STABILIZED OFFSHORE DRILLING APPARATUS

Original Filed March 27, 1967 2 Sheets-Sheet 1

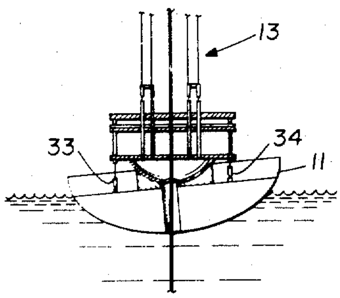


FIG. 2

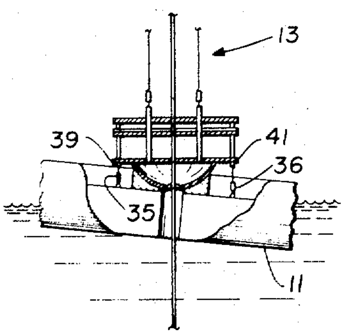


FIG. 3

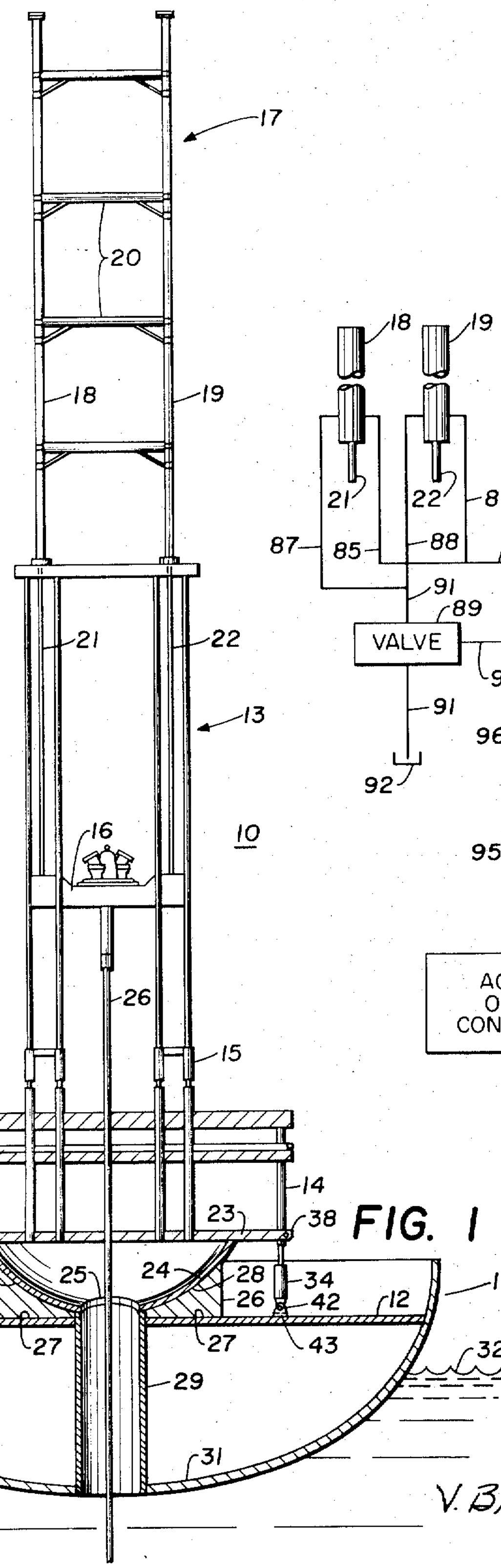
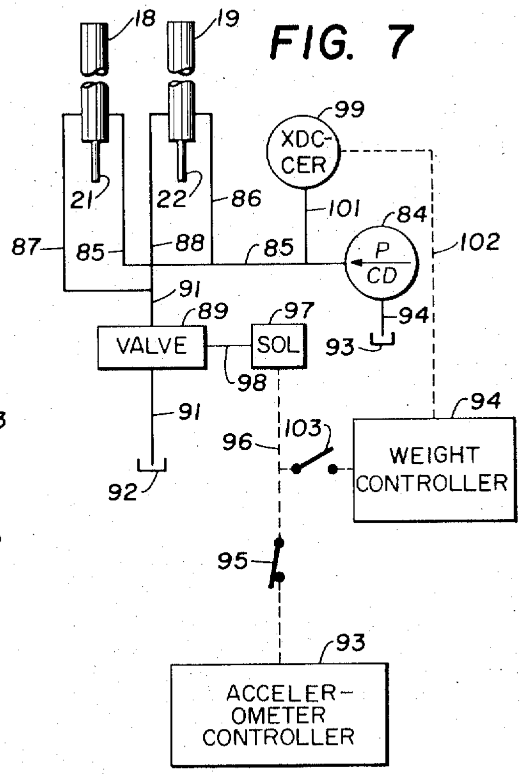


FIG. 1

FIG. 7



INVENTORS
RAY. J. BROMELL
MARION D. LACKEY

V. Bryan Medlock, Jr.
ATTORNEY

STABILIZED OFFSHORE DRILLING APPARATUS

Original Filed March 27, 1967 2 Sheets-Sheet 2

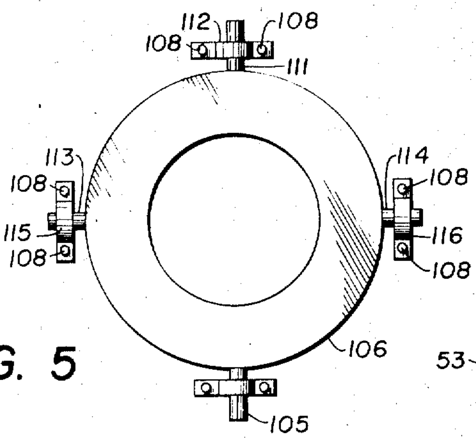


FIG. 5

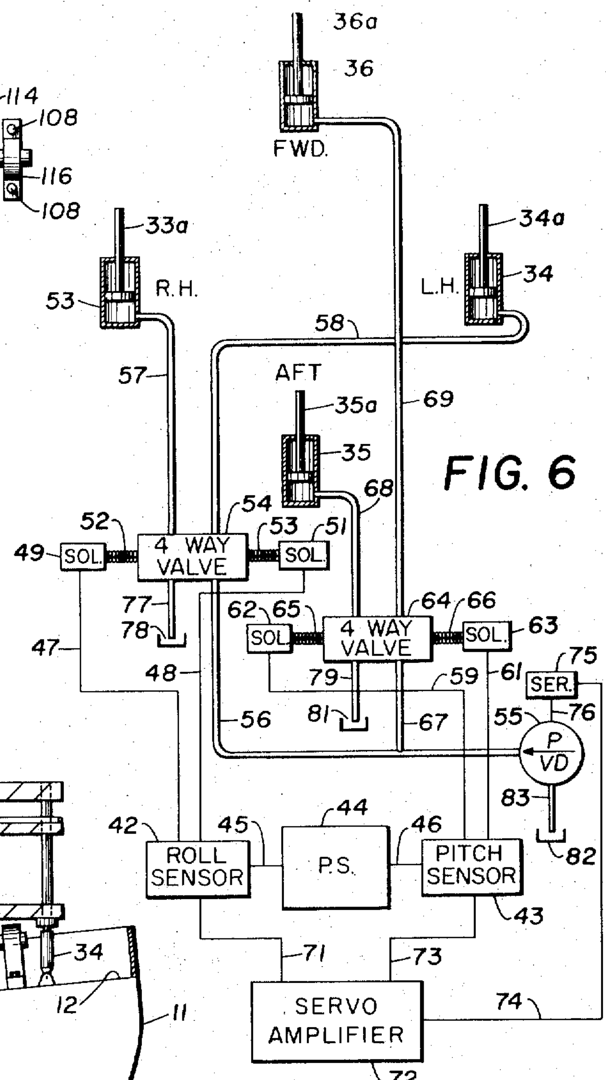


FIG. 6

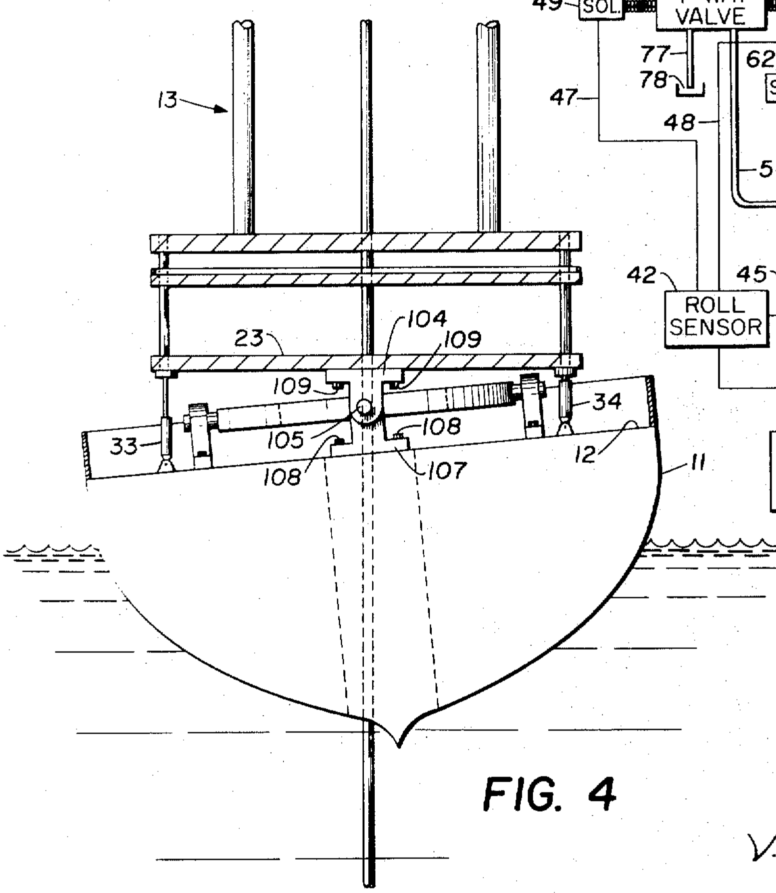


FIG. 4

INVENTORS
RAY J. BROMELL
MARION D. LACKEY

V. Bryan Medlock, Jr.

ATTORNEY

27,261

STABILIZED OFFSHORE DRILLING APPARATUS

Raymond J. Bromell and Marion D. Lackey, Dallas, Tex., assignors to Kendrick Cattle Company, Sheridan, Wyo.

Original No. 3,390,654, dated July 2, 1968, Ser. No. 626,091, Mar. 27, 1967. Application for reissue May 11, 1970, Ser. No. 36,192

Int. Cl. B63b *35/00*

U.S. Cl. 114—.5 13 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

An offshore drilling apparatus mounted on a floating vessel so that the vessel can both roll and pitch relative to the drilling apparatus. Roll and pitch sensors, in response to movements of the vessel, actuate a plurality of hydraulic cylinder and rod assemblies disposed about the periphery of the base of the drilling apparatus to maintain the drilling string in a vertical position during pitch and roll of the vessel. The pitch and roll compensating means act in combination to compensate for simultaneous pitch and roll of the vessel. The drilling apparatus includes hydraulic cylinder and rod means for suspending the drill string through the bottom of the vessel and means are provided for compensating for vertical movement of the floating vessel to maintain the drill string in a relatively fixed position relative to the earth.

Field of the invention

The invention relates to earth boring apparatus, and more particularly to offshore earth boring apparatus which are mounted on a floating vessel.

The prior art

Conventional offshore drilling is usually performed from a platform fixed to the bottom of the ocean or from a floating vessel upon which the drilling apparatus is mounted. When drilling is to be done in an offshore area which is relatively shallow, fixed platforms are usually suitable for the drilling; but when drilling is to be done in relatively deep water, the construction of a platform which may be affixed to the bottom of the sea becomes quite expensive and is extremely difficult to transport to the drilling location. Therefore, for drilling in relatively deep water, floating vessels are usually employed. Various problems are encountered in drilling from a floating vessel during turbulent sea conditions. When the sea becomes turbulent, the vessel upon which the drilling apparatus is mounted begins to pitch and roll, as well as move vertically. During the pitching and rolling movement of the vessel, bending stresses are created in the drill string. During vertical movement of the vessel, the drill bit or the like is either lifted from the bottom of the hole being drilled, or alternatively, the drill string to which the bit is attached is subject to compressive stresses which can shear the string. For example, if the drill bit is in contact with the bottom of the bore hole at one elevation of the drilling vessel and the vessel moves upwardly, the drill bit will be lifted from the bottom of the bore hole, during which time rotation of the drill bit is ineffective to drill a hole. If the vessel moves downwardly, the drill string is placed in compression, placing excessive weight on the drill bit and the string to which it is attached; and excessive weight can damage both the bit and the drill string.

Also, in certain drilling applications, it becomes necessary to attach blow-out preventers and well completion equipment to the ocean floor. Such equipment must be suspended from the drilling apparatus mounted on the vessel, and movement of the vessel relative to the ocean floor can render difficult the location of equipment over a bore hole. All of the above problems have been appreciated by the prior art, and various attempts have been made at stabilizing the drilling apparatus, as well as compensating for the movement of the apparatus. For example, very expenseive slip joints have been devised to compensate for vertical movement of the drill string. These slip joints are subject to extreme wear and often fail in service.

Other efforts to solve the above problems are exemplified by the following U.S. Letters Patents: 2,945,676, 3,158,208, 3,158,206, 2,777,669, and 3,208,728.

Summary

This invention may be generally described as an offshore drilling apparatus including a vessel which supports a mast and carries means for supporting lowering, raising and rotating a drill string adapted to be inserted into the earth below, which includes the improvement of means for mounting the mast to the vessel so that the vessel can roll and pitch relative to the mast. First sensing means are provided for sensing the roll of the vessel and generating an outlet signal when the vessel rolls relative to the horizontal. First stabilizing means are responsive to the signal from the first sensing means for maintaining the mast in a vertical position during rolling movement of the vessel. Second sensing means are provided for sensing the pitch of the vessel and generating an output signal when the vessel pitches relative to the horizontal. Second stabilizing means are responsive to the signal from the second sensing means for maintaining the mast in a vertical position during pitching movement of the vessel. Third sensing means, which are responsive to vertical movement of the vessel, generate a signal upon vertical movement of the mast for actuating third stabilizing means which serves to maintain the drill string in a predetermined position upon vertical movement of the vessel.

The drawings:

FIGURE 1 is a front elevational view, partially cross sectioned, of one embodiment of the present invention, with the sensing and stabilizing elements omitted for ease of illustration;

FIGURE 2 is a view similar to FIGURE 1 to illustrate the relative position of the vessel and drilling apparatus, when the vessel has rolled relative to the drilling apparatus;

FIGURE 3 is a side elevational view, partially cutaway, of the FIGURE 1 embodiment illustrating the relative position of the drilling apparatus and mast when the vessel has pitched relative to the drilling apparatus;

FIGURE 4 is a front elevational view, partially cross sectioned, to illustrate yet another embodiment of the invention with the sensing and stabilizing means omitted for ease of illustration;

FIGURE 5 is a top plan view of the mounting means illustrated in FIGURE 4;

FIGURE 6 is a schematic illustration of the sensing and stabilizing means employed to compensate for pitching and rolling movement of the vessel relative to the drilling apparatus; and

FIGURE 7 is a schematic illustration of the sensing and stabilizing means employed to compensate for vertical movement of the vessel and drilling apparatus.

The preferred embodiments

With reference to FIGURE 1, the offshore drilling apparatus **10** includes a vessel **11** provided with a top deck **12** which supports a drilling rig **13**. Drilling rig **13** includes a multi-level platform **14** which supports a mast **15** within which is slidably carried a vertically moveable drillhead assembly **16**. Drillhead assembly **16** is threadably engaged with and supports a drill string **26**. Movement of drillhead **16** relative to mast **15** is accomplished by a suitably braced tower **17** fixed to the top of mast **15**. Tower **17** includes cylinders **18** and **19** which are suitably braced by struts **20**. Rods **21** and **22**, which are reciprocally mounted with cylinders **18** and **19**, respectively, are affixed to drillhead **16** at their lower end and serve to effect vertical movement of drillhead **16** upon introduction of hydraulic fluid into cylinders **18** and **19** through hydraulic lines (not illustrated in FIGURE 1). Attached to base **23** of platform **14** is a semi-spherical shell **24** which is provided with an opening **25** through which is suspended drill string **26**. Shell **24** is supported upon deck **12** of vessel **11** by a plurality of vertical plates **26** which are affixed at their bottom edge **27** to deck **12** and are provided at their upper edge **28** with arcuate surfaces adapted to mate with the shell **24**. Passing interiorly of plates **26** and extending through deck **12** is a housing **29** which also passes through the bottom **31** of vessel **11** and is secured thereto in a watertight relationship by any suitable means. Housing **29** permits drill string **26** to pass therethrough, out through the bottom of vessel **11** and through the sea **32** to permit drilling through the earth's crust (not illustrated).

In drilling from a floating vessel it is desirable to maintain the drill string **26** in a relatively stationary vertical position in order to maintain a fixed weight on the bit and to prevent creating stresses in the string **26** which would arise if the sea **32** causes rolling pitching movement of vessel **11**. To insure that the drilling rig **13** is maintained in a relatively vertical position during movement of vessel **11** under the influence of the sea **32**, means are provided for sensing the movement of vessel **11** and in response to such movement actuating hydraulic means for maintaining drilling rig **13** in the relatively vertical position. Specifically, disposed between base **23** and deck **12** are a plurality of hydraulic cylinder-rod assemblies **33–36**. Hydraulic cylinder-rod assembly **33** is attached to base **23** at approximately the midpoint of edge **37** and cylinder and rod assembly **34** is attached to base **23** at the midpoint of its opposite edge **38**. As illustrated in FIGURE 3, cylinder and rod assembly **35** is attached to base **23** proximate the midpoint of edge **39** and cylinder and rod assembly **36** is attached to base **23** proximate the midpoint of edge **41**. The cylinder portions of each of hydraulic cylinder and rod assemblies **33–36** is attached by a pin **42** to a clevis **43** which is in turn secured to deck **12** of vessel **11**. Pins **42** and clevis **43** permit pivotal movement of hydraulic cylinder and rod assemblies **33–36** relative to deck **12**.

The hydraulic cylinder and rod assemblies **33–36** are actuated by means illustrated in FIGURE 6. With reference to FIGURE 6, means are provided for sensing the roll and pitch of vessel **11**, and take the form of a roll sensor **42** and a pitch sensor **43**. Roll sensor **42** and pitch sensor **43** preferably comprise conventional gyroscopes which are powered by a power source **44** through electrical conductors **45** and **46**, respectively. When, under the influence of sea **32**, vessel **11** rolls, as illustrated in FIGURE 2, roll sensor **42** will send a signal through either conductor **47** or conductor **48**, depending upon the direction of the roll, to solenoids **49** and **51**, respectively. Solenoids **49** and **51** control movement of four-way valve **54**, which in the relaxed position is centered by springs **52** and **53**. Valve **54** is interposed between a variable displacement hydraulic pump **55** and cylinder and rod assemblies **33** and **34**. Variable displacement pump **55** communicates through conduit **56** with four-way valve **54**, and depending upon the position of valve **54**, communicates with cylinder and rod assembly **33** through conduit **57** and with cylinder and rod assembly **34** through conduit **58**. Pitch sensor **43**, upon sensing pitch of vessel **11**, will send a signal through either conductor **59** or conductor **61**, depending upon the direction of the pitch, to solenoids **62** and **63**, respectively. Solenoids **62** and **63** control four-way valve **64** which in a relaxed position is centered by springs **65** and **66**. Four-way valve **64** is interposed between variable displacement pump **55** and cylinder and rod assemblies **35** and **36**. Specifically, variable displacement pump **55** will communicate through conduits **56** and **67** with either cylinder and rod assembly **35** through conduit **68** or cylinder and rod assembly **36** through conduit **69**, depending upon the position of four-way valve **64**.

Roll sensor **42**, upon roll of the vessel **11**, sends a signal through conductor **71** to servo-amplifier **72**, which signal is proportional to the degree of roll. Likewise, pitch sensor **43** sends a signal to servo-amplifier **72** through a conductor **73**, which signal is also proportional to the degree of pitch of vessel **11**. Servo-amplifier **72**, in response to signals through conductors **71** and **73** sends a signal through conductor **74** to servo **75** which through conductor **76** controls the output or variable displacement pump **55**. Specifically, the greater the degree of pitch and/or roll, the greater will be the output of pump **55**.

Each of the cylinder and rod assemblies **33** and **34** is adapted to discharge hydraulic fluid through conduits **57** and **58**, respectively, and four-way valve **54**, into conduit **77** which discharges it into an atmospheric fluid tank **78**. Similarly, cylinder and rod assemblies **35** and **36** discharge fluid through conduits **68** and **69** and four-way valve **64** into conduit **79** which discharges into an atmospheric storage tank **81**. Storage tanks **78** and **81** may conveniently communicate through conduits (not illustrated) with atmospheric tank **82** from which variable displacement pump **55** derives its hydraulic fluid through conduit **83**.

Means are also provided for compensating for vertical movement of vessel **11** under the influence of sea **32**. One embodiment of such means is illustrated in FIGURE 7, to which reference is here made. In FIGURE 7, hydraulic cylinders **18** and **19** receive a continuous charge of hydraulic fluid from constant displacement hydraulic pump **84** through conduits **85** and **86**, respectively. The fluid introduced through conduits **85** and **86** will pass through cylinders **18** and **19** and be discharged through conduits **87** and **88**, respectively, where they pass through a valve **89** interposed in conduit **91**. Conduit **91** discharges into an atmospheric storage tank **92** which through conduits (not illustrated) may communicate with the atmospheric storage tank **93** from which pump **84** derives its charge through conduit **94**.

Operation of valve **89** may be controlled by an accelerometer controller **93** or a weight controller **94**. Control of valve **89** by accelerometer controller **93** may be effected by closing switch **95** in conductor **96** to permit a signal from accelerometer controller **93** to control solenoid **97**, which in turn controls valve **89** through conductor **98**. Alternatively, weight controller **94** may be used to control the amount of hydraulic fluid circulated to cylinders **18** and **19**. Specifically, transducer **99** in communication with conduit **85** through conduit **101**, will, in response to pressure in conduit **101**, send an electrical signal through conductor **102** to weight controller **94**. Weight controller **94** compares the signal or voltage from transducer **99** with a programmed signal or voltage, and if a variation exists, sends a signal through switch **103**, when closed. The signal passing through switch **103** communicates through conductor **96** with solenoid **97** for controlling valve **89** through conduit **98**. Drilling rig **13** may be mounted on vessel **11** by a universal joint-type connection rather than the gimbals arrangement illustrated in FIGURES 1, 2 and 3. For example, and with reference to FIGURE 4, rig **13** has base **23** thereof attached to cradle **104** by bolts **109** or the like. The cradle **104** receives a pin **105** therethrough. Pin **105** is integral with the periphery of an annular collar **106**, as illustrated in FIGURE 5. Pin **105** also passes through a cradle **107** attached to deck **12** of vessel **11** by any suitable means, such as bolts **108**.

Collar **106** is provided with a pin **111** diametrically opposed to pin **105**. Pin **111** is rotatably carried within a cradle **112** attached to deck **12** of vessel **11** by suitable means such as bolts **108**. The end of pin **111** is also rotatably carried within a crandle attached to base **23** of drilling rig **11**, in the same manner that crandle **104** is attached, as illustrated in FIGURE 4. Collar **106** includes another set of diametrically opposed pins **113** and **114** which are received within crandles **115** and **116** attached to deck **12** of vessel **11** by bolts **108**. Intermediate the edges of base **23** are disposed hydraulic cylinder and rod assemblies **33–36** in the same manner described in connection with the embodiment illustrated in FIGURE 1. Also, the hydraulic circuitry illustrated in FIGURES 6 and 7 is used with the embodiment illustrated in FIGURE 4.

In operation, when the vessel **11** rolls to the port side, as illustrated in FIGURE 2, roll sensor **42** senses the roll motion and transmits a signal through conductor **48** to actuate solenoid **51** thereby moving four-way valve **54** to admit hydraulic fluid from variable displacement pump **55** into cylinder and rod assembly **33** to extend rod **33a**. Simultaneously, actuation of four-way valve will permit discharge of hydraulic fluid from cylinder and rod assembly **34** through conduit **58** and four-way valve **54** into tank **78** through conduit **77**. Thus, rolling movement of the vessel to the port side will be compensated for by admitting fluid to cylinder and rod assembly **33** and withdrawing fluid from cylinder and rod assembly **34**. Conversely, if the vessel **11** rolls to the starboard side, roll sensor **42** transmits a signal through conductor **47** to actuate solenoid **49** which in turn drives four-way valve **54** to admit fluid from pump **55** into cylinder and rod assembly **34** through conduit **58** for extending rod **34a**. Simultaneously, fluid from cylinder and rod assembly **33** will be permitted to discharge through four-way valve **54** and conduit **77** into tank **78**. Roll sensor **42**, in addition to transmitting a signal through either conductor **47** or **48**, transmits a signal through conductor **71** to servo-amplifier **72**. The signal to servo-amplifier **72** is proportional to the degree of roll of vessel **11** from the horizontal, and servo-amplifier **72** through servo **75** will control the rate at which variable displacement pump **55** discharges hydraulic fluid into either cylinder and rod assembly **33** or cylinder and rod assembly **34**.

If the bow of the vessel moves downward, e.g. the vessel pitches forward, pitch sensor **43** will send a signal through conductor **61** to actuate solenoid **63**. Solenoid **63** moves four-way valve **64** to admit hydraulic fluid from variable displacement pump **55** through conduit **68** into cylinder and rod assembly **35** to extend rod **35a**. Actuation of four-way valve **64** by solenoid **63** also opens conduit **69** through to conduit **79** to permit discharge of hydraulic fluid from cylinder and rod assembly **36** into tank **81**. Conversely, if the vessel pitches in the reverse direction, i.e. the bow moves upward, pitch sensor **43** transmits a signal through conductor **59** to actuate solenoid **62**. Solenoid **62** moves four-way valve **64** to permit fluid to flow from variable displacement pump **55** through four-way valve **64** and conduit **69** into cylinder and rod assembly **36** to extend rod **36a**. Actuation of four-way valve by solenoid **62** also permits fluid to flow from cylinder and rod assembly **35** through conduit **68** and four-way valve **64** into tank **81**.

A combination of pitch and roll will result in actuation of both roll sensor **42** and pitch sensor **43** causing simultaneous actuation of four-way valves **54** and **64** to compensate for the simultaneous pitching and rolling of vessel **11**.

With the embodiment illustrated in FIGURES 1–3, compensation for pitching and rolling movement of vessel **11** is permitted by the gimbal connection between drilling rig **13** and vessel **11**. Specially, semi-spherical shell **24** is moveably accommodated with the partitions **26** so that cylinder and rod assemblies **33–36** may freely move rig **13** relative to vessel **11**.

The embodiment of FIGURE 4 is similarly freely mounted to permit pitching and rolling of vessel **11** relative to rig **13**. In the instance of FIGURE 4, the universal joint-type arrangement permitted by various cradles and collar **106** permits compensation by cylinder and rod assemblies **33–36** for the vessel movement.

The embodiments illustrated also permit compensation for vertical movement of vessel **11**. In particular, if vessel **11** is being used to conduct a drilling operation, switch **103** is closed and switch **95** opened. Thus, the weight to be applied to the drill bit used in the drilling operation may be applied by adjustment of weight controller **94**. Once a weight is selected, that weight may be maintained by use of weight controller **94**. Specifically, if vessel **11** moves upward, greater weight will be placed upon rods **21** and **22** and concomitantly the pressure of hydraulic fluid flowing through cylinders **18** and **19** from constant displacement pump **84** will be increased. The increase in fluid pressure will be sensed by transducer **99** through conduit **101**. Transducer **99** transmits a signal through conductor **102** to weight controller **94** which is proportional to the pressure in conduit **101**. An increase in the voltage of the signal through conductor **102** will be sensed by weight controller **94**. Weight controller **94** in response to the increased voltage signal will actuate solenoid **97** to further open valve **89** thereby increasing fluid flow therethrough. Increased fluid flow through valve **89** will permit rods **21** and **22** to move downward thus compensating for the upward vertical movement of vessel **11**. Conversely, a decrease in pressure sensed by transducer **99** will lower the voltage of the signal through conductor **102**. Weight controller **94**, upon sensing the decrease in voltage below the desired level, will transmit a signal through switch **103** and conductor **96** into solenoid **97** to slightly close valve **89** thus retaining more fluid from constant displacement pump **84** within cylinders **18** and **19** to compensate for the movement of vessel **11**. Flow from pump **84** through cylinders **18** and **19** is continuous, and thus only slight movement of valves **89** will effect either upward or downward movement of rods **21** and **22**.

In instances where the weight carried by drill string **26** will not appreciably vary, but where vertical movement of vessel **11** can be critical, accelerometer controller **93** may be utilized. For example, in placing a wellhead assembly or a blow-out preventer on the conductor pipe or wellhead at or near the ocean floor, it is necessary to gently position the equipment on the bottom to prevent damage to the equipment or minimize the possibility of injury to personnel who may be working on the bottom to connect the equipment. In these instances, the weight suspended from drill string **26** will not vary appreciably upon vertical movement of vessel **11**. Thus, accelerometer controller **93** which senses vertical acceleration of the vessel **11** will be placed into operation by opening switch **103** and closing switch **95**. Either upward or downward acceleration of vessel **11** will result in signal generation from accelerometer controller **93** which signal will be transmitted through conductor **96** to solenoid **97** for actuation of valve **89**. For example, acceleration of vessel **11** upwardly will result in a signal transmission through conductor **96** which will through solenoid **97** open valve **89** to permit rods **21** and **22** to move downward under the influence of the weight of drill string **26**, and downward acceleration of vessel **11** will generate a signal of the opposite polarity causing solenoid **97** to close valve **89** resultıg in upward movement of rods **21** and **22**. With the mbodiments of the invention illustrated in FIGURES –7, it is possible to compensate for pitching and rolling s well as vertical movement of vessel **11** thereby mainaining drilling rig **13** in a vertical position relatively unffected by movements caused by turbulence of the sea **32**. Iowever, none of the sensing and stabilizing means will ıterfere with the use of drill head **16** while making hole r making a trip. Thus, while drill head **16** will be in verical motion while making hole or making a trip, the deıred vertical motion will not be affected by vertical ıovement of the vessel **11**.

Various sensing and stabilizing means may be emloyed. While gyroscopes are preferred for roll and pitch ensors, accelerometers could be substituted. Also, a lumb operated rheostat could be employed. Further, the ansducer used to sense hydraulic pressure changes durıg vertical movement of the rig could be replaced by a rain gauge or the like. Also while hydraulic stabilizing ıeans are illustrated and described, electrical stabilizing ıeans could be utilized. While two hydraulic pumps are lustrated, only one pump either of the constant or varible displacement type may be used if desired.

Additional stabilizing means may be used in combinaon with the sensing and stabilizing means of the present ıvention to prevent horizontal movement of the vessel, desired.

After a reading of the above, it will be noted that the ıvention may be equally useful for stabilizing a floating rane. Specifically, the mast of the illustrated embodiıents may incorporate a crane structure for use in transerring articles between the vessel and another surface ıch as a dock or offshore drilling platform. Since the ıast or crane would be stabilized during pitching, rolling nd vertical movement of the vessel, loads could be asily transferred between the vessel and an adjacent ırface without fear of damaging the transferred object ue to its collision with the surface or another object hen the vessel is moved by action of the sea.

While rather specific terms have been used to describe arious embodiments of the invention, they are not inended, nor should they be construed, as limitations upon ıe invention as defined by the following claims.

What is claimed is:

1. In an offshore apparatus including a vessel which ıpports a mast, the improvement comprising:

means for mounting said mast to said vessel so that said vessel can pitch and roll relative to said mast;

first sensing means for sensing the roll of said vessel and generating an output signal when said vessel rolls relative to a desired level position;

first stabilizing means responsive to the signal from said first sensing means for maintaining said mast in a vertical position during rolling movement of said vessel;

second sensing means for sensing the pitch of said vessel and generating an output signal when said vessel pitches relative to a desired level position; and

second stabilizing means responsive to the signal from said second sensing means for maintaining said mast in a vertical position during pitching movement of said vessel.

2. The apparatus of claim **1** wherein said mast is dapted to support a body therefrom and means are proided for raising and lowering said body relative to said ıast, and said apparatus includes:

third sensing means responsive to vertical movement of said vessel for generating a signal upon vertical movement of said vessel from a desired elevation; and

third stabilizing means responsive to the signal from said third sensing means for maintaining a body suspended from said mast in a predetermined vertical position upon vertical movement of said vessel.

3. The apparatus of claim **1**, wherein said means for mounting said mast to said vessel includes:

a gimbals connection between said mass and said vessel.

4. The apparatus of claim **1**, wherein said first sensing and first stabilizing means comprises:

a first gyroscope assembly adapted to transmit a first signal upon roll of the vessel in one direction and a second signal upon roll of the vessel in the opposite direction;

a first hydraulic cylinder and rod assembly positioned to one side of the longitudinal axis of said vessel with one end attached to said mast and the other end attached to said vessel;

a second hydraulic cylinder and rod assembly positioned to the opposite side of the longitudinal axis of said vessel with one end attached to said vessel and the other end attached to said mast;

first pump means for supplying hydraulic fluid to said first and second hydraulic cylinder and rod assemblies; and

first valve means interposed between said pump means and said first and second hydraulic cylinder and rod assemblies and in communication with said first gyroscope, said first valve means being responsive to said first and second signals from said first gyroscope means to control fluid flow from said first pump means to said first and second cylinder and rod assemblies for maintaining said mast in a vertical posiiton during rolling movement of said vessel.

5. The apparatus of claim **4**, wherein said second sensing and second stabilizing means comprises:

a second gyroscope assembly adapted to transmit a first signal upon pitch of the vessel in one direction and a second signal upon pitch of the vessel in the opposite direction;

a third hydraulic cylinder and rod assembly positioned along the longitudinal axis of said vessel to one side of the centerline of said mast with one end attached to said vessel and the other end attached to said mast;

a fourth hydraulic cylinder and rod assembly positioned along the longitudinal axis of said vessel to the opposite side of the centerline of said mast with one end attached to said vessel and the other end attached to said mast; and

second valve means interposed between said first pump means and said third and fourth cylinder and rod assemblies and in communication with said second gyroscope, said second valve means being responsive to said first and second signals from said second gyroscope assembly to control flow from said first pump mean to said third and fourth cylinder and rod assemblies for maintaining said mast in a vertical position during pitching movement of said vessel.

6. The device of claim **5** wherein said mast includes at least one hydraulic cylinder and rod assembly, pump means for supplying hydraulic fluid under pressure to said mast cylinder and rod assembly for raising and lowering of a body suspended from said mast, and [said third sensing and third stabilizing means comprises] *also includes:*

a transducer in communication with the hydraulic fluid in said mast cylinder and rod assembly and adapted to transmit a signal proportional to the pressure therein;

a weight controller adapted to compare the signal from said transducer with a predetermined standard and transmit a signal proportional in sign and magnitude to the disparity between the signal from said transducer and the predetermined standard; and

valve means interposed between said hydraulic pump and said mast cylinder and rod assembly and responsive to the signal from said weight controller to control the amount of the fluid introduced into said mast cylinder and rod assembly and thereby maintain said body at a predetermined position during vertical movement of said vessel.

[7. The device of claim 1, wherein said third sensing means comprises an accelerometer.]

8. The apparatus of claim **1**, wherein said means for mounting said mast to said vessel comprises:

a universal joint having:

a yoke with four pins equally spaced about its outer periphery and an aperture through the center thereof through which a body may be suspended;

a first pair of cradles which are attached to said mast and rotatably receiving therethrough a pair of oppositely spaced yoke pins, and

second pair of cradles which are attached to said vessel and rotatably receiving therethrough the remaining oppositely spaced yoke pins.

9. The apparatus of claim **8**, wherein said first sensing and first stabilizing means comprises:

a first gyroscope assembly adapted to transmit a first signal upon roll of the vessel in one direction and a second signal upon roll of the vessel in the opposite direction;

a first hydraulic cylinder and rod assembly positioned to one side of the longitudinal axis of said vessel with one end attached to said mast and the other end attached to said vessel;

a second hydraulic cylinder and rod assembly positioned to the opposite side of the longitudinal axis of said vessel with one end attached to said vessel and the other end attached to said mast;

first pump means for supplying hydraulic fluid to said first and second hydraulic cylinder and rod assemblies; and

first valve means interposed between said pump means and said first and second hydraulic cylinder and rod assemblies and in communication with said first gyroscope, said first valve means being responsive to said first and second signals from said first gyroscope means to control fluid flow from said first pump means to said first and second cylinder and rod assemblies for maintaining said mast in a vertical position during rolling movement of said vessel.

10. The apparatus of claim **9**, wherein said second sensing and second stabilizing means comprises:

a second gyroscope assembly adapted to transmit a first signal upon pitch of the vessel in one direction and a second signal upon pitch of the vessel in the opposite direction;

a third hydraulic cylinder and rod assembly positioned along the longitudinal axis of said vessel to one side of the centerline of said mast with one end attached to said vessel and the other end attached to said mast;

a fourth hydraulic cylinder and rod assembly positioned along the longitudinal axis of said vessel to the opposite side of the centerline of said mast with one end attached to said vessel and the other end attached to said mast; and

second valve means interposed between said first pump means and said third and fourth cylinder and rod assemblies and in communication with said second gyroscope, said second valve means being responsive to said first and second signals from said second gyroscope assembly to control flow from said first pump means to said third and fourth cylinder and rod assemblies for maintaining said mast in a vertical position during pitching movement of said vessel.

11. The device of claim **10**, wherein said mast includes at least one hydraulic cylinder and rod assembly, pump

means for supplying hydraulic fluid under pressure to said mast cylinder and rod assembly for raising and lowering of a body suspended from said mast, and [said third sensing and third stabilizing means comprises] *also includes:*

a transducer in communication with the hydraulic fluid in said mast cylinder and rod assembly and adapted to transmit a signal proportional to the pressure therein;

a weight controller adapted to compare the signal from said transducer with a predetermined standard and transmit a signal proportional in sign and magnitude to the disparity between the signal from said transducer and the predetermined standard; and

valve means interposed between said hydraulic pump and said mast cylinder and rod assembly and responsive to the signal from said weight controller to control the amount of fluid introduced into said mast cylinder and rod assembly and thereby maintain said body at a predetermined position during vertical movement of said vessel.

12. In an apparatus for maintaining a body suspended from a floating vessel in a relatively stationary position during vertical movement of the vessel by interposing a hydraulic ram and cylinder assembly between the body and the vessel, one of the members of said assembly being supportable in a fixed position relative to said vessel and the other member of said assembly being fixed relative to said body, an improvement which comprises:

means for supplying a hydraulic fluid under pressure to said hydraulic cylinder and ram assembly;

transducer means for sensing the weight being supported by said hydraulic cylinder and ram assembly and adapted to transmit a signal proportional thereto;

a weight controller adapted to compare the signal from said transducer means with a predetermined standard and transmit a signal proportional to the disparity between the signal from said transducer means and said predetermined standard; and

means responsive to the signal from said weight controller for controlling the amount of fluid introduced into and withdrawn from said cylinder and ram assembly for maintaining said body at a predetermined position during vertical movement of said vessel.

13. The apparatus of claim 12, wherein said means for controlling the fluid introduced into and withdrawn from said cylinder and ram assembly comprises: valve means interposed between said hydraulic pump and said cylinder and ram assembly, said valve means being responsive to said signal from said weight controller.

14. The apparatus of claim 12, wherein the means for sensing the weight comprises: a transducer in communication with the hydraulic fluid in said cylinder and ram assembly.

References Cited

The following references, cited by the Examiner, are of record in the patented file of this patent or the original patent.

UNITED STATES PATENTS

2,497,065	2/1950	Braddon	114—191
3,177,954	4/1965	Rand	175—7
3,158,208	11/1964	Kammerer	175—27
3,208,728	9/1965	Parks	175—27
3,372,584	3/1968	Jageler	175—7 UX
3,421,581	1/1969	Van Geijn	175—7 X

TRYGVE M. BLIX, Primary Examiner

U.S. Cl. X.R.

175—7