG. 13.

Floating drilling system 20, general description

Referring initially to FIG. 3 of the drawings, designated generally therein by the numeral **20** is a floating offshore drilling system of the invention in operation to drill a well bore **22** into the earth **24** at a well location **26** submerged beneath water **28** having a mean level **30**.

The basic component of the floating drilling system **20** is a spar buoy **32** adapted to float freely in the water **28** with its upper end a sufficient distance above the mean water level **30** to clear the highest anticipated waves or swells. The spar buoy **32** extends downwardly into the water **28** to a depth such that a major portion of its length is submerged in water relatively unaffected by surface wave or swell action. More particularly, the length of the spar buoy **32** is such as to provide it with a natural heaving period longer than the longest period of the waves or swells anticipated above the submerged well location **26**. With this construction, the spar buoy **32** is virtually insensitive to wave and swell action. Even in the presence of fifteen to twenty foot waves, the spar buoy **32** will oscillate vertically only a few inches at most and will oscillate angularly not more than about three degrees.

Thus, the spar buoy **32** provides an extremely stable floating base or support for a more-or-less conventional drilling rig **34**, comprising as its principal components a drilling platform **36** surmounted by a derrick or mast **38**. Preferably, the drilling rig **34** is mounted on the upper end of the spar buoy **32** so as to be above the highest anticipated waves or swells, and is coaxial with the spar buoy.

Set in the earth **24** at the submerged well location **26** is a drill shoe **40** which includes what will be referred to herein as a "surface" casing **42** for convenience. Interconnecting the surface casing **42** and the lower end of the spar buoy **32** is a flexible conductor tubing **44** which is maintained in tension by the spar buoy. As will be explained in more detail hereinafter, all operations required in drilling the well bore **22** and in completing, and, if desired, producing, the resulting well are carried out from the drilling rig **34** through the spar buoy **32**, the conductor tubing **44** and the surface casing **42**, these elements permitting the passage therethrough of all of the equipment and well components necessary for drilling and completing, and, if desired, producing the well.

In the particular floating drilling system **20** of the invention under consideration, the spar buoy **32** carries only the drilling rig **34** and the equipment usually associated therewith, such as a rotary table **46** and a rotary table drive, crown block, traveling block, draw works, and the like, not all shown. All other equipment and components necessary for the operation of the drilling rig **34**, such as engines for powering the rotary table drive and the draw works, drilling mud storage and recovery equipment, drill string storage racks, casing and tubing storage racks, living quarters for the drilling crew or crews, and the like, are carried by an auxiliary floating vessel **48** connected to the spar buoy in such a manner as to prevent, or at least minimize, transmission to the spar buoy of motions induced by surface wave or swell action. The manner in which the spar buoy **32** and the floating vessel **48** are interconnected to achieve this will be described in more detail hereinafter. The floating vessel **48** may be of any suitable type, e.g., a ship, barge, or the like. It may be located alongside the spar buoy **32**, or, as shown, it may be provided with a central well **50** through which the spar buoy projects.

The final general component of the floating drilling system **20** comprises mooring means **52** for maintaining the spar buoy **32** within a predetermined range of horizontal positions relative to a point directly above the submerged well location **26**. To minimize bending of a drill string **54** extending downwardly from the traveling block in the derrick **38** through the spar buoy **32**, the flexible conductor tubing **44** and the surface casing **42** into the well bore **22**, lateral excursions of the spar buoy **32** from a point directly above the surface casing **42** are preferably limited by the mooring means **52** to a circle having a radius equal to about ten per cent of the depth of the water **28**. This limits bending of the drill string **54** to an acceptably large radius at the critical point where it enters the surface casing **42**. Although the mooring means **52** may take other forms, it is shown as comprising and preferably comprises synthetic elastic mooring lines **56** connected to the floating vessel **48**, the number and orientations of such mooring lines being so selected as to permit heading the vessel into any prevailing swell, and to limit lateral excursions of the floating vessel to the desired extent. Since deep-water mooring techniques utilizing synthetic elastic mooring lines are well known, no further description thereof is necessary herein.

Spar buoy 32

Referring to FIGS. 1 to 5 of the drawings, and particularly to FIG. 4 thereof, the spar buoy **32** comprises a lower buoy member **58** which is preferably an elongated hollow cylinder. Connected to the upper end of the buoy member **58** is a neck or neck member **60** of reduced diameter which projects upwardly through the well **50** in the floating vessel **48** and which carries the drilling platform **36**. The over-all length of the spar buoy **32** including its reduced neck **60** is sufficient to provide it with the hereinbefore-discussed long natural heaving period for maximum stability as respects vertical and angular oscillations induced by surface wave and swell action. (The heaving period is inversely related to the neck diameter and directly related to the square-root of the total submerged length. Reducing the neck diameter permits reducing the over-all length, while still maintaining an acceptably long heaving period.) For example, the over-all length of the spar buoy **32** may be of the order of two hundred to three hundred feet, or more. The mean water level **30** intersects the reduced-diameter neck or neck member **60**. The length of the reduced-diameter neck **60** is sufficient to place the upper end thereof well above the crests of the highest anticipated waves or swells and to place the lower end thereof below the bottoms of the troughs of the highest anticipated waves or swells. With this construction, surface wave or swell action on the spar buoy **32** is minimized.

As will be described in more detail hereinafter, the neck **60** is connected to the floating vessel **48** in such a manner that transmission of various motions of the floating vessel, due to wave or swell action, to the spar buoy **32** is prevented, or at least minimized. The upper end of the buoy member **58** is hingedly connected to the lower end of the neck **60**, as indicated at **62** in FIG. 4, so that the buoy member **58** can be pivoted upwardly into a retracted, transport position beneath the floating vessel **48**, as shown in FIGS. 1 and 2. Preferably, the floating vessel **48** is provided with a longitudinally-extending, central channel **64** in its hull to receive the buoy member **58** when the latter is pivoted upwardly into its retracted position. A cable **66** connected to the lower end of the buoy member **58** and powered by a winch **70** on the floating vessel **48** may be utilized to swing the buoy member upwardly into its transport position within the channel **64**.

For transport purposes to and from the drilling site, in addition to swinging the buoy member **58** upwardly into a retracted position, the derrick **38** is also preferably swung downwardly into a retracted position above the floating vessel **48**, as shown in FIG. 1 of the drawings. For this purpose, there is a hinged connection **72** between the derrick **38** and the drilling platform **36**. The derrick **38** may be lowered into its retracted position, and raised into its erected position, by means of a cable **74** powered by a winch **76** on the floating vessel **48**.

Adverting to the spar buoy **32**, it is provided with a coaxial guide tube **80** which extends from the drilling platform **36** to the lower end of the spar buoy and which is provided with a suitable coupling **82** at the level of the hinge connection **62** to permit swinging the buoy member **58** upwardly into its transport position. The flexible conductor tubing **44** extends upwardly through the guide tube **80** and is suitably secured relative to the drilling platform **36** at its upper end. Securing the upper end of the flexible conductor tubing **44** at the drilling platform **36** in this manner makes it possible to add sections to the flexible conductor tubing as the drill shoe **40** is lowered to and set in the bottom **24** in a manner to be described hereinafter.

Durng transport to and from the drill site, the upper end of the drill shoe **40** is received within a coaxial recess **84** in the lower end of the buoy member **58**, as suggested in FIG. 1. (Also see FIG. 13.) Suitable locking devices **86**, FIG. 4, are engageable with the upper end of the drill shoe **40** to lock it within the recess **84**. (See also FIG. 13.) The locking devices **86** may be hydraulic locking devices, or they may be devices actuable in any other suitable manner.

The spar buoy **32** is provided within the lower end of the buoy member **58** with ballast **88** for maintaining the spar buoy in an upright position. In addition, the lower portion of the buoy member **58** provides a water ballast compartment **90** into which water may be admitted and from which water may be pumped as required to maintain the spar buoy **32** at the proper level despite variations in the load carried thereby, which variations may be due to adding sections or removing sections from the drill string **54**, or in running casing strings, tubing strings, or other equipment and components.

Instead of a spar buoy incorporating a single submerged buoy member, spar buoys utilizing two or more interconnected buoy members **92** or **94**, FIG. 8 or FIG. 9, circumferentially spaced about the axis of the spar buoy, may be used. The buoy members **92** or **94** may be parallel, or may diverge downwardly for greater stability. The spar buoy shown in FIG. 8 is provided with a coaxial guide tube **96** for the flexible conductor tubing **44**. In the spar buoy of FIG. 9, there are no interconnections between two of the three buoy members **94** shown to provide for lateral insertion and withdrawal of the flexible conductor tubing **44**, the latter being held in place on the axis of the spar buoy by suitable vertically spaced, remotely controllable clamps **98**. Each of the spar buoys of FIGS. 8 and 9 is preferably provided at its upper end with a reduced horizontal cross section to minimize wave action. For example, the buoy members **92** and **94** may terminate at their upper ends in reduced-diameter necks, not shown, corresponding to the reduced-diameter neck **60** of the spar buoy **32**.

Drilling rig 34

As previously indicated, the drilling rig **34** may be of more-or-less conventional construction, its principal components being the drilling platform **36** and the hinged derrick or mast **38**. The drilling platform **36** is suitably mounted on the spar buoy **32** in a position such that the rotary table **46** and the spar buoy are coaxial. The derrick **38** carries the usual crown and traveling blocks, and the drilling platform **36** may carry the usual rotary-table drive and draw works. Other components of the drilling rig **34** may be carried by the floating vessel **48**.

Drill Shoe 40

As best shown in FIG. 7 of the drawings, the drill shoe **40** may comprise a relatively-large-area plate **102** which is adapted to seat on the bottom **24** at the desired submerged well location **26**, and to which the surface casing **42** is suitably secured, this surface casing extending through the plate **102**. The lower end of the flexible conductor tubing **44** is secured to the upper end of the surface casing **42** by suitable coupling **104** engageable by the locking devices **86** when the floating drilling system **20** is in its transport condition.

Considering the manner in which the drill shoe **40** may be set in the earth **24** at the submerged well location **26**, after the spar buoy **32** has been lowered into its operative position and the derrick **38** has been raised into its erected position, the drill shoe is lowered to the bottom by adding sections to the flexible conductor tubing **44** at the drilling platform **36**, preferably utilizing the traveling block carried by the derrick. After the lower end of the surface casing **42** has made contact with the bottom, water is pumped through the conductor tubing **44** and the surface casing and is discharged from the lower end of the surface casing as a jet which forms a cavity **106** in any sediment layer **108** overlying a suitably consolidated formation **110**. (The thickness of any sediment layer **108** can be determined in advance so that the drill shoe **40** can be provided with a surface casing **42** of a length sufficient to reach nearly to the consolidated formation **110**.)

After the sediment layer **108** has been jetted away in the foregoing manner to a depth sufficient to seat the plate **102** on the bottom **24**, the drill shoe **40** may be cemented in place by discharging cement from the lower end of the surface casing **42** until the cavity **106** is completely filled with a body of cement **112**. Preferably, this cementing operation is carried out through a separate cement tubing, not shown, within the flexible conductor tubing **44** to avoid contaminating the interior of the conductor tubing, such cement tubing being equipped at its lower end with a suitable remotely-controllable packer, not shown, engageable with the interior of the surface casing **42**. If desired, water for the jetting operation for placing the drill shoe **40** may also be pumped downwardly through such an inner tubing.

In lieu of utilizing a surface casing **42** of preselected length, the length of surface casing **42** incorporated in the drill shoe **40** may be relatively short and a separate inner casing, not shown, may be run in through the flexible conductor tubing **44** and the short surface casing **42**, sections being added to such inner casing as required to reach the suitably consolidated layer **110**.

It will be understood that throughout the foregoing operations, the amount of water ballast in the compartment 90 within the spar buoy 32 is varied as required to maintain the spar buoy at a constant level despite variations in the weight carried by the spar buoy.

Flexible conductor tubing 44

Referring particularly to FIG. 6, the flexible conductor tubing 44 is preferably a metallically-reinforced nonmetallic hose having inner and outer layers 114 and 116 of any suitable abrasion and corrosion resistant elastomeric material, such as rubber, plastic, or the like. Molded into the flexible conductor tubing or hose 44 are a sheath 118 of wire braid, or other suitable material, to resist longitudinal tension in the hose, and a layer 120 comprising a closed-coil, or close-coil, spring for resisting hoop tension due to internal pressure.

As hereinbefore indicated, the flexible conductor tubing 44 has a diameter sufficient to permit the passage therethrough of all equipment and well components required in drilling and completing the well, including such things as the drill string 54 carrying a drill bit at its lower end, coring equipment, logging equipment, side wall sampling and scraping equipment, casing strings as required during drilling and/or completing operations, tubing strings as required for completing the well, various well head eqiupment for performing such functions as preventing blowouts and for producing the well, and the like. Thus, the flexible conductor tubing 44, in conjunction with the surface casing 42 of the drill shoe 40, completely isolate all operations from the surrounding aqueous environment.

The isolation provided by the flexible conductor tubing 44 has a number of important advantages. For example, it permits utilizing a fresh-water drilling mud, thereby preventing any chemical reaction of sea water with the drilling mud, and, further, it permits conventional drilling mud recovery, the drilling mud and drilled materials carried thereby being returned through the annulus between the conductor tubing and the drill string for processing aboard the floating vessel 48. Another advantage is that the flexible conductor tubing 44 prevents sea-water corrosion of the drill string, and reduces drill-string tension by supporting that portion of the drill-string weight which is buoyed up by the drilling mud. The flexible conductor tubing 44 also serves to support the drill string 54 to some extent to prevent local bending thereof, and maintains the drill string in a smooth, large-radius curve, particularly at the critical point where the drill string enters the drill shoe 40, in the event that the spar buoy 32 drifts laterally from a point directly above the submerged well location 26. Further, since the drill string 54 rotates in drilling mud within the flexible conductor tubing 44, it is not subject to the lateral oscillations which would result from the Magnus effect of water currents on a naked drill string rotating in open water.

Other advantages of the flexible conductor tubing 44 are that it elastically stabilizes the spar buoy 32 since it is maintained in longitudinal tension by the buoyancy of the spar buoy, thereby further reducing the inherently-small vertical and angular oscillations to which the spar buoy is subject. The flexible conductor tubing 44 also, as hereinbefore pointed out, serves as the means for emplacing and anchoring the drill shoe 40 at the desired well location 26.

In the event of a storm severe enough to require temporary cessation of operations during drilling, for example, the drill string 54 may be withdrawn and the upper end of the flexible conductor tubing 44 capped. The conductor tubing 44 may then be disengaged from the spar buoy 32 (an operation which is simplified by the embodiment of FIG. 9) and a marker buoy attached to the upper end of the conductor tubing. The site may then be abandoned until such time as weather conditions permit a resumption of operations.

A procedure somewhat similar to the foregoing may be followed upon completion of the well if production thereof is not to be initiated immediately. In other words, the flexible conductor tubing 44 may be equipped with suitable valving and left at the drilling site, attached to a marker buoy, so that it can be recovered and reconnected for subsequent production operations.

Should it become necessary or desirable to cap the well, a suitable expansible cap can be introduced through the flexible conductor tubing 44 into and engaged with the surface casing 42. The flexible conductor tubing 44 can then be recovered by disengaging the coupling 104. This may be accomplished, for example, by providing the coupling 104 with explosive bolts adapted to be detonated by means of wiring 122, FIG. 6, embedded in the flexible conductor tubing 44. (It might be well to point out that additional wiring or hydraulic lines, not shown, may also be embedded in the flexible conductor tubing 44 for performing various other functions to be carried out at the well head and controlled from the drilling rig 34, or the floating vessel 48.)

The flexible conductor tubing 44 can also be retrieved in a similar manner after completion of the well and after installation of suitable equipment for producing the well by flowing, pumping, gas lifting, and the like. It will be understood that the production from the completed well may be delivered to any suitable recovery point, as is well known in the offshore production art.

Connecting means between spar buoy 32 and floating vessel 48

As previously pointed out, the spar buoy 32 and the floating vessel 48 are interconnected in such a way as to prevent, or severely minimize, the transmission to the spar buoy of the various motions of the floating vessel caused by the action of waves and swells. More particularly, the means interconnecting the spar buoy 32 and the floating vessel 48 includes means for preventing transmission of upward and downward movement of the floating vessel to the spar buoy, includes means for preventing transmission of pitching and rolling motions of the floating vessel to the spar buoy, and includes means for preventing or minimizing transmission of lateral movement or accelerations of the floating vessel to the spar buoy.

Considering the foregoing in more detail, transmission of heaving motions of the floating vessel 48 to the spar buoy 32 is prevented by providing the neck 60 of the spar buoy with circumferentially spaced, vertical tracks 126, FIGS. 4 and 5, each engageable by vertically spaced rollers or wheels 128 connected to the floating vessel 48 in a manner to be described in the next paragraph. As the floating vessel 48 rises and falls in response to wave and/or swell action, the wheels 128 merely run upwardly and downwardly along the tracks 126 so that the spar buoy 32 is not affected by such motions of the floating vessel.

The sets of wheels 128 are mounted on an inner gimbal ring 130 which is pivotally connected to an outer gimbal ring 132, the latter being pivotally connected to opposite sides of the well 50 through the floating vessel 48, for pivotal movement about an axis perpendicular to the pivot axis of the inner gimbal ring. With this construction, pitching and rolling motions of the floating vessel 48 are not transmitted to the spar buoy 32.

Turning to FIGS. 10 and 11 of the drawings, illustrated therein is an alternative connection between the spar buoy 32 and the floating vessel 48 wherein the pivots for the outer gimbal ring 132 are oriented longitudinally of the vessel and are mounted in crossheads 134 movable along tracks 136 extending laterally of the vessel. Each crosshead 134 has connected thereto opposed piston rods 138 extending along the corresponding track 136 into hydraulic damping cylinders 140, the piston rods being connected to pistons 142 within such cylinders. Centering springs 144, for centering the spar buoy 32 relative to the well 50 through the floating vessel 48, are seated against the pistons 142. With this construction, the hydraulic damping cylinders 140 minimize transmission to the spar buoy 32 of lateral horizontal movement of the floating vessel 48 due to rolling or swaying thereof. (A similar damping arrangement for minimizing the effect of longitudinal motion of the floating vessel 48 due to pitching thereof might be used, but this may not be essential since such longitudinal motion is normally quite small.)

It will be noted that the foregoing interconnections between the spar buoy 32 and the floating vessel 48 make no provision for avoiding the transmission of yawing motion of the floating vessel to the spar buoy. If avoiding the transmission of such yawing motion is desired, this can be accomplished readily by providing the gimbal system with an intermediate ring, not shown, which is rotatable relative to the outer gimbal ring 132 and to which the inner gimbal ring 130 is pivotally connected.

Floating drilling system 150

The embodiments of the invention hereinbefore described and illustrated in FIGS. 1 to 11 of the drawings utilize a spar buoy having a displacement sufficient only to carry the drilling rig 34, the equipment directly associated therewith, and the equipment and components handled thereby. Thus, the floating vessel 48 is provided as an auxiliary base for other equipment and components.

FIGS. 12 to 14 of the drawings illustrate a spar-buoy floating drilling system 150 of the invention which is completely self contained and which carries all of the equipment and components necessary for drilling and completing a well at a submerged location, no auxiliary floating vessel being necessary, except perhaps for supplying the floating drilling system with additional equipment and components as required, and for towing the floating drilling system to and from the drilling site. Further, the floating drilling system 150 is, as will be described, a telescoping system capable, when telescoped, of weathering even extremely severe storms without disconnection from the well being drilled.

The floating drilling system 150 includes a free-floating upright spar buoy 152 which is generally similar to the spar buoy 32 and which carries a coaxial drilling rig 154 similar to the drilling rig 34.

More particularly, the spar buoy 152 includes a cylindrical buoy member 156 the upper portion of which forms a cylinder 158 for a vertically movable plunger 160. The spar buoy 152 includes a neck 162 which corresponds to the neck 60 of the spar buoy 32, but which is carried by the plunger 160. When this plunger is at the upper end of its stroke, as shown in FIG. 12, the neck 162 is so positioned that its upper and lower ends are respectively above the crests and below the troughs of the highest anticipated waves or swells, thereby minimizing the effect of wave and swell action on the floating drilling system 150.

Mounted on the upper end of the neck 162 is a drilling platform 164 forming part of the drilling rig 154 and carrying a derrick 166. The length of the cylinder 158 in the buoy member 156 is such that when the plunger 160 is at the lower end of its stroke, the neck 162 of the spar buoy and the drilling rig 154 are disposed entirely within the buoy member 156, as shown in FIG. 13. When the drilling rig 154 is retracted downwardly into the buoy member 156 in this manner, the upper end of the buoy member is closed by a closure member 170 atop the derrick 166. In either the extended or retracted position of the drilling rig 154, the closure member 170 may be used as a landing platform for helicopters for ferrying crew members and/or equipment and supplies to and from the drill site.

It will be understood that the drilling rig 154 may be erected by pressurizing the cylinder 158 below the plunger 160 with compressed air, for example, in which case the plunger acts as a piston. (Alternatively, the hereinafter-described telescoping guide tube 176 may be pressurized to erect the drilling rig 154.) If desired, the drilling rig 154 may be mechanically locked in its erected position by any suitable means, not shown. Upon relieving the pressure below the plunger 160 (or within the guide tube 176), the drilling rig 154 will automatically descend into its retracted position.

It will be noted that when the drilling rig 154 is erected, the upper end of the buoy member 156 is below the mean water level 30 so as to position the neck 162 at the proper level to minimize the effects of wave and swell action. Conversely, when the drilling rig 154 is retracted, the upper end of the buoy member 156 is preferably above the mean water level 30, although it might be below the mean water level in some instances. The vertical position of the buoy member 156 relative to the mean water level 30 is adjusted by varying the amount of water ballast in a ballast compartment 172 at the lower end of the buoy member 156. Variations in the weight carried by the spar buoy 152 are also compensated for by varying the amount of water ballast in the compartment 172, as hereinbefore described in connection with the spar buoy 32.

When the drilling rig 154 is telescoped downwardly into the buoy member 156 as shown in FIG. 13, the floating drilling system 150 can withstand severe storms for several reasons. First, since most or all of the length of the floating drilling system 150 is below the mean water level, direct wind effects are minimized or eliminated. Secondly, since nearly all of the length of the floating drilling system 150 is below the wave or swell level, waves or swells have very little effect. Thirdly, when the floating drilling system 150 is in the condition shown in FIG. 13, its center of gravity is relatively low so that the resulting structure is quite stable. Consequently, in the event of an approaching storm of unusual severity, it is merely necessary to retract the drilling rig 154 so that the storm can be weathered without leaving the drilling site.

As previously indicated, the floating drilling system 150 is completely self contained. Thus, all equipment and components necessary for drilling and completing a well at the submerged well location 26 which are not carried by the drilling rig 154 itself, are carried within the buoy member 156 below the cylinder 158 therein. Examples of equipment which can be carried within the buoy member 156 are engines for powering the drilling rig 154, drilling mud storage and handling systems, and the like. (It will be understood that if internal combustion engines are used for powering the drilling rig 154, air may be delivered thereto and products of combustion exhausted therefrom through suitable lines, not shown, leading upwardly through the neck 162 to a point above the maximum anticipated water level.) Examples of well components which may be carried within the buoy member 156 are racks of drill string sections, casing sections, tubing sections for readying the well for production, and the like, as indicated by the numeral 174. Living quarters for the crew or crews may also be provided within the buoy member 156, suitable ventilating equipment being provided for the crews' quarters.

The flexible conductor tubing 44 interconnects the lower end of the spar buoy 152 and the drill shoe 40 in the same manner as it interconnects the lower end of the spar buoy 32 and the drill shoe 40. One difference is that the flexible conductor tubing 44 extends upwardly through the spar buoy 152 within a telescoping guide tube 176, such a telescoping guide tube being necessary to permit extension and retraction of the drilling rig 154. All of the operations necessary in drilling, completing, and, if desired, producing a well drilled at the submerged well location 26 are carried out through the flexible conductor tubing 44 in the same manner as hereinbefore described in connection with the floating drilling system 20.

It will be noted that the lower end of the spar buoy 152 is provided with the same recess 84 and locking devices 86 as the lower end of the spar buoy 32, the recess 84 and the locking devices **86** receiving and engaging the upper end of the drill shoe **40** for transport purposes to the drilling site.

In the floating drilling system **150**, the spar buoy **152** is maintained within a predetermined horizontal distance of the axis of the drill shoe **40** by mooring lines **180** connected to anchor points **182** circumferentially spaced around the upper end of the buoy member **156**. The mooring lines **180** are threaded through free blocks **184** connected to lines **186** which are trained under pulleys **188** on the lower portion of the buoy member **156** and which extend upwardly to winches **190**, shown as mounted on the upper end of the buoy member adjacent the respective anchor points **182**. Retrieval lines **192** are also connected to the free blocks **184**.

With the foregoing mooring system, actuation of the winches **190** in one direction or the other causes the free blocks **184** to move upwardly or downwardly along the mooring lines **180**. This results in vertically adjusting the effective points of attachment of the mooring lines **180** to the spar buoy **152** so that maximum stability can be achieved.

Although exemplary embodiments of the present invention have been disclosed herein for purposes of illustration, it will be understood that various changes, modifications and substitutions may be incorporated in such embodiments without departing from the spirit of the invention as defined by the claims which follow.

I claim:

1. In an offshore drilling system for drilling a well at a submerged location, the combination of a free floating spar buoy adapted to float in an upright position in the water overlying said submerged location, said spar buoy being provided adjacent its upper end with a neck having reduced cross-sectional dimensions in the vicinity of and above the main water level, means associated with the spar buoy for adjusting the dimensions and effective mass thereof whereby the natural heaving period of the spar buoy can be regulated and controlled as to dimensions, mass or area of said reduced cross-section in accordance with the action of the surface waves to provide optimum vertical stability to the spar buoy, and a drilling rig carried by said spar buoy.

2. An offshore drilling system as defined in claim **1** wherein said spar buoy comprises a single cylindrical member.

3. An offshore drilling system according to claim **1** wherein said spar buoy includes interconnected, circumferentially spaced cylindrical members.

4. In an offshore drilling system for drilling a well at a submerged location, the combination of:

(a) a free floating spar buoy adapted to float in an upright position in the water overlying said submerged location;

(b) a drilling rig carried by said spar buoy including a drilling platform and derrick mounted on the upper end of and coaxially with said spar buoy for support above the water level thereby;

(c) a drill shoe anchored to the earth at the submerged location; and

(d) a flexible conductor tubing associated with said spar buoy and interconnecting said drilling platform and drill shoe.

5. An offshore drilling system as set forth in claim **4** including means for limiting lateral displacement of said spar buoy from a location directly above said submerged location.

6. An offshore drilling system as defined in claim **4** wherein said spar buoy carries all of the equipment necessary for drilling into the earth at said submerged location through said conductor tubing and said drill shoe.

7. An offshore drilling system according to claim **4** wherein said drilling rig is retractable downwardly into said spar buoy.

8. An offshore drilling system as set forth in claim **4** including closure means at the upper end of said derrick for closing the upper end of said spar buoy when said drilling rig is retracted downwardly into said spar buoy.

9. An offshore drilling system according to claim **4** wherein said spar buoy is provided adjacent its lower end with a water ballast compartment which is adapted to receive water ballast to maintain said spar buoy upright and wherein the amount of ballast can be varied to compensate for variations in the weight supported by said spar buoy.

10. An offshore drilling system as set forth in claim **4** wherein said conductor tubing includes a metallically reinforced nonmetallic hose.

11. An offshore drilling system according to claim **4** wherein said conductor tubing is maintained in tension by the buoyancy of said spar buoy.

12. An offshore drilling system as set forth in claim **4** wherein said drill shoe includes a casing set in the earth at said submerged location.

13. An offshore drilling system as defined in claim **4** wherein said means for limiting lateral displacement of said spar buoy includes mooring lines connected thereto.

14. An offshore drilling system according to claim **13** including means for vertically adjusting the effective points of connection of said mooring lines to said spar buoy.

15. In an offshore drilling system for drilling a well at a submerged location the combination of:

(a) a free floating spar buoy adapted to float in an upright position in the water overlying said submerged location;

(b) a drilling rig carried by said spar buoy;

(c) a floating vessel; and

(d) connecting means interconnecting the floating vessel and said spar buoy adjacent the upper end thereof, said connecting means including means providing for relative vertical movement of said floating vessel and spar buoy to prevent transmission of upward and downward movement of said floating vessel to said spar buoy.

16. An offshore drilling system according to claim **15** wherein said connecting means includes gimbal means for preventing transmission of pitching and rolling motions of said floating vessel to said spar buoy.

17. An offshore drilling system according to claim **15** wherein said connecting means includes means providing for relative lateral movement of said floating vessel and said spar buoy to minimize transmission of lateral movement of said floating vessel to said spar buoy.

18. An offshore drilling system as set forth in claim **15** wherein said means for limiting lateral displacement of said spar buoy comprises mooring lines connected to said floating vessel.

19. In an offshore drilling system for drilling a well at a submerged location the combination of:

(a) a free floating spar buoy adapted to float in an upright position in the water overlying said submerged location;

(b) a drilling rig carried by said spar buoy;

(c) a floating vessel; and

(d) connecting means interconnecting the floating vessel and said spar buoy adjacent the upper end thereof, said connecting means including means for providing upward pivotal movements of the spar buoy into a retracted position beneath the floating vessel for transport purposes.

20. An offshore drilling system according to claim **19** wherein said floating vessel is provided in its underside with a channel to receive said spar buoy when the latter is pivoted upwardly into its retracted position.

21. An offshore drilling system as set forth in claim **20** including a derrick mounted on the upper end and coaxially with the spar buoy, and means providing for downward pivotal movement of the derrick into a retracted position above and in alignment with the floating vessel so as to be transported thereby.

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