April 11, 1967 W. R. POSTLEWAITE ET AL 3,313,358

CONDUCTOR CASING FOR OFFSHORE DRILLING AND WELL COMPLETION

Filed April 1, 1964 5 Sheets-Sheet 1

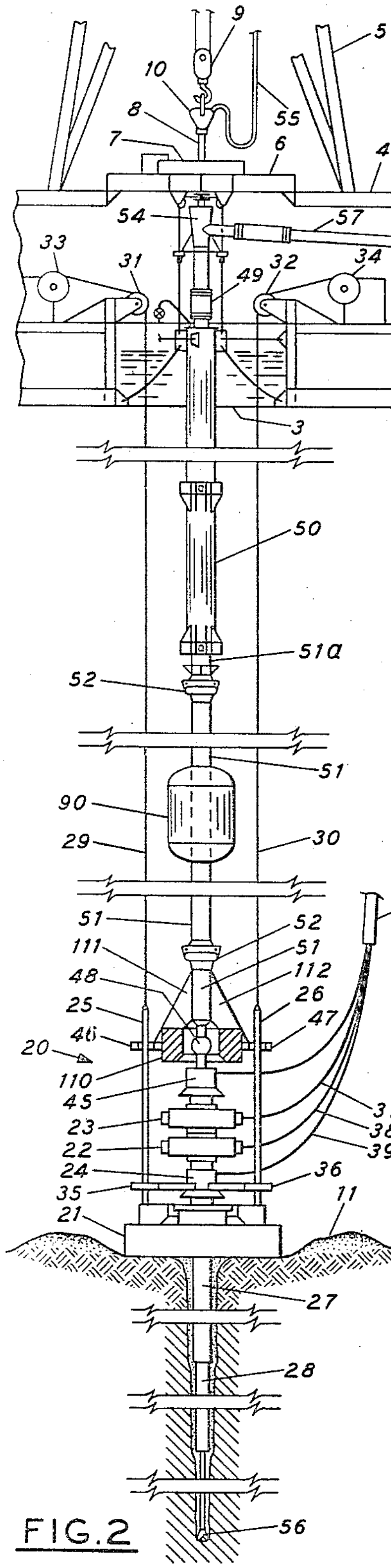

FIG.2

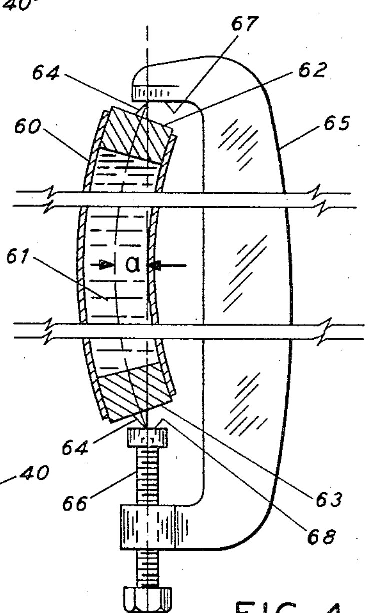

FIG.4

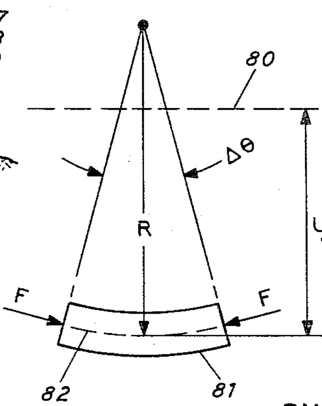

FIG.3

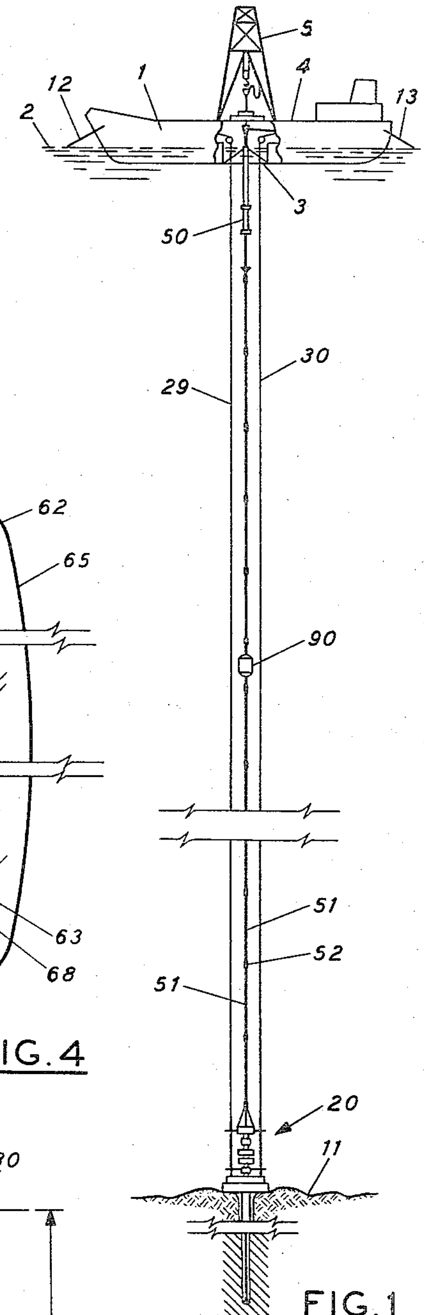

FIG.1

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CONDUCTOR CASING FOR OFFSHORE DRILLING AND WELL COMPLETION

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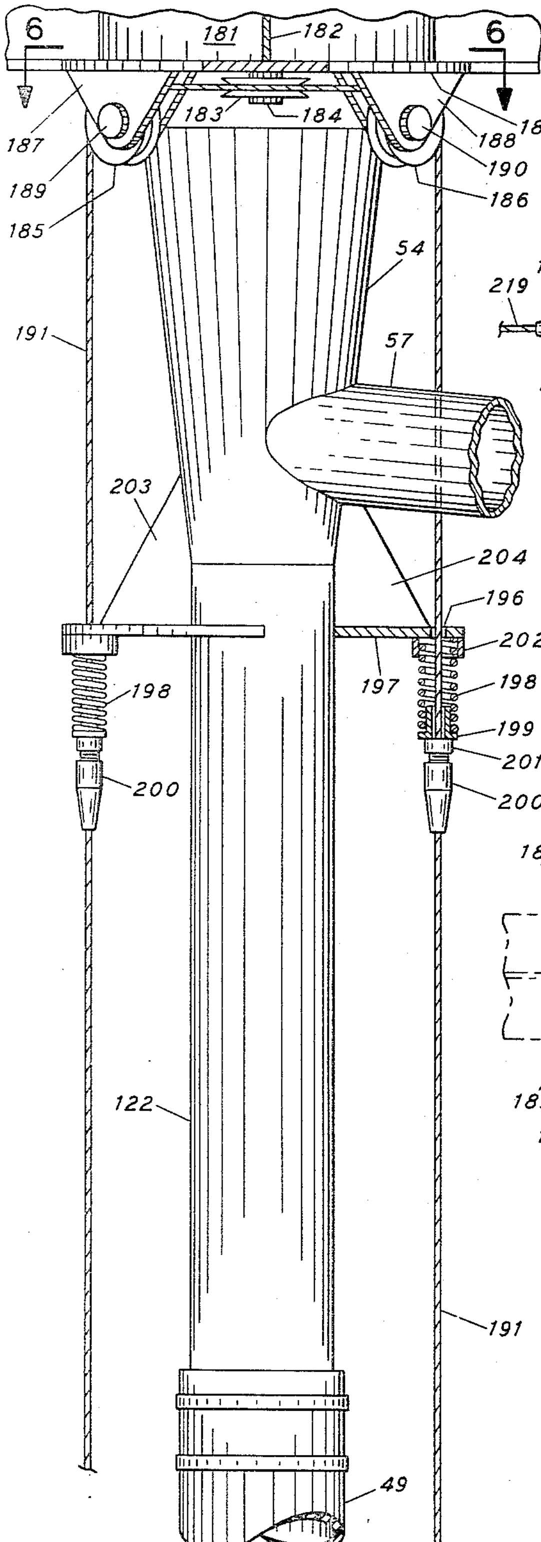

FIG. 5

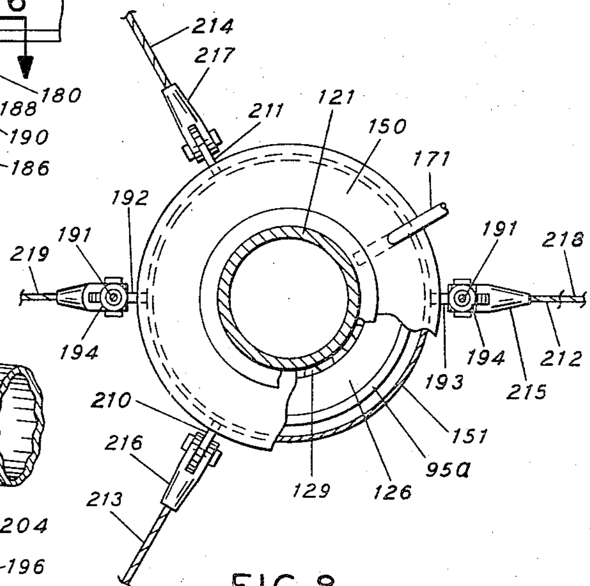

FIG. 8

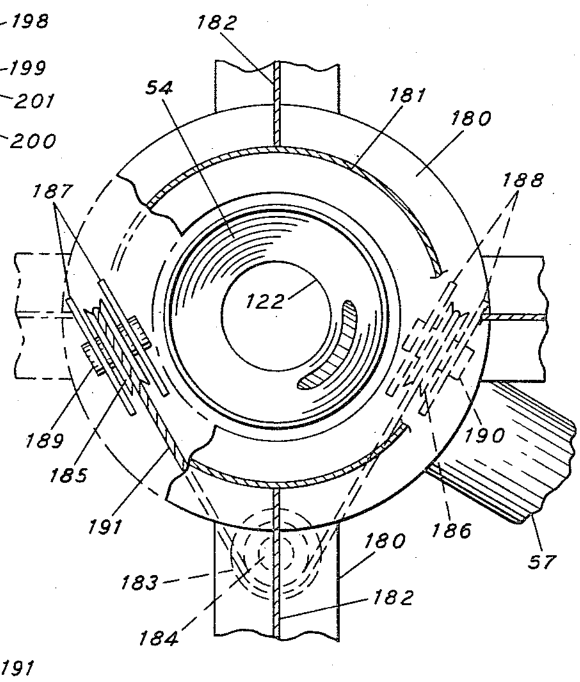

FIG. 6

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CONDUCTOR CASING FOR OFFSHORE DRILLING AND WELL COMPLETION

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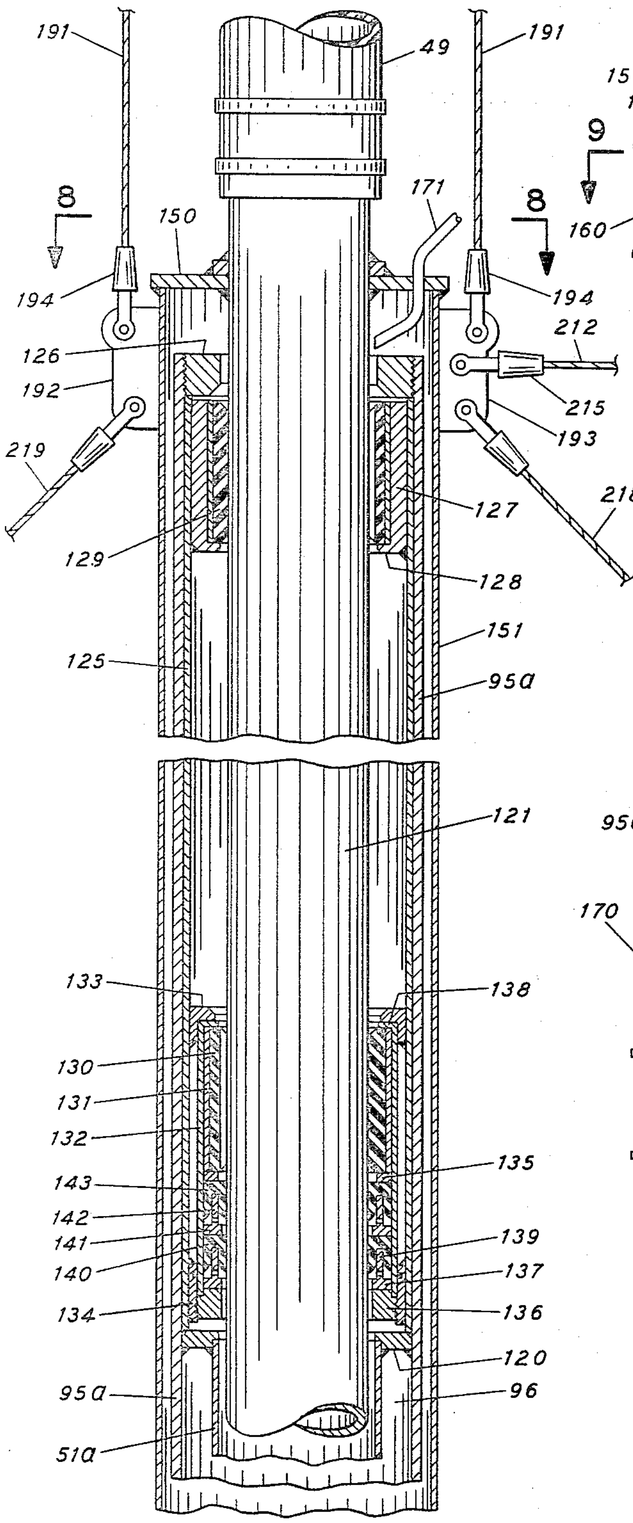

FIG. 7A

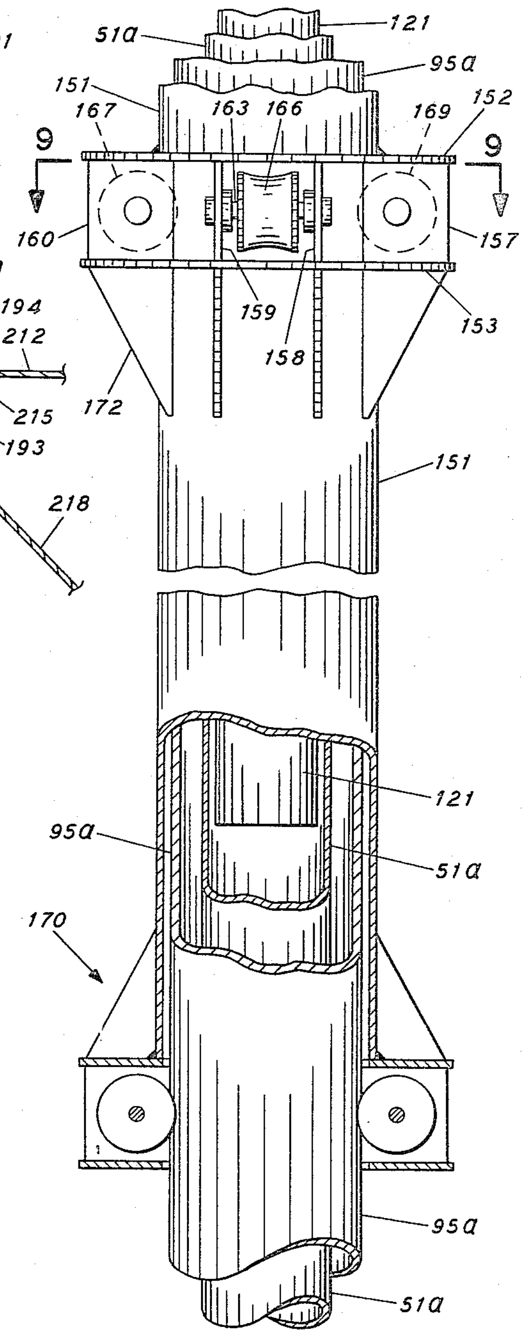

FIG. 7B

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CONDUCTOR CASING FOR OFFSHORE DRILLING AND WELL COMPLETION

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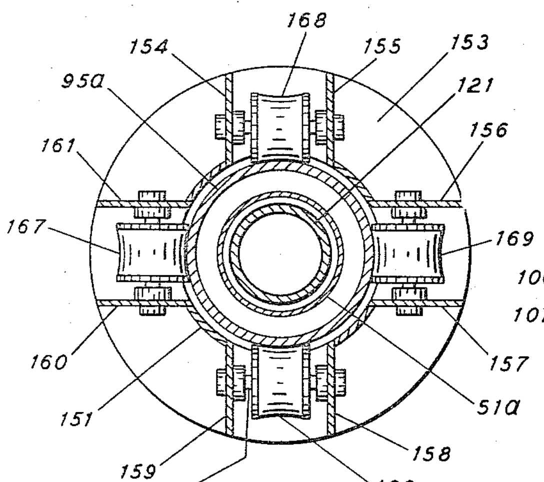

FIG.9

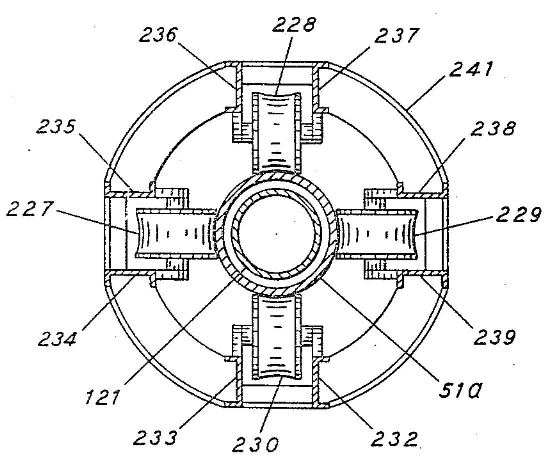

FIG.12

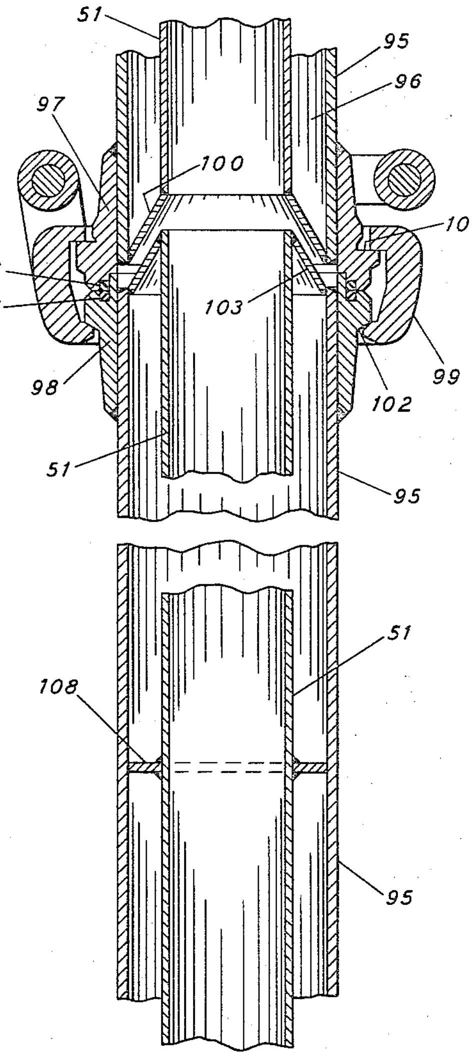

FIG.10

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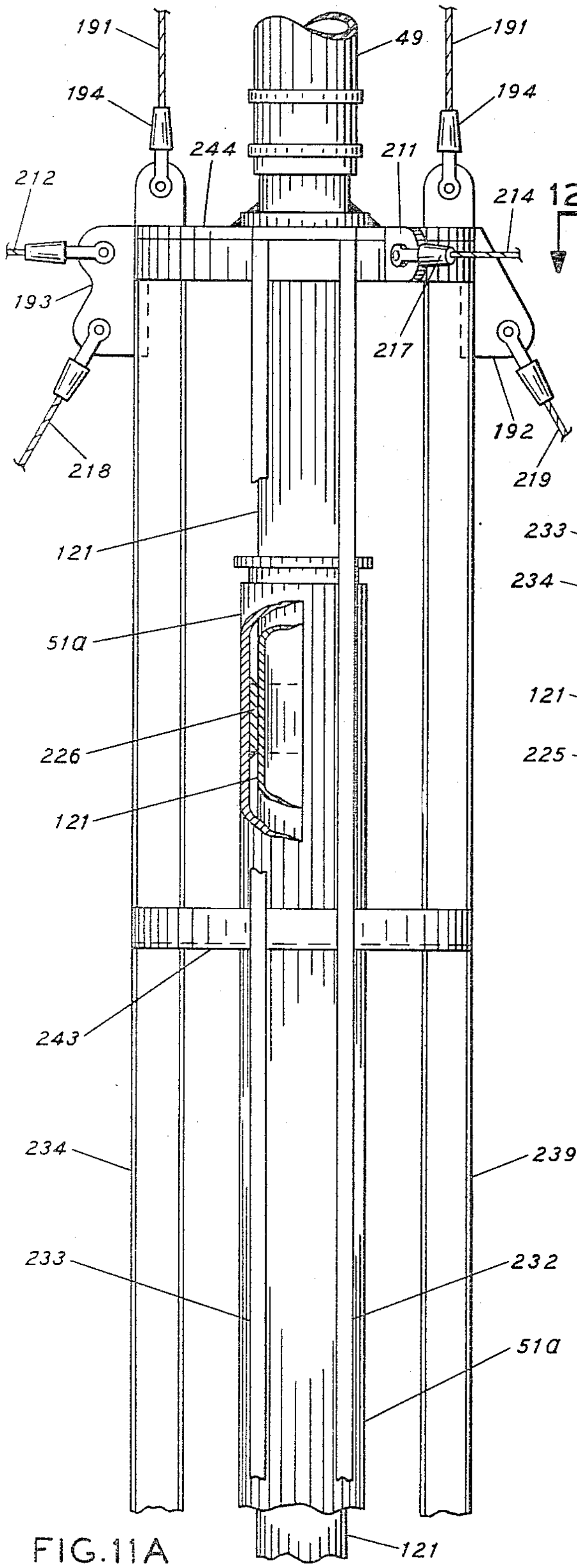

FIG. 11A

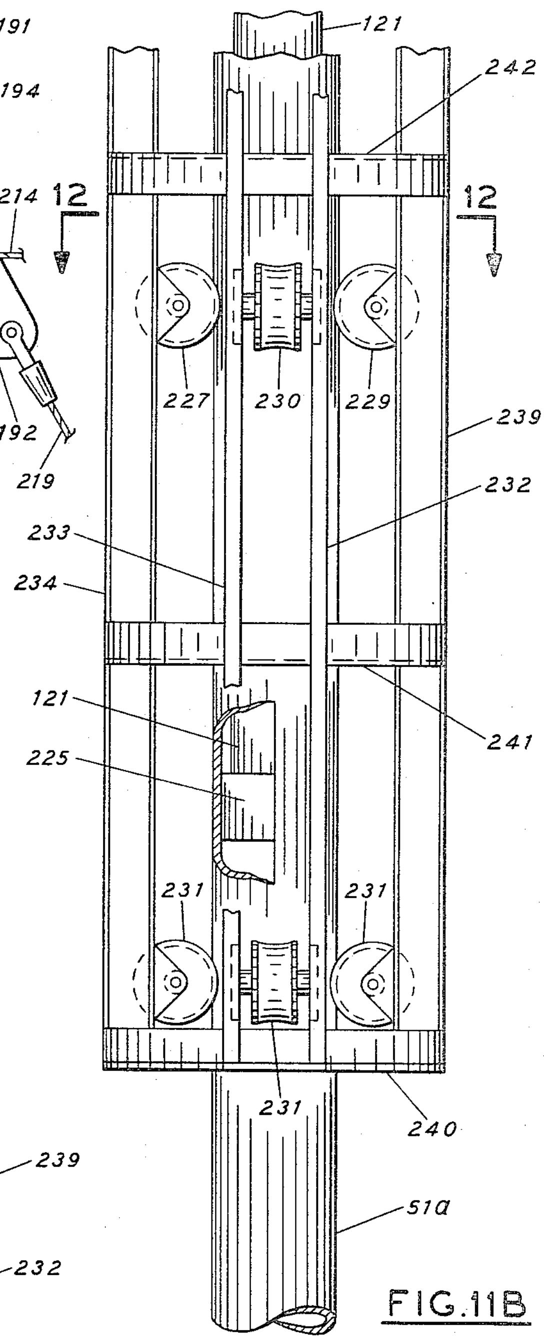

FIG. 11B

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United States Patent Office

3,313,358

Patented Apr. 11, 1967

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3,313,358

CONDUCTOR CASING FOR OFFSHORE DRILLING AND WELL COMPLETION

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Filed Apr. 1, 1964, Ser. No. 356,461
5 Claims. (Cl. 175—7)

This invention relates to drilling in earth formations located beneath a body of water, particularly deep, open water such as an ocean. More specifically, this invention relates to a method and apparatus for preventing bending and buckling of a drilling fluid conductor casing in offshore drilling and well completion, which casing extends from the ocean floor to a drilling platform at the ocean surface.

In recent years it has become desirable in some circumstances to conduct offshore drilling operations from a floating vessel rather than from a rigid structure or a platform support from the ocean bottom. In such operations the floating vessel is sometimes connected to the well bore in the submerged formation by a long tubular member through which drilling and well working tools, drilling fluid, etc., pass between the vessel and the well bore. This long tubular member will hereinafter be called a conductor casing or riser.

In one procedure for offshore drilling the lower end of the conductor casing is connected to a wellhead, which includes blowout preventors and control equipment, while the upper end of the casing is connected to the drilling vessel. The wellhead is designed to remain stationary on the ocean floor. The drilling vessel, on the other hand, is continuously moving under the action of tides, currents, waves and wind. Movement of the vessel is somewhat restricted by anchoring and by special positioning systems. But, the violent and constantly changing forces acting on the vessel often shift it from its position over the well bore by lateral distances in excess of four percent of the water depth. Experience has shown that vertical heaving movements of up to 25 feet at velocities of three to four feet per second can also be expected in addition to the relatively slower vertical movement effected by tides. One accepted method of allowing for the relative lateral and vertical movement between the vessel and the wellhead is to place laterally flexible joints and telescopic joints in the conductor casing. This permits the conductor casing to accommodate the movement of the vessel within design limits.

As drilling operations were carried on in deeper water, it was found that the conductor casing itself tended to deflect or bend along its length between the flexible joints. This bending has often been so great that structural failure of the conductor casing column has resulted. Even when failure does not occur, bending is undesirable if it results in a sharp angle in the casing at any point along its length, thereby causing difficulty in passing drill pipe, well casing, etc. This problem is particularly acute where the flexible or universal joint must be included in the casing near its lower end to allow for vessel movement. Since bending moments are not transmitted through such a joint, any bending of the conductor casing tends to create a sharp angle at this joint. When using a ball and socket joint, for example, an angle greater than five degrees at the joint makes it very difficult to pass the drill string through the joint. The tendency toward angularity at the lower universal joint is accentuated by vessel movement laterally from its position over the wellhead.

In analyzing the causes of the extreme lateral deflection of the conductor casing, it is appropriate to consider the casing as a long tubular column. When drilling in deep water the length of this column becomes so great as compared to the moment of inertia of its cross sectional area that the casing has virtually no column stiffness. Thus any axial compression or lateral forces will cause severe deflection or bending of the conductor casing.

If the conductor casing is supported solely at its lower end, its own effective weight, i.e., weight in water, causes it to be in axial compression, increasing from zero at the top to a maximum at the bottom support. When drilling in deep water the compressive stress in the casing wall from this source alone is sufficient to buckle the casing. Friction in the telescopic joint as the vessel moves vertically toward the ocean bottom as well as drilling or well working tools which may bind on and be supported by the conductor casing as they are passed through it add compressive stress to the conductor casing wall and thereby increase the deflection of the casing.

In addition to the buckling effect of the above-mentioned axial compressive forces which create net compressive stress in the casing wall, current and wave forces acting transversely along the length of the conductor casing tend to bend it. Although wave forces decrease exponentially with depth below the surface, recent submarine measurements have shown that they extend deep enough to be a substantial factor in bending the conductor casing. Also strong current forces have been found at substantial depths. For convenience in discussion these current and wave forces will be called environmental forces. It should be noted that since they act generally transverse to the conductor casing length they do not create a net axial compression in the casing wall at any cross-section but create a tensile force in one diametrical half of the section which is equal and opposite to the compressive force in the other half.

The types and magnitudes of the various forces, such as those discussed above, which create net axial compression in the casing wall as well as the environmental forces which act generally transverse to the casing length vary under different operating conditions. The prior art recognizes the existence of these forces and has sought to overcome their effect by applying enough axial tension to the conductor casing to compensate for the weight of it and to counteract the bending caused by the transverse environmental forces.

In water depths up to approximately 250 feet satisfactory results have usually been obtained by applying tension sufficient only to compensate for the types of forces discussed above. However, in greater depths buckling and excessive bending still occur when this method is employed. The offshore drilling industry has been unable to determine the cause of this and has suffered large financial losses as a result.

It has now been discovered that the buckling that has been repeatedly experienced with deep water risers is a result of the high density of the drilling fluid in the conductor casing. Although the difference in density between the drilling fluid and the surrounding sea water does not cause a net compressive force to be applied directly to the conductor casing, it has a buckling effect on the casing. The proof of this, both analytical and experimental, will be discussed below in the detailed description of this invention.

It also will be proven that in long conductor casings transmitting dense drilling fluid, this effect may be compensated for by applying to the conductor casing, in addition to the tensile forces applied to compensate for axial compressive forces acting directly on the conductor casing and the transverse environmental forces as shown by the prior art, an extra tensile force in an amount calculated in accordance with formulas developed in this specification to compensate for the bending effect of the dense drilling fluid.

Several alternative arrangements of concentrated floats, elongated buoyant members, and a concentrated bottom end counterweight are provided for applying the desired tension. Two alternative types of telescopic joint and a cable and pulley arrangement for connecting the upper end of the conductor casing to the vessel are also provided. These serve also to reduce the direct compressive buckling forces transmitted from the moving vessel to the conductor casing.

The operation and advantages of the method and apparatus of this invention will be clear from the following detailed description. Throughout this description reference will be made to the accompanying drawings in which:

FIGURE 1 is an overall elevation view of apparatus of this invention in operating position.

FIGURE 2 is an enlarged view of portions of FIGURE 1.

FIGURE 3 is a schematic diagram showing the effect of axial compression on a column.

FIGURE 4 is a schematic illustration of the effect of axial compression on a fluid filled tubular column.

FIGURE 5 is an elevation view of the upper end of the conductor casing above the telescopic joint and its connection to the vessel.

FIGURE 6 is a sectional view along lines **6—6** of FIGURE 5.

FIGURE 7A is an elevation view of the upper portion of the telescopic joint of this invention with portions shown in section for clarity.

FIGURE 7B is a downward continuation of FIGURE 7A.

FIGURE 8 is a sectional view along line **8—8** of FIGURE 7A with portions removed for clarity.

FIGURE 9 is a sectional view along line **9—9** of FIGURE 7B.

FIGURE 10 is a vertical elevation in section through a portion of the conductor casing.

FIGURE 11A is an elevation view of the upper portion of a modified form of the telescopic joint of this invention, with portions removed for clarity.

FIGURE 11B is downward continuation of FIGURE 11A.

FIGURE 12 is a sectional view along line **12—12** of FIGURE 11B.

Referring to FIGURES 1 and 2, vessel **1** is floating on a body of water **2** such as an ocean. The vessel includes a vertical opening **3** through its hull near the longitudinal and transverse center of the vessel. Supported on the upper deck **4** of the vessel and approximately centered over the opening **3** is a derrick structure **5** from which the upper end of drill pipe **8** is supported by a traveling block **9** and swivel **10**. The derrick structure and much of the associated equipment are of a type commonly used in offshore rotary drilling and are not shown in detail. Approximately centered in the base of the derrick are a platform **6** and rotary table **7**. The drill pipe **8** passes vertically through aligned openings in the platform and rotary table and is rotated by the rotary table **7** in a standard manner. Anchors connected to anchor chains **12** and **13** limit the movement of the vessel from its normal position over the well.

A wellhead **20** is located on the submerged formation **11** in which the hole is being drilled. The wellhead includes a base **21**, and stacked blowout preventers **22** and **23** which are releasably connected to the base by coupling **24**. Several lengths of well casing **27** and **28** extend beneath the wellhead into the well. At least two guideposts **25** and **26** extend vertically from spaced points near the circumference of base **21**. Guide lines **29** and **30** extending from guideposts **25** and **26**, respectively, to the vessel **1** are used to guide equipment as it is lowered from the vessel to the wellhead. These guide lines extend upward through the opening **3** in the bottom of the vessel, over pulleys **31** and **32**, and are connected at their upper ends to constant tension winches **33** and **34** respectively. These winches maintain the guide lines taut in spite of relative movement between vessel **1** and wellhead **20**. Guide arms **35** and **36** extend outwardly from coupling **24** and include guide sleeves near their outer ends. After the base **21** with its guideposts **25** and **26** and guide lines **29** and **30** are in place, the blowout preventer assembly including coupling **24** may be lowered from the vessel with a guide line passing through each guide sleeve to position the assembly as shown. The coupling and blowout preventers are remotely actuable from the vessel by fluid under pressure from lines **37**, **38**, and **39** which extend to the vessel through tubing **40**.

With the wellhead in place on the ocean bottom the conductor casing may be lowered to connect the floating vessel to the wellhead. This conductor casing is releasably connected at its lower end to the wellhead by coupling **45** and is connected at its upper end to the vessel in a manner which will be described below. The heavy coupler **45** is pendant below the universal ball joint **48**. Guide arms **46** and **47** are aligned on the center of **48** so that the connection at coupler **45** is assured and is independent of the angularity of the conductor casing. The conductor casing includes a ball and socket joint **48** near its lower end and a flexible member **49** near its upper end to permit angular movement of the casing relative to vertical, and to reduce the torsional stress transmitted to the wellhead and to the upper connection of the casing at the vessel as the vessel shifts laterally from its position over the well under the action of wind, tides, waves, and currents. Below flexible member **49**, the conductor casing includes a telescopic joint **50** which permits axial elongation and shortening of the casing as the vessel moves laterally and vertically.

The major portion of the conductor casing consists of a series of elongated tubular conductor members **51** connected end to end by couplings **52** to extend from telescopic joint **50** to ball and socket joint **48**. The upper end of the conductor casing is flared out at **54** for receiving the drill pipe and other equipment which passes through the connector casing.

High density drilling fluid is fed to the well from a sump on the vessel. The drilling fluid passes through flexible hose **55**, down through a passageway in the axis of the drill pipe, and out bit **56** at the bottom of the well. The drilling fluid is returned to the sump by passing upwardly around the outside of the drill pipe through well casing **28** and **27**, through wellhead **20** and then upward through the conductor casing. The drilling fluid is returned to a sump through pipe **57** which is flexibly connected to the conductor casing near its upper end.

Axial forces applied to a confined liquid tend to deflect the confining pipe. Referring to the example in FIGURE 4 there is shown a longitudinal cross-section through a length of tubular steel pipe **60** filled with a liquid **61**. The pipe is extremely long in comparison with its diameter so that it acts as a long column with a large slenderness ratio. Portions of its length have been omitted for convenience in the drawings. The ends of the pipe **60** are sealed by slidable pistons **62** and **63** which are free to move axially along the pipe **60**. Each piston includes a pivot bearing **64** on its outer face. A clamp **65** including a screw member **66** is designed to exert pressure between stationary face **67** of the clamp and movable face **68** of the screw. The pressure is transmitted through the pistons **62** and **63** to the fluid **61**, which is substantially incompressible. Hence the effect is similar to placing end loading on a solid column. A sufficiently great force placed on bearing **64** by tightening of the screw **66** will cause the pipe **60** to buckle from its original straight position. The deflection of the pipe is indicated by the letter "*a*." It is apparent that as the slenderness ratio of the pipe **60** becomes greater, less force is required to buckle the pipe since it acts as a long column. Thus it can be seen that compressive force applied to a liquid confined in an elongated tubular member causes flexing and buckling of the tubular member in the same manner as compressive forces applied to a solid long column.

The above phenomenon has been repeatedly substantiated by actual instances of conductor casing failure where the effect of the drilling fluid was not accounted for. Also experiments have been conducted using a small scale model of a conductor casing. In these experiments a long steel tube of small diameter was supported only at its top (to remove any compressive stress from the weight of the tube itself) and filled with mercury. The weight of the mercury was supported by a plug at the bottom. The plug was slidable axially along the tube. Under these conditions the loading of the mercury imposed on the tube was similar to that of drilling fluid on a conductor casing. The deflection of the tube under such loading was completely consistent with the above analysis.

Practical application of the above analysis to a conductor casing in offshore drilling requires consideration of the conditions to which the conductor casing is subjected. As was pointed out above, the wave and current forces as well as the forces created by vessel movement are continuously varying within large parameters. While the magnitude of these forces may be calculated and determined experimentally, any such determination is necessarily only an approximation due to the naturally varying and complex nature of these forces. Therefore it is desirable to add a safety factor in the form of extra tension.

Another practical consideration is that in offshore drilling operations in deep water the conductor casing is extremely long in comparison with the moment of inertia of its cross-section so that it may be considered to have virtually no column stiffness. Thus, even in the absence of lateral environmental forces, it will not withstand any substantial net axial compressive force throughout a substantial portion of its length without undesirably large deflection and possible structural failure. While in the absence of lateral environmental forces, the conductor casing could theoretically withstand some axial compressive force over relatively short increments of its length, for practical purposes, and to insure safe operation, it is preferred to assume that the net axial compressive force must equal zero or preferably be negative, i.e., tensile rather than compressive, throughout the length of the conductor casing, and then to add an overpull, or additional tensile force, to limit the deflection from the environmental forces.

For convenience it may be preferable to express the net axial compressive force as it applies to conductor casings in offshore drilling as: the net axial compressive force acting on any transverse cross-section is equal to the weight in water of the column of drilling fluid above that section, plus the weight in water of the conductor casing column above that section, plus any other axial compressive forces applied directly to the conductor casing above that section. This relationship is based on the assumption that the pressure of the drilling fluid is zero at the top of the column and that its pressure increases linearly with depth in proportion to its weight. While not precisely true in all cases this form of the equation is generally adequate to arrive at a practical determination of the forces involved in a riser used for offshore drilling.

Still another force which may cause buckling of the conductor casing during drilling and well working operations is created by compressive stress incurred by material such as well casing which is being passed axially through the conductor casing. If the well casing becomes bound against the interior wall of the conductor casing so that the well casing weight is supported on the conductor casing, the compressive stress S in the conductor casing wall will be increased. If, instead, the well casing becomes supported from below, such as against the sides of the well bore, the well casing will develop compressive stress in its own walls. The well casing, if of great length,

will have virtually no column stiffness. Thus the transverse force of the buckled well casing will be imposed on the wall of the riser. A drill pipe in axial compression would have a similar effect. In order to design for the worst conditions which may be encountered, it is desirable to incorporate these forces in the design.

The generic relationship for the net axial compressive force may be conveniently stated as: the net axial compressive force tending to bend or buckle the conductor casing at any transverse cross section is equal to the algebraic sum of all the axial forces acting on the walls of the conductor casing at that section and all the axial forces acting on all materials within the conductor casing at that section minus the product of pressure of the sea water outside that section times the external area of the conductor casing.

As pointed out heretofore, it is undesirable to have a sharp angle at the ball joint located at the bottom of the conductor casing. As the vessel moves laterally from a position over the wellhead, the weight of the materials contained in the riser accentuates this angle because the weight develops a moment about the ball joint. This angle can be controlled by the amount of overpull added to the conductor casing.

The relationship between the amount of overpull and the angle at any point along the riser may be determined from

$$EI\frac{d^4y}{dx^4}=q+w\frac{dy}{dx}+F\frac{d^2y}{dx^2}$$

wherein

E=the modulus of elasticity for the conductor casing, in pounds per square inch,
I=the cross-sectional moment of inertia for the conductor casing in inches fourth,
x=the vertical distance from the bottom of the conductor casing in inches,
dx=an increment of x,
y=the lateral offset of the conductor casing from vertical in inches,
dy=an increment of y,
dy/dx=tangent of angle between the riser and the vertical,
q=the lateral load in pounds per inch of length,
w=the vertical component of the change of tension in pounds per inch of riser length,
F=the vertical component of net axial force.

Since the lateral movement of the vessel is small relative to the length of the conductor casing, the axial component of the vertical force F is substantially equal to the vertical force F and may be assumed to be the same.

As a specific example of application of the above analysis to a conductor casing, it will be assumed that operations are to be carried on in water 600 feet deep with a 13⅜" O.D. x ⅜" pipe as the conductor casing, and drilling fluid weighing 120 pounds per cubic foot being the only material in the casing.

The maximum force F will occur at the lower end of the conductor casing. It will be approximately equal to the weight in water of the entire conductor casing column (27,100 pounds), plus the weight in water of the entire volume of drilling fluid contained in the conductor casing (29,200 pounds), giving a total F of 56,300 pounds. Thus an upward force in excess of this amount is required.

If the operations are to be carried on from a floating vessel which will be displaced laterally from a position over the wellhead, for example, by twenty-four feet, and assuming normal current forces, the angle of the riser at the ball joint can be limited to five degrees by an overpull of 20,300 pounds. This overpull is an upward force in addition to the 56,300 pounds required to reduce F to zero. Further overpull can be added as a safety factor and/or to account for friction in the telescopic joint.

Having determined the magnitude of tensile stress to be applied to the casing in accordance with the procedure discussed above, tensile force may be applied to the conductor casing in any of several manners. For example an upward force can be applied through cables connected at their one end to the conductor casing and at their other end either to one or more constant tension winches located on the vessel, or to weights suspended over pulleys mounted on the vessel. However, the preferred apparatus of this invention uses one or more submerged buoyant members attached to the conductor casing for applying the desired upward force. This eliminates the problems inherent in pulling on the casing from the vessel which is continuously moving relative to the major portion of the riser.

In view of the magnitude of the upward force imposed on the riser to achieve the result of this invention, a counteracting downward force is necessary to prevent the riser from being pulled out of the water. The weight in water of the conductor casing opposes the upward force but is insufficient to completely counteract it. Additional downward force may be applied, for example, through cables connected at their one end to the conductor casing and at their other end either anchored to the ocean floor, or connected to submerged buoyant members through pulleys which are anchored on the ocean floor. Alternatively the wellhead and associated equipment may be relied on to either completely or partially counteract the upward force, either by its weight, or by weights added to the wellhead, or by anchoring the wellhead or the well casing which is suspended from it to the submerged formation. In order to avoid reliance on anchors and the possibility of damaging the wellhead equipment by transmitting substantial tensile stress through it, the preferred apparatus of this invention uses a large weighted mass or counterweight connected to the bottom end of the riser.

Referring to FIGURES 1 and 2, which illustrate an embodiment of the invention, a large buoyant member or float **90** is connected around the conductor casing to apply a relatively large upward force concentrated at one location on the casing. The buoyancy of the illustrated float is constant, but can be made adjustable by known modifications.

FIGURE 10 illustrates another embodiment of the invention wherein a buoyant member for applying upward force to the conductor casing is distributed uniformly along a substantial portion of the casing length. Each of the tubular conductor members **51** which form the major portion of the conductor casing is surrounded by a larger diameter sealed shell member **95**. A conical member **100** connects the lower end of each conductor member **51** to the lower end of the associated shell member **95**. Similarly a conical member **103** connects the upper end of each conductor member **51** to the upper end of the associated shell member **95**. A sealed chamber **96** is thus formed bounded by conductor member **51**, shell member **95**, and conical members **100** and **103**. Chamber **96** is filled with air, or some other material less dense than the surrounding sea water, to exert an upward buoyant force on tubular member **51**.

Each shell member **95** includes an annular collar **97** at its lower end and an annular collar **98** at its upper end. A clamp **99** of a type commonly used in oil well drilling cooperates with shoulders **101** and **102** on collars **97** and **98** respectively to connect the conductor members **51** in end-to-end relationship. Ring seals **106** and **107** in flanges **97** and **98** respectively prevent loss of drilling fluid through the connection between adjacent outer shell members.

When drilling at great depths, it is preferable to use high pressure air or gas in chamber **96** in order to safeguard against collapsing of the walls of shell members **95** under the external pressure of the sea water. Discs **108** connected between conductor member **51** and shell member **95** at axially spaced intervals aid in preventing collapse of the shell member and also increase the column stiffness of the conductor casing by making the shell and the casing act as a single unit.

Referring again to FIGURE 2 a toroidal concentrated mass or counter-weight **110** surrounds ball joint **48** and has its center of gravity at the center of the ball joint's rotation. It is connected to the lower end of the conductor casing by rigid steel gusset plates **111** and **112** to position it centrally relative to the center of the ball joint. The counter-weight thus exerts a downward force at the lower end of the conductor casing. Since the center of mass of the counter-weight coincides with the center of rotation of the ball and socket joint **48**, the counter-weight exerts no bending moment about the ball and socket joint even when the conductor casing is inclined from the vertical.

Several arrangements of the above described concentrated float **90** and/or distributed buoyant shell **95** are used alternatively in conjunction with the concentrated counter-weight **110** to apply the desired tensile forces to the conductor casings. In one such arrangement one or more large floats **90** are located immediately below telescopic connector **50**, and provide the entire desired upward force. This upward force is opposed by the weight of the conductor casing and concentrated mass **110** acting on the bottom of the conductor casing. In some instances it may be desirable to rely on the wellhead and associated equipment which is anchored to the submerged formation for providing a portion of the downward force. In a second alternative the buoyant shell **95** is connected along the entire length of the conductor casing between the telescopic connector and the bottom ball and socket joint to provide a uniformly distributed upward force of a total magnitude equal to that desired. In this arrangement the tensile stress in the conductor casing is at a minimum near the upper end of the conductor casing where the compressive force of the drilling fluid is also at a minimum, and is at a maximum near the lower end of the conductor casing where the buckling force is at a maximum. This alternative eliminates the problem of handling a large submerged float and also reduces the effective area subjected to the large ocean current and wave forces which exist near the ocean surface.

Other alternative methods use at least one concentrated float **90** in combination with distributed buoyant shells **95**. For example, a concentrated float is connected to the conductor casing at a depth of approximately 180 feet where the current and wave forces are substantially reduced. The concentrated float is proportioned so as to provide an upward buoyant force equal to the maximum net axial compressive force applied at the transverse section where the float is located plus the desired overpull to reduce the bending effect of the transverse environmental forces to within design limits. Upward force is applied to the portion of the conductor casing above the concentrated float either by use of a second concentrated float immediately below the telescopic joint or alternatively by use of a shell member along that portion of the conductor casing. In such an arrangement the portion of the conductor casing above the first concentrated float acts as a separate system from that portion below the concentrated float insofar as bending of the conductor casing relative to vertical is concerned.

Still another arrangement includes a shell member connected to the conductor casing substantially along its entire length but proportioned so as to provide only a portion of the upward force desired. One or more concentrated floats are then connected to the conductor casing to provide the remainder of the desired upward force. Thus the diameter of the concentrated floats is reduced, thereby reducing the problems of wave force and handling.

Many other arrangement may be used to obtain the desired tensile stress in the conductor casing as contemplated by the above analysis of buckling and bending forces, as will be obvious from the teaching of the above disclosure.

Reference is now made to FIGURES 5–9 in conjunction with the description of the telescopic joint and support for the upper end of the conductor casing.

It is imperative that this joint be constructed in a manner which will reduce to a minimum the frictional load transmitted through it to the conductor casing string below it, and also in a manner to prevent binding of the joint as the vessel moves vertically toward the ocean bottom.

The uppermost of the casing members **51** in the conductor casing string is designated **51***a*. It is surrounded by cylindrical shell **95***a* (FIGURE 7B) and terminates a substantial axial distance below the upper end of shell **95***a*. A ring **120** is connected to the upper end of conductor member **51***a* and to the inner surface of shell **95***a* to seal the upper end of chamber **96**. Conductor member **121** is of a smaller outer diameter than the inner diameter of conductor member **51***a* and extends into member **51***a* in telescopic relationship. The upper end of conductor member **121** is supported from the floating vessel in a manner which will be described below. Thus as the floating vessel moves vertically relative to the wellhead, conductor member **121** moves vertically with it and relative to conductor member **51***a* and shell **95***a*.

A slide bearing arrangement is provided between conductor members **51***a* and **121** to prevent binding during relative axial sliding movement. This bearing arrangement is housed in cylindrical casing **125** which has an outside diameter substantially equal to the inside diameter of shell **95***a*. Thus casing **125** fits snugly in the upper end of shell **95***a* with the lower end of casing **125** resting on ring **120**. A plug **126** is threaded into the upper end of shell **95***a* to retain casing **125** in place. The plug is removable for access to the bearings in casing **125**. A bearing **129** of low friction material slidably engages the outer wall of conductor member **121** and rests on shoulder **128** of sleeve **127** which is connected to the interior of casing **125** near the upper end of the casing. Bearing **129** maintains the upper end of shell **95***a* concentric with conductor member **121**. Near the lower end of casing **125** a second bearing **130**, similar to bearing **129** slidably engages conductor member **121**. Bearing **130** is surrounded by sleeve **131** and rests on shoulder **135** of sleeve **131**. An outer sleeve **132** surrounds sleeve **131** and includes a shoulder **138** at its upper end which abuts internal shoulder **133** of casing **125**. The upper end of sleeve **131** abuts shoulder **138**. The lower end of outer sleeve **132** extends down beyond the lower end of sleeve **131** and is connected to ring **134**. Ring **134** is connected to the inner wall of casing **125**. Pressure actuated lip type rubber packings **140** and **143** surround conductor member **121** to prevent drilling fluid from escaping upward around conductor member **121** where the abrasive cuttings would destroy guide bearings **129** and **132**. A pair of retainer rings **137** and **141** include upward annular protrusions **139** and **142** respectively which are wedged into grooves or lips in the lower face of seal packings **140** and **143**. A removable ring **136** is threaded into ring **134** to retain bearing **130**, and packing seals **140** and **143** in place. As ring **136** is tightened, its upper face forces lip spreader ring **137** axially toward shoulder **135** and annular protrusions **139** and **142** in turn hold packings **140** and **143**, which have a natural garter action to hug in tight engagement with conductor member **121**. Bearing **130** maintains the upper end of conductor member **51***a* concentric with member **121**.

Rigidly connected around the upper portion of conductor **121** is a disc shaped plate **150**. Suspended from plate **150** is a tubular member **151** which has an internal diameter larger than the external diameter of shell **95***a* and surrounds the shell in telescopic relationship. The lower end of tubular member **151** extends slightly below the lower end of conductor member **121**. Intermediate the ends of member **151** two axially spaced ring-shaped plates **152** and **153** are rigidly connected around member **151**. These plates are connected to each other by four pairs of spaced plates **154–155**, **156–157**, **158–159**, and **160–161** (FIGURE 9). A wheel **166** is rotably mounted on an axle **163** which extends between plates **158** and **159**. The wheel has a concave surface which bears against the outer surface of shell **95***a* through an opening in the wall of tubular member **151**. Wheels **167**, **168** and **169** are similarly mounted between the other pairs of plates. Braces such as **172** connected between tubular member **151** and plate member **153** add rigidity to the structure. As conductor member **121** and appended shell **151** move axially relative to conductor member **51***a* causing the associated tubular member **151** to move relative to shell **95***a*, wheels **166–169** will roll along shell **95***a* and maintain shell **95***a* and tubular member **151** in concentric relationship. A similar four wheel bearing arrangement is designated generally by the numeral **170** in FIGURE 7B and is located at the lower end of tubular member **151**.

A nipple **171** extends through plate **150** and directs a flow of liquid such as water through nozzle **171** onto conductor member **121** to act as a lubricant during the telescopic motion. Bearings **129** and **131** each include longitudinal grooves which permit the lubricant to pass through them.

The means for connecting the upper end of the conductor casing to the floating vessel will be described with reference to FIGURES 2, 5, 6, and 7A. A steel plate **180** (FIGURE 5) is connected to the under side of platform **6** of the vessel in parallel relation thereto. Plate **180** includes a circular opening in its center which is coextensive with the opening in platform **6** through which the drill pipe **8** is passed. Bracing members **181** and **182** of FIGURE 6 are arranged so as not to interfere with passing of the drill pipe through the opening. A pulley **183** is mounted on the under side of plate **180** for rotation about an axle **184** which is perpendicular to the plane of plate **180**. A pair of pulleys **185** and **186** are supported from the bottom of plate **180** in housings **187** and **188** respectively, for rotation about horizontal axles **189** and **190** respectively, each of which is parallel to the plane of plate **180**. One end of a cable **191** is connected by clevis **194** to bracket **192**. The cable extends upward over pulley **185**, around pulley **183** and over pulley **186** down to a bracket **193** to which the opposite end of the cable is connected by clevis **194**. Brackets **192** and **193** are connected to the top of shell **95***a*. Pulleys **183**, **185**, and **186** are arranged so that the portion of cable **191** between pulley **185** and pulley **186** will lie substantially in a single plane parallel to plate **180**. As is clear from FIGURE 6, the two vertical portions of cable **191** are diametrically opposed relative to the opening in plate **180**. The portion of cable **191** between pulley **186** and bracket **193** passes freely through a hole **196** in a disc-shaped steel plate **197** which is connected around conductor member **122**. A coil spring **198** surrounds cable **191**, the upper end of spring **198** normally abutting the lower face of plate **197** and the lower end of spring **198** normally abutting a collar **199** which is adjustably fixed to cable **191** by clamp **200**. The initial tension on spring **198** may be adjusted by turning screw **201** which moves sleeve **199** along cable **191**. A short cylindrical sleeve **202** retains the upper end of spring **198** in concentric relationship with cable **191**. The lower end of spring **198** is held in concentric relationship with cable **191** by collar **199**. A similar spring and clamp arrangement is located on the portion of cable **191** between pulley **185** and bracket **192**. Plate **197** is braced to tubular member **122** by triangular members **203** and **204**. This supporting arrangement permits limited movement of the upper end of the conductor casing relative to the platform **6**, but springs **198** bias the upper portion of the conductor casing to its normal position vertically below the opening in the operating platform.

Referring to FIGURES 2, 7A, and 8, brackets **210** and **211** are connected to tubular member **151** and spaced approximately 120° around the circumference of tubular member **151** on opposite sides of bracket **193**. Cables **212, 213**, and **214** are connected to brackets **193, 210**, and **211**, respectively by swivel joints **215, 216**, and **217** respectively. Cables **212, 213**, and **214** extend radially from the tubular member **151** each to a swivel connection with the vessel structure to restrain the upper end of members **121** and **151** in a position approximately aligned with the opening in platform **6**. Safety cables **218** and **219** are swivelly connected to brackets **193** and **192** respectively and extend downwardly and outwardly therefrom to points of connection on the structure of the vessel. These safety cables serve to limit the upward movement of the upper end of the conductor casing relative to platform **6** and the vessel.

FIGURES 11A, 11B, and 12 illustrate a modified form of telescopic joint. As in the joint of FIGURES 7A and 7B, in FIGURES 11A and 11B, the conductor member **121** is slidably inserted into conductor member **51*a***. Low friction bearing **225** is connected to the lower end of conductor member **121**. Bearing **225** provides a tight seal to prevent loss of mud around conductor member **121**, and also maintains the lower end of conductor member **121** in concentric relationship with conductor member **51*a***. A second bearing **226** connected to the interior of conductor member **51*a*** near the top of the conductor member tightly surrounds member **121** to provide a second seal and to maintain the upper end of member **51*a*** in concentric relationship with member **121**. A set of four wheels **227, 228, 229**, and **230** bear on tubular member **51*a*** at circumferentially spaced points in a manner similar to wheels **160–169** of the telescopic joint of FIGURES 7A and 7B. Four wheels **231** bear on the circumference of tubular member **51*a*** at a point axially spaced below wheels **227–230** in a manner similar to the arrangement **170** of FIGURE 7A and 7B. The eight wheels are connected to the upper end of conductor member **121** through an open framework which includes eight spaced apart members **232, 233, 234, 235, 236, 237, 238**, and **239**, each of which extend in a direction parallel to the axis of conductor member **121**. These eight members are connected together at their bottoms by plate **240** and are braced together intermediate their lengths by rings **241, 242**, and **243**. The tops of the eight members are connected by circular plate **244** which surrounds and is rigidly connected to the upper end of conductor member **121**.

The telescopic joint of FIGURES 7A and 7B is shown in combination with a conductor casing member **51*a*** which includes a shell **95*a*** around it, while the conductor casing shown in combination with the telescopic joint of FIGURES 11A and 11B does not include a shell. This difference is for purposes of illustration only and each of the joints is easily modifiable for use with either type of casing member.

These and other modifications will be obvious from the above teachings and the invention described herein should be limited only by the following claims.

We claim:

1. A conductor casing for connecting a wellhead on the ocean bottom to a vessel floating on the ocean surface substantially vertically above the wellhead comprising: an elongated tubular member containing a drilling fluid denser than water, said member having its lower end connected to a fixed wellhead adjacent the ocean floor and its upper end connected to a floating vessel, means near the lower end of said member for permitting universal angular movement of the axis of said member relative to said wellhead, means near the upper end of said member for permitting universal angular movement of the axis of said member relative to said floating vessel, means in the upper portion of said member permitting axial elongation and contraction of said member, means for exerting an upward force on said member, a mass operatively connected to said member adjacent its lower end for resisting said upward force, said mass and said upward force exerting means being proportioned with respect to each other and said member so that the longitudinal compressive force exerted by the drilling fluid in said member does not exceed the longitudinal tensile force exerted on said member throughout any substantial portion of the length of said member.

2. A conductor casing for connecting a wellhead fixed on the ocean bottom to a vessel floating substantially vertically above the wellhead comprising: an elongated tubular member containing a dense drilling fluid, said member having its lower end connected to said wellhead and its upper end connected to said floating vessel, means near the lower end of said member for permitting universal angular movement of the axis of said member relative to said wellhead, means near the upper end of said member for permitting universal angular movement of the axis of said member relative to said floating vessel, means in the upper portion of said member permitting axial elongation of said member, a mass connected to said member near its lower end for exerting a downward force on said member, buoyant means affixed to said member at a point intermediate its ends, said buoyant means being proportioned to exert a first upward force on said member in excess of the weight in water of the portion of said member below said buoyant means plus the weight in water of the dense drilling fluid contained in that portion, means exerting a second upward force on the portion of said member above said buoyant means, said second force being in excess of the weight in water of the portion of said member above said buoyant means plus the weight in water of the drilling fluid contained therein, and said concentrated mass being proportioned to exert a downward force on said member substantially equal in magnitude to the total of said first and second upward forces minus the weight in water of said member.

3. A conductor casing as recited above in claim **2** wherein said means for exerting a second upward force comprises a second buoyant means affixed to said conductor casing and distributed substantially uniformly along the length of the portion of said member above said first buoyant means.

4. For use in offshore drilling from a floating vessel, means for connecting the upper end of a conductor casing to the floating vessel comprising: a cable one end of which is pivotally connected to the conductor casing at a first point and the other end of which is pivotally connected to said conductor casing at a second point, said first and second points each being below the top of said conductor casing and circumferentially spaced from each other, first and second pulleys connected to said floating vessel, each of said pulleys having a horizontal axis of rotation, said cable extending upward from said first point over said first pulley, across from said first pulley over said second pulley, and downward from said second pulley to said second point, the upward and downward extending portions of said cable each being substantially parallel to said conductor casing axis, guide means connected to said conductor casing through which means said upward and downward extending portions pass, and resilient means connected to each of said upward and downward extending portions, each of said resilient means bearing against said guide means to yieldably resist movement of said cable through said guide means.

5. For use in offshore drilling and well working from a floating vessel, an elongated tubular conductor comprising an elongated lower tubular member, an elongated upper tubular member, means for fixing the lower end of said lower member relative to and adjacent the submarine earth formation, means for connecting the upper end of said upper member to said floating vessel, said upper member and said lower member being proportioned so that one of said members nests in the other of said members in telescopic relationship throughout a portion of its length to form a continuous conduit at all positions of said vessel relative to said submarine formation with selected design limits and means for maintaining the nested portion of said members in axial alignment with each other and for reducing friction between said members as said members move axially relative to each other, said last recited means comprising first bearing means connected to one of said members and in slidable engagement with the other of said members, second bearing means connected to one of said members at a location axially spaced along said members from said first bearing means and in slidable engagement with the other of said members, a frame structure connected to the inner one of said members at a location axially spaced from the nested portion of said member and extending axially along said member in surrounding relationship with the nested portions of said upper and lower members, and third and fourth axially spaced bearing means for maintaining said frame structure in axial alignment with the outer one of said members.

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