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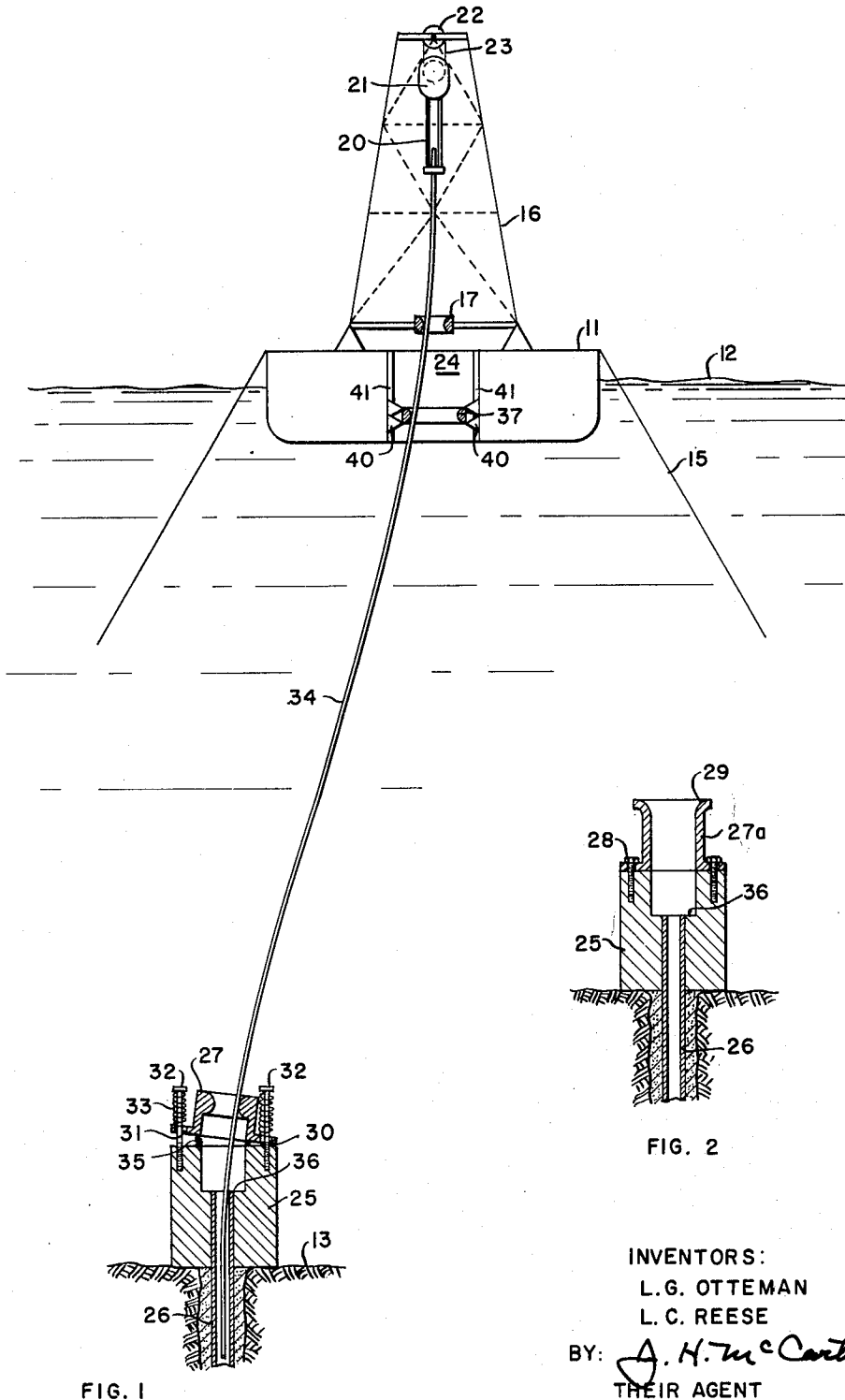
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METHOD AND APPARATUS FOR DRILLING UNDERWATER WELLS

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3 Sheets-Sheet 1



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3 Sheets-Sheet 2

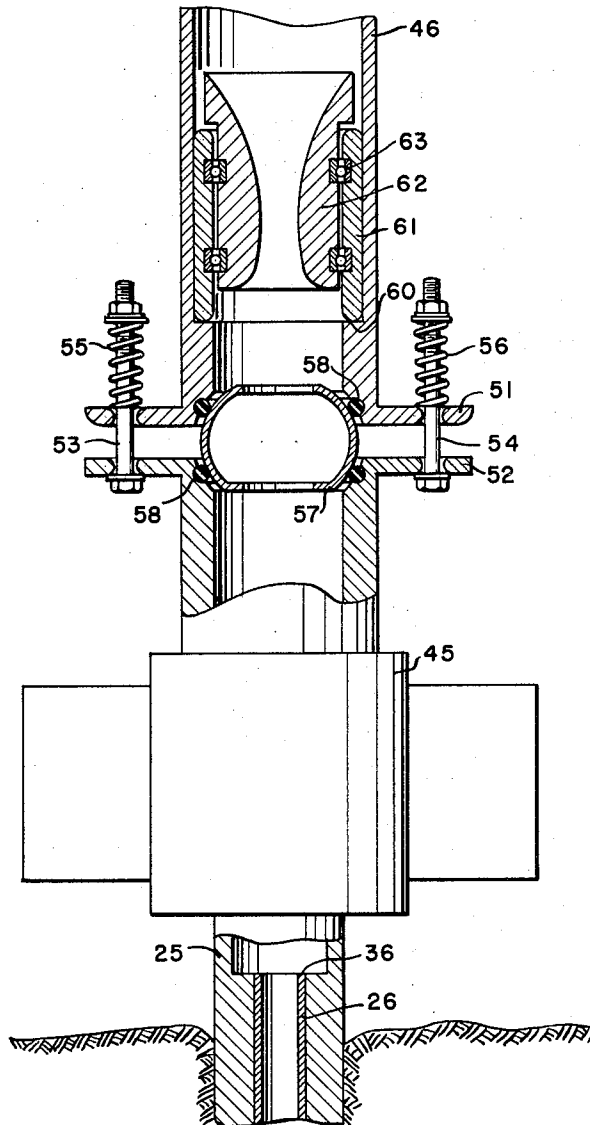


FIG. 3

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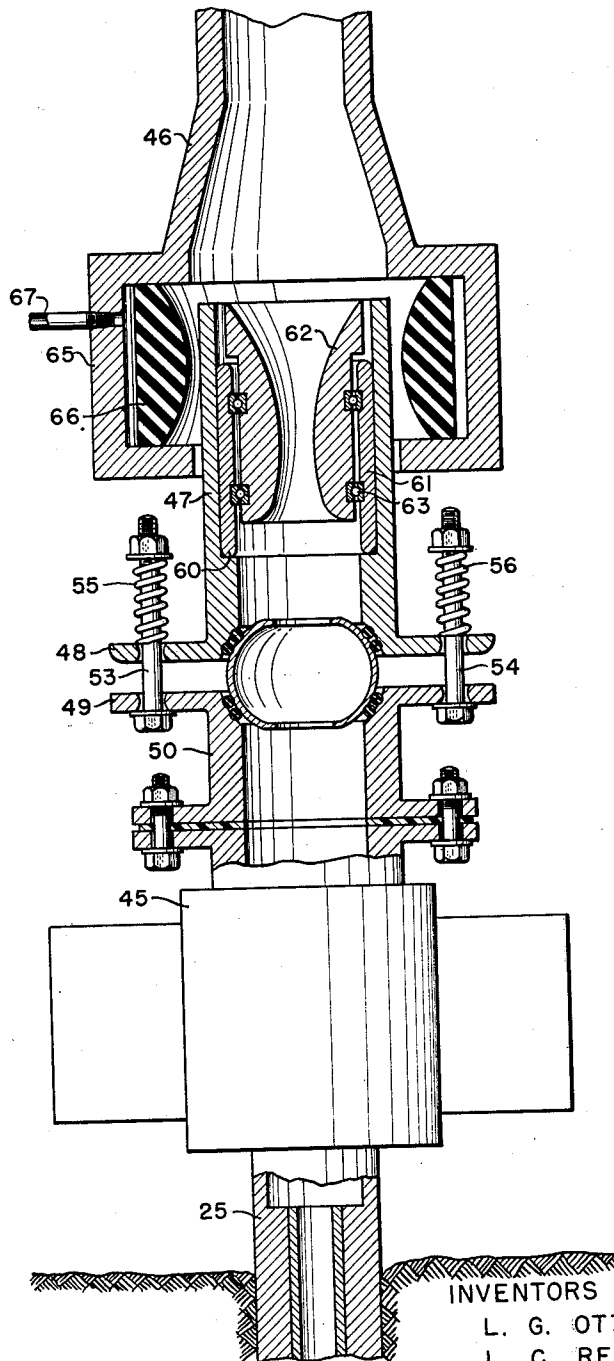


FIG. 4

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METHOD AND APPARATUS FOR DRILLING UNDERWATER WELLS

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4 Claims. (Cl. 175-7)

This invention relates to the drilling of oil and gas wells and pertains more particularly to a method and apparatus for drilling wells at offshore locations where the drilling operations are carried out from a floating base positioned on the surface of the water and the well being drilled is provided with a wellhead assembly positioned below the surface of the water.

Heretofore most offshore wells have been drilled either from stationary platforms anchored to the ocean floor or from movable barges temporarily positioned on the ocean floor. Regardless of the manner in which the wells were drilled, most wells were completed in a manner such that the outermost tubular member of the well extends upwardly from the ocean floor to above the surface of the water where a wellhead or Christmas tree was mounted thereon for controlling the production of the well. Drilling offshore wells by either of these methods was carried out in much the same manner that wells are drilled on land. Thus, the string of drill pipe that was suspended from the derrick passed through the rotary table in the floor of the derrick and thence downwardly into the wellhead assembly which was positioned just below the operating floor of the derrick or the drill barge, well above the surface of the water. At most, there was only a few feet of drill pipe between the rotary table and the top of the conductor pipe or wellhead assembly on which blowout preventers were usually mounted.

A recent development in the art of drilling wells offshore has been a method for drilling and completing wells from a floating drilling base which was employed to suspend a string of drill pipe therefrom, with the drill pipe extending down through the water to a wellhead or conductor pipe positioned below the surface of the body of water. Generally, the wellhead assembly was positioned on the ocean floor and anchored thereto by cementing a conductor pipe into the ocean floor. With the floating drilling base anchored over the wellhead assembly positioned on the ocean floor, well drilling operations could be carried on in water depths of from 100 to 1500 feet or more. A method of drilling and completing an underwater well on the ocean floor in this manner is described in copending application Serial No. 830,538, filed July 30, 1959, to Haerber et al.

Since it is impossible to anchor a floating drilling unit or barge to the ocean floor so that the barge maintains a fixed position at all times directly over a wellhead assembly positioned on the ocean floor, strings of tubular goods employed in drilling the well from the floating drilling unit are subjected to unusual bending condition due to the movement of the drilling unit. Movement of a floating drilling unit on the surface of the ocean is caused by wind and wave forces and may take the form of a roll and/or horizontal movement from a position directly over the well being drilled. If the bending forces to which a string of pipe is subjected are too severe, the pipe will be damaged. To prevent damage of a pipe string, for example a string of drill pipe, drilling operations have to be sus-

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ended whenever conditions of the sea are such that the drilling unit's movement exceeds the allowable working range or bending limits of the pipe string.

It is therefore an object of this invention to provide a method and apparatus for increasing the working range of a floating well drilling unit subjected to wave and other forces tending to cause the unit to roll on the surface of a body of water or to move horizontally from a position directly over an underwater well.

A further object of the present invention is to provide a method and apparatus for properly distributing the bending forces induced in a string of drill pipe extending from a floating drilling barge into a wellhead positioned beneath the surface of a body of water when the barge moves from a position directly over the wellhead.

These and other objects of this invention will be understood from the following description taken with reference to the drawing, wherein:

FIGURE 1 is a diagrammatic view illustrating a floating drilling unit or barge anchored to the ocean floor over a drilling location with a string of drill pipe extending from the barge into a wellhead assembly positioned on the ocean floor; and,

FIGURES 2, 3 and 4 are diagrammatic views taken in cross-section of alternate arrangements of equipment on or adjacent a wellhead assembly for supporting a pipe string passing through the wellhead assembly in accordance with the present invention.

Referring to FIGURE 1 of the drawing, a drilling barge 11, of any suitable floating type is illustrated as floating on the surface of a body of water 12 and substantially fixedly positioned over a preselected drilling location, as by being anchored to the ocean floor 13 by suitable anchors (not shown) at the ends of anchor lines 14 and 15. Equipment of this type may be used when carrying out well drilling operations in water varying from about 100 feet to 1500 feet or more in depth. The drilling barge is equipped with a suitable derrick 16 as well as other auxiliary equipment needed during drilling, such for example as a rotary table 17, elevators 20, traveling block 21, crown block 22 and fall lines 23. The derrick 16 on the drilling barge is positioned over a drilling slot or well 24 which extends vertically through the barge in a conventional manner. When using the equipment of the present invention, the slot 24 of the barge may be either centrally located or extended in from one edge. Additionally, well drilling operations may be carried out over the side of a barge without using the slot, if desired.

A wellhead assembly 25 is schematically shown as being positioned on the ocean floor 13 and being fixedly anchored thereto by a conductor pipe or well casing 26 which extends into the ocean floor 13 and is preferably cemented therein. While an underwater wellhead assembly of this type as described in the copending application Serial No. 830,538, filed July 20, 1959, to Haerber et al., is generally provided with a series of guide columns for guiding equipment into place on top of the wellhead assembly, and with a series of guide lines extending from the wellhead assembly on the ocean floor to the drilling barge floating on the surface of the water, since these elements do not form a part of the present invention they will not be further described here.

The top of the wellhead assembly 25 is provided with a tiltable collar or bushing 27 suitably connected for slight tilting movement in any direction around the top of the

wellhead assembly, for example, the tiltable collar 27 may be provided with a lower flange 30 having a series of large diameter holes 31 therethrough with bolts 32 extending through each of the holes 31. A compression spring 33 is mounted above the flange 30 to exert pressure against the flange when it is being tilted. In FIGURE 1, a string of drill pipe 34 is shown as extending down through the tiltable collar 27 and into the wellhead assembly 25. In drilling underwater wells of this type it is general to have a conductor pipe of larger diameter than the drill pipe 34 extend in a fluidtight manner from the top of the wellhead assembly 25 or the tiltable collar 27 to a point just below the rotary table 17 on the barge 11. In the event that a conductor pipe (not shown) of this type is employed, a fluidtight seal, for example a bellows 35 would be installed between the bottom of the tiltable collar 27 and the top of the wellhead assembly 25. Thus it may be seen that the tiltable collar 27 forms a horizontal pipe support device so that down at the ocean floor a pipe string 34 would bear against the tiltable collar 27 and also against the top edge 36 of the conductor pipe 26, as illustrated in FIGURE 1. The distance between the top edge 36 of the conductor pipe 26 and the pipe contacting face of a tiltable collar 27 is generally in the order of five feet or more.

The simplest form of a horizontal pipe support adapted to be secured to the barge 11 is that of a ring 37 located directly below the rotary table 17. For ease in explanation and descriptive purposes the term pipe string will be employed, it being understood that the principles discussed hereinbelow apply to any tubular goods that may be used in well operations such as casing, tubing, drill pipe, drill tubing, etc., and that the equipment described herein may be used on any type of tubular goods. Also, the principles to be discussed hereinbelow apply to a pipe string being run in or pulled out of a well, while rotating or not rotating as the case may be.

If desired, the horizontal pipe support ring 37 may be fixedly secured to the vessel 11 within the slot 24 thereof, as by welding, bolting, etc., or it may be fixedly secured to carriages 40 which are adapted to be run up and down and positioned at any point on vertical tracks 41. The ring 37 has an internal diameter somewhat greater than the internal diameter of the rotary table 17. A ring shaped to the horizontal pipe support 37 is employed so that the support 37 functions when the floating drilling unit 11 moves in any direction off the center line of the wellhead assembly 25.

In the operation of the equipment of FIGURE 1, the pipe string 34 is suspended by the elevators 20 and passes down through the rotary table 17, the horizontal support ring 37, into the water and down the well. The drilling barge 11 is originally anchored so that a vertical line passes through the rotary table 17, the support ring 37 and the wellhead assembly 25 on the ocean floor. As wind and wave forces move the drilling barge 11 horizontally off this center line through the well, the pipe string 34 first comes into contact with the rotary table 17. A force is developed between the pipe string 34 and the rotary table 17 so that a bending of the pipe string 34 takes place opposite the rotary table, that is, where the two are in contact. As the amount of horizontal movement of the drilling barge 11 increases, the force between the rotary table 17 and the pipe string 34 increases with a resultant increased bending in the section of the pipe string 34 opposite and for some distance above and below the rotary table. Generally, the bending is at a maximum at the point of contact between the rotary table 17 and the pipe string 34 and decreases to an insignificant magnitude about 20 feet or so from the point of contact. Continued movement of the drilling barge 11 in the same direction horizontally causes the pipe string 34 to come in contact with the horizontal support ring 37 and a force is developed between the pipe string 34 and the support ring 37 with bending being induced in this section of the

pipe opposite the support ring 37 as well as in the section of pipe opposite the rotary table 17. With continued movement of the vessel 11 in the same direction, the force between the horizontal support ring 37 and the pipe string 34 which causes bending in the pipe string at a point opposite the ring to increase, while the force between the rotary table 17 and the pipe string 34 as well as the bending in the pipe string at a point opposite the rotary table remains fairly uniform.

If the bending in the pipe string 34 opposite the rotary table 17 was near the maximum working limit of the pipe string at the time the pipe string contacted the lower point of support and thereafter remains nearly constant, then any additional horizontal movement of the vessel will merely induce an amount of bending in the section of pipe opposite the support ring 37 without endangering the pipe at the point opposite the rotary table 17. The method and apparatus of the present invention provides for additional horizontal support for a drill pipe in order to reduce the maximum curvature or bending of the pipe by distributing the bending over more length of the pipe. With conventional floating drilling units, the drill pipe is supported vertically with either slips set in the rotary table or by the elevators on the traveling block. In either case, as the drilling barge 11 moves horizontally and/or rolls, a horizontal force develops between the pipe and the rotary table. Bending results in the section of pipe opposite the rotary table. The magnitude of the bending is a function of the magnitude of the movements of the drilling vessel 11. If the vessel's movement exceeds certain limits, the magnitude of the bending will cause damage to the pipe. Thus, by providing a horizontal pipe support in addition to the rotary table, the magnitude of the bending in the section of pipe opposite the rotary table can be reduced by inducing bending in the section of pipe opposite the other horizontal pipe supports. Instead of using a multiple number of horizontal supports, a multiplicity of supports could be interconnected to form a continuous horizontal pipe support member in the form of a cone.

If the equipment of the present invention is properly designed, the magnitude of the bending induced in a pipe string can be reduced by, say, 30 percent or more for a given amount of vessel movement. The range of the vessel movement would therefore be increased by a proportional amount and would result in significant reduction in the amount of drilling time lost on a barge when it is necessary to shut down operations because waves are causing the barge to roll too much or the barge has moved too far off the center of the well. When equipment with a balanced design is employed, the magnitude of the bending in the section of the pipe opposite the rotary table and in the section of pipe opposite a second horizontal pipe support ring would be nearly equal at the limiting amount of vessel movement.

Movement of the drilling barge 11 off the center of the well also induces bending in the section of the pipe string 34 opposite the first fixed horizontal support below the barge 11. This first fixed horizontal support is generally the top of the wellhead assembly or the top edge 36 of the conductor pipe 26. Additional support can be supplied to the pipe string 34 by providing the tiltable collar 27 which would operate on the pipe string 34 to cause bending therein in the same manner as the horizontal support ring 37 operates near the top of the pipe string.

In the apparatus shown in FIGURE 1, four points of contact have been provided for inducing bending in the pipe string, that is, at the rotary table 17, the ring 37, the tiltable collar 27 and the top edge 36 of the conductor pipe 26. The dimensions of the internal diameter of the support ring 37 are very important. In the example given hereinbelow, the pipe string 34 was assumed to make contact with the ring 37 at the time the bending in the section of the pipe string opposite the rotary table 17 had reached a predetermined magnitude. In employing

the method of the present invention it is necessary to know both the magnitude of the bending in the pipe string 34 at a point opposite the rotary table 17, and also the relative position of the pipe string 34 at the level of the second point of contact which is the horizontal support ring 37. This information depends on several factors such as, size of pipe, type of drilling equipment on the drilling unit, design and characteristics of the drilling vessel especially with regard to the relative relationship of roll and horizontal displacement, load on the hook or elevators 20, properties of the pipe material, and distance between the support ring 37 and the rotary table 17. By application of engineering principles it is possible to determine the proper internal diameter for the support ring 37 for any combination of the above factors.

The desired internal diameter of the support ring 37 will vary as any of the above factors vary. Either various size rings can be used or a ring of variable internal diameter can be employed. Thus, under some conditions the support ring 37 of FIGURE 1 could be removed with a ring of smaller diameter being substituted therefor. Alternatively, instead of changing the ring to one of a different size, the same results can be accomplished by changing the vertical distance between the horizontal supports, i.e., the rotary table 17 and the ring 37. Thus, the point at which the ring 37 contacts the pipe string 34 can be changed at any time by moving the carriage 40 up or down track 41 to change the position of the ring.

The simplest form of a horizontal pipe support adapted to be secured to a wellhead assembly 25 is illustrated in FIGURE 2 of the drawing as comprising a rigid tubular element or collar 27a which is fixedly secured, as by bolts 28, to the top of the wellhead assembly 25. The upper lip 29 of the collar 28 is preferably flared, as illustrated, to reduce wear on a pipe bearing against the flared end while being rotated therein. The top of the collar 27a is a predetermined height above the top edge 36 of the conductor pipe 26 while the internal diameter of the collar 27a is larger than that of the conductor pipe 26. The distance between the top edge 36 of the conductor pipe 26 and the top edge 29 of the collar 27a should be at least five feet.

Another form of a horizontal pipe support apparatus adapted to be positioned adjacent a wellhead assembly 26 is shown in FIGURE 3 of the drawing. In this embodiment of the invention a blowout preventer 45 is shown as being secured in a fluidtight manner to the top of the wellhead assembly 25, for example in a manner described in copending application Serial No. 830,538, filed July 30, 1959, to Haeber et al. A string of pipe, known as a marine conductor 46, is secured, as by means of a flange 51, to a cooperating flange 52 on the top of the blowout preventer 45. The flanges 51 and 52 are secured together by means of bolts 53 and 54. Preferably, compression springs 55 and 56 are mounted on the bolts 53 and 54 thus converting the pipe support device to one of the force-displacement type.

Since a fluid such as drilling mud is often pumped through the marine conductor pipe string 46, a suitable seal element such as a fluid pressure control ring 57 is mounted between the flanged bottom of the conductor 46 and the flanged top of the blowout preventer 45. The seal element control ring 57 is provided with packing or O-ring seals 58 thus forming a fluidtight flexible joint at the lower end of the marine conductor pipe string 46.

Formed within the lower end of the marine conductor string 46 are suitable means, for example a shoulder 60 for receiving and seating thereon a tubular mandrel 61 within which a bushing 62 is rotatably mounted, as by bearings 63. The stress-reducing and wear bushing 62 is preferably freely supported in the marine conductor pipe 46 so that it may be readily retrieved therefrom. The internal diameter of the stress-reducing and wear bushing 62, which forms a horizontal pipe support in accordance with the present invention, is large enough to permit pas-

sage of a pipe string, such as a drill pipe, therethrough while at the same time being preferably large enough to allow the circulation of fluid past the pipe on the outside thereof. Thus, it may be seen that the stress-reducing and wear bushing 62 in the lower end of the tiltable marine conductor pipe string 46 forms a horizontal pipe support device so that a pipe string passing down through the marine conductor pipe 46 and down through the wellhead assembly 25 and the conductor pipe 26 would bear against the wear bushing 62 and also against the top edge 36 of the conductor pipe 26.

In FIGURE 4, the stress-reducing and wear bushing 62 is rotatably mounted in its tubular mandrel 61 which in turn is mounted in a marine conductor landing mandrel 47. The landing mandrel 47 is provided at its lower end with a flange 48 for connection to the upper flange 49 of a special spool piece 50 which in turn is connected to the top of the blowout preventer 45. The lower end of the marine conductor 46 is provided with a suitable type of a marine conductor landing head 65 of a type described in copending application Serial No. 830,538, filed July 30, 1959, to Haeber et al. The landing head 65 contains an expansible rubber element 66, which under fluid pressure from conduit 67, expands and seals against the landing mandrel 47.

We claim as our invention:

1. Apparatus for providing horizontal support to a non-vertical section of drill pipe extending from a floating drilling base on the surface of a body of water and through a wellhead assembly positioned below the surface of said body of water, said apparatus comprising a wellhead assembly positioned below a body of water, pipe means secured to the bottom of said wellhead assembly and extending downwardly into the floor of said body of water for anchoring said wellhead assembly thereto, a floating drilling base on the surface of the body of water normally positioned and anchored over said wellhead assembly, a marine conductor pipe string suspended by said floating drilling base and extending downwardly through said water to said wellhead assembly, flexible joint means securing the lower end of said marine conductor pipe string to the top of the wellhead assembly, at least one horizontal pipe support ring means arranged within the lower end of said marine conductor pipe string to contact a pipe string passing therethrough at a point above the wellhead assembly and positioning means in said marine conductor pipe near the bottom thereof for limiting the ring means against downward movement.

2. The apparatus of claim 1 wherein the horizontal pipe support ring means within the marine conductor pipe string is of a size and shape to be freely rotatable therein and removable therefrom.

3. Apparatus for providing horizontal support to a non-vertical section of drill pipe extending from a floating drilling base on the surface of a body of water and through a wellhead assembly positioned below the surface of said body of water, said apparatus comprising

- a wellhead assembly positioned below a body of water, and including at least one casing string secured within said wellhead assembly and depending therefrom into a well,

- anchoring means secured to said wellhead assembly for anchoring said wellhead assembly to the ocean floor,
- a pair of vertically-spaced horizontal pipe support means secured to said wellhead assembly and adapted to contact a pipe string passing therethrough on the same side of the pipe string when said pipe string assumes a non-vertical position, and

- wherein the upper support means of the pair of vertically-spaced horizontal pipe support means comprises a ring element fixedly secured to the top of the wellhead assembly and wherein the lower support means comprises the upper edge of said casing string.

4. Apparatus for providing horizontal support to a non-vertical section of drill pipe extending from a floating drill-

ing base on the surface of a body of water and through a wellhead assembly positioned below the surface of said body of water, said apparatus comprising

a wellhead assembly positioned below a body of water,
anchoring means secured to said wellhead assembly for
anchoring said wellhead assembly to the ocean floor, 5
a pair of vertically-spaced horizontal pipe support
means secured to said wellhead assembly and adapted
to contact a pipe string passing therethrough on the
same side of the pipe string when said pipe string 10
assumes a non-vertical position,
wherein the upper support means of the pair of verti-
cally-spaced horizontal pipe support means comprises

a force-displacement type rigid collar element axially
aligned with the well bore and means flexibly attach-
ing said collar to the top of the wellhead assembly for
limited movement relative thereto.

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