

United States Patent

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[54] DRILLING RISER
7 Claims, 2 Drawing Figs.

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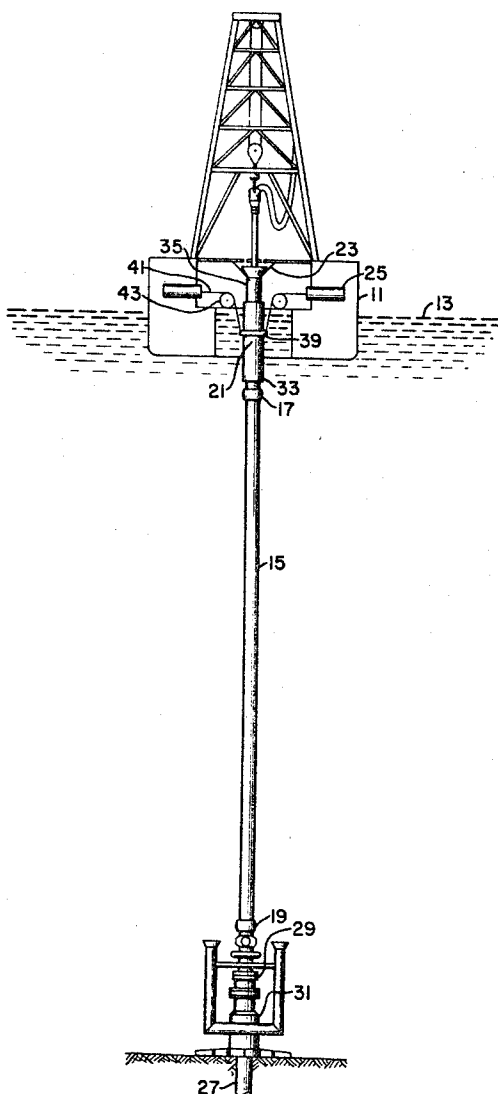
[50] **Field of Search**..... 166/5, .6:

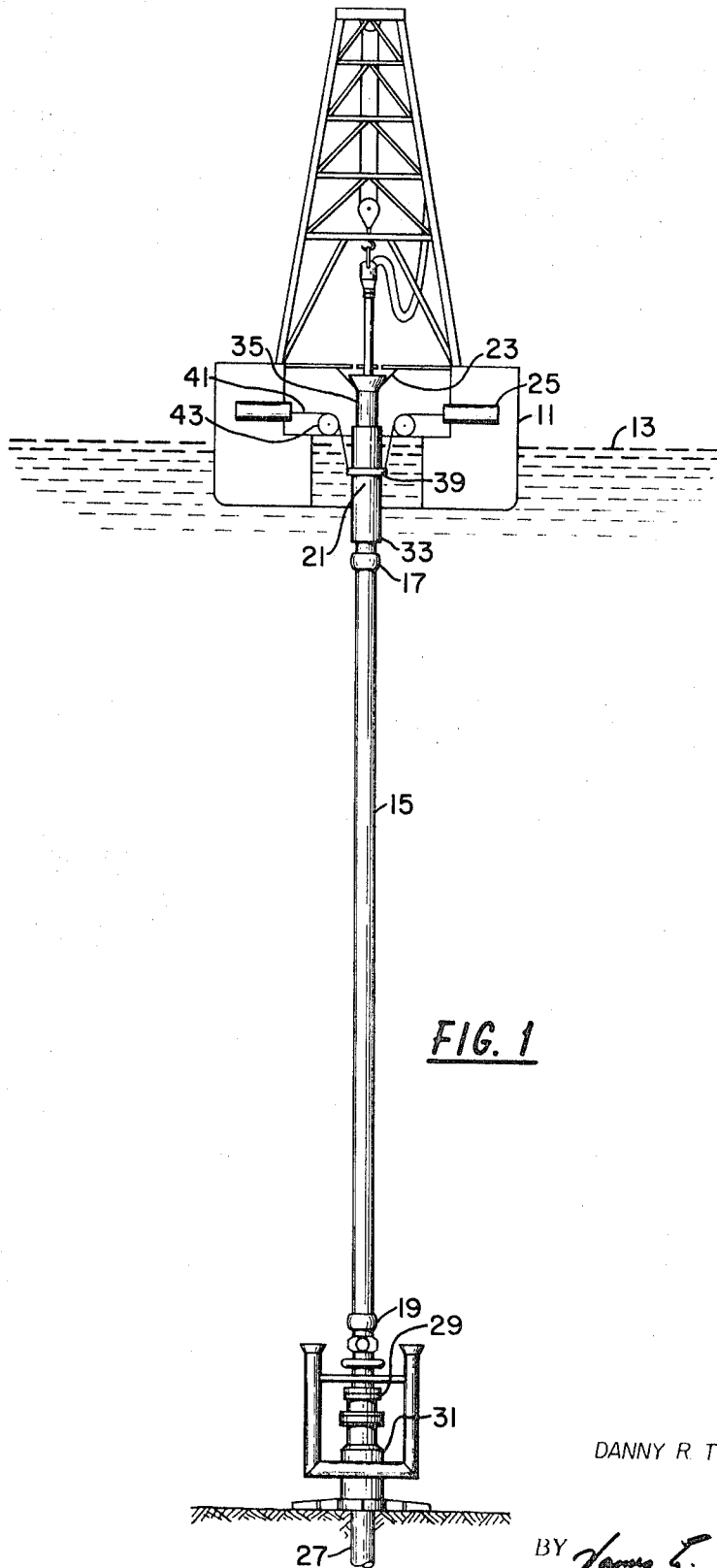
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ABSTRACT: A marine riser, for use with floating drilling equipment, that has flexible joints attached to its upper and lower ends. The lower flexible joint connects the riser to a sub-sea wellhead. The upper joint links the riser to a vertically extensible joint which is in turn pivotally connected to the drilling vessel. A tensioning device aboard the vessel maintains the riser in tension, preventing it from buckling.





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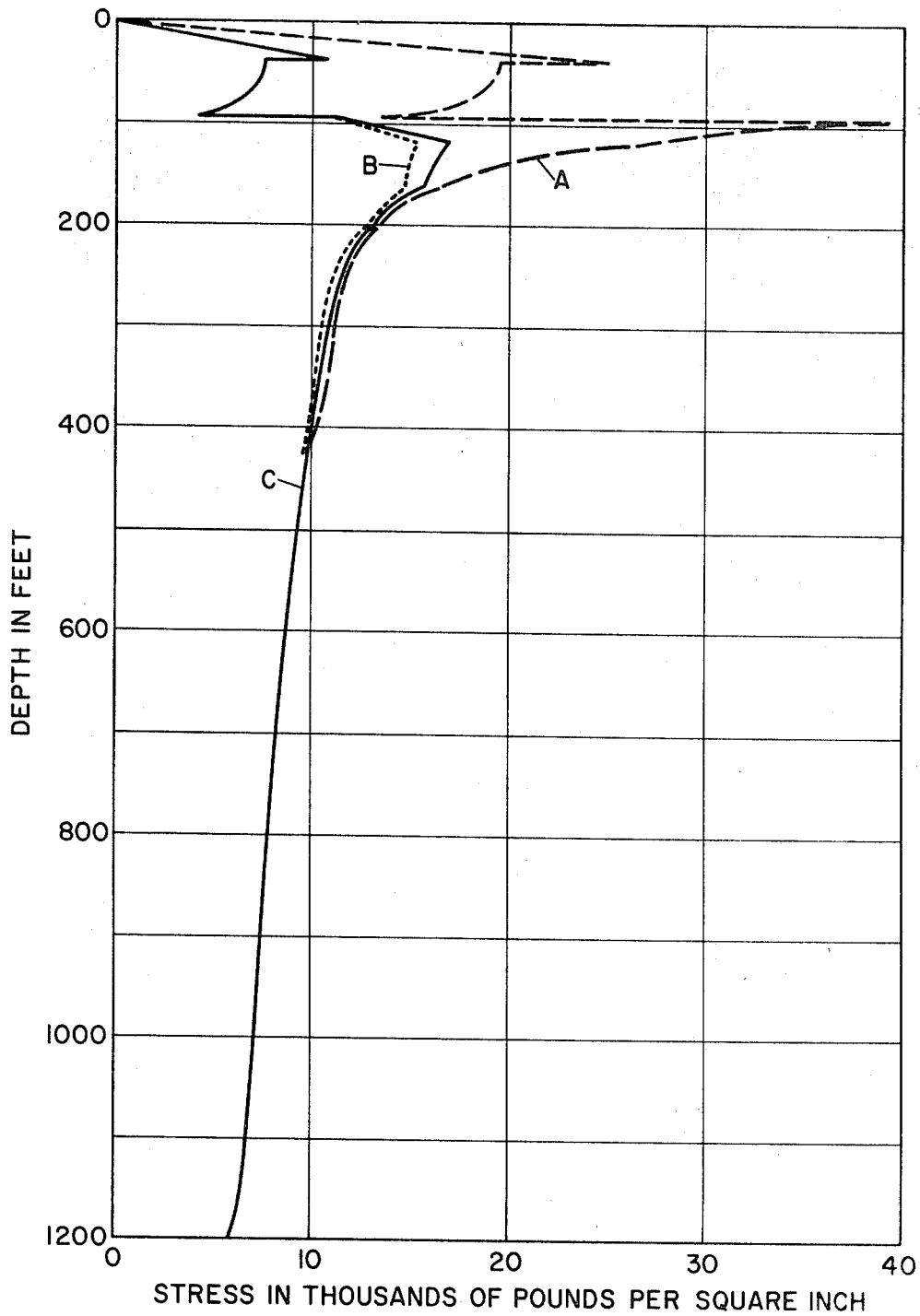


FIG. 2

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DRILLING RISER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention applies to marine riser apparatus for use in drilling oil wells and similar boreholes from floating vessels.

2. Description of the Prior Art

Most offshore drilling operations carried out in deep water are conducted from floating vessels. This method is particularly suited for such operations since the derrick, hoist, and associated drilling equipment are supported by the vessel, eliminating the need for bottom-founded supports. The only substantial connections between the floating vessel and the ocean bottom are the mooring lines and the riser pipe. The riser serves to guide the drill pipe into the well and conduct drilling fluid back to the vessel. A vertically extensible slip joint is placed in the upper end of the riser string to prevent vertical motion of the vessel from damaging the riser. A tensioning device on the vessel applies tension to the riser to prevent it from buckling. The marine riser is generally regarded as a limiting element in floating drilling systems since the depth capability of present of present floating drilling vessels is to great extent governed by the stress level in the riser.

One problem with risers is structural failure caused by horizontal movement of the vessel from the centerline of the wellbore. Wind, waves, and currents generally cause some vessel movement during drilling operations even though the vessel is properly moored. It is therefore necessary to increase the flexibility of the large diameter, relatively stiff riser to prevent riser failure. The use of one or more flexible joints placed intermediate the ends of the riser has been suggested as a means of increasing riser flexibility. The approach generally taken, however, has been to attach the upper end of the riser to the drilling vessel by means of a pivotal connection and to join the lower end of the riser to the blowout preventer stack with a flexible joint. These flexible risers may, however, fail in deep water because of overstress and fatigue. One reason for this is that the tension that must be applied to the riser to prevent it from buckling increases rapidly with depth. In addition, stress levels induced within the riser by waves, currents and the like also increase with depth, although at a somewhat lower rate than the tensile load. These increased stress levels coupled with the cyclic variation in stresses caused by vessel heave lead to accelerated fatigue failure.

SUMMARY OF THE INVENTION

The riser apparatus of the invention increases the depth capability of floating drilling equipment by reducing riser stresses. Studies have shown that peak stresses in conventional risers normally occur in the upper section of the riser near the lower end of the slip joint. A major reason for this appears to be the large diameter of the slip joint relative to that of the riser. The combined effects of the relatively large force imparted to the large diameter slip joint by wave action and the relative stiffness of the slip joint compared to that of the riser create a high level of stress in the riser just beneath the slip joint. It has been found, however, that placing a flexible joint in the riser string in close proximity to the lower end of the slip joint substantially reduces the maximum stress. Such a joint extends the maximum operating depth of any given riser configuration or, alternatively, increases riser operating life at any particular operating depth.

The riser apparatus of the invention includes a riser pipe, a flexible joint attached to the lower end of the riser pipe, means for connecting this flexible joint to wellhead equipment fixed to a subsea bottom, a flexible joint attached to the upper end of the riser, a slip joint attached to the upper end of this flexible joint, means for applying an axial tensile load to the riser, and means for pivotally connecting the upper end of the riser pipe to the drilling vessel. The preferred flexible joint is a pressure balanced ball joint, although other joints that remain flexible under high axial loadings may be used.

The apparatus of the invention substantially increases the life of risers in floating drilling operations, in both deep and shallow water. In addition, the new riser system has made it possible to drill safely with fluid returns in water depths exceeding 1,250 feet. As a result, the system has wide application and is particularly useful in deep water areas where the limitations of conventional riser may otherwise preclude effective drilling operations.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows floating drilling equipment including the riser apparatus of the invention.

FIG. 2 compares graphically the stress distribution in a conventional riser with that in riser systems built according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows riser apparatus built according to the invention for use with a floating drilling vessel. A drilling vessel 11 is shown floating on a body of water 13. A marine riser 15 which has flexible joints attached to its upper and lower ends, 17 and 19 respectively, extends downwardly beneath the vessel. The upper joint 17 links the riser with a vertically extensible slip joint 21 which in turn is pivotally connected to the drilling vessel by cable 23 and tensioners 25 acting through cable 41. These tensioners maintain the riser string in tension to prevent it from buckling.

The riser pipe 15 is normally composed of a series of short joints. These joints may be threaded together or joined in some other fashion. The riser guides drill pipe into subsea well 27 and conducts drilling fluid returns back from the subsea well to the vessel. It will therefore normally be a relatively large diameter conduit through which the drill pipe and the drill bit may pass. It should have sufficient burst resistance to withstand the differential pressures generated by the use of drilling fluids with densities of 18 pounds per gallon or more on the inside and sea water with a density of about 8.5 pounds per gallon on the outside. The riser should also have the strength to withstand the tensile stresses generated in response to the forces applied to maintain it in a substantially vertical position.

The lower ball joint 19 links the riser to a blowout preventer 29, which is attached in turn to a subsea wellhead 31. The lower ball joint prevents the transfer of moments from the riser to the wellhead and blowout preventer stack and allows the riser to flex when the vessel is moved away from the centerline of the wellbore. While this flexible joint should be located in the riser pipe string close to the blowout preventer stack, it need not be joined to the stack. Large diameter ball joints have been found to make particularly effective flexible joints for this purpose, but any flexible joint that can withstand both tensile and compressive loads would do. In deep water operations it may be necessary to balance the axial forces that act on the ball joint to assure its flexibility. A pressure balanced ball joint may be used to accomplish this purpose. One joint that has been found particularly suitable is the type CR-1 ball joint manufactured by Regan Forge and Engineering Company of San Pedro, California.

Slip joint 21 includes an outer barrel 33 and an inner barrel 35 slidable within the outer barrel. Seal members, not shown, prevent drilling fluid contained within the riser string from escaping between the inner and outer barrels of the slip joint. This vertically extensible joint compensates for vertical motion of the drilling vessel relative to the riser string. This prevents excessive stresses in the riser pipe due to vessel heave.

Clamp 39, attached to outer barrel 33, is used to apply tension to the riser string to prevent it from buckling. Tensioner 25 develops the tensile force, and acting through cable 41 which passes over pulley 43 and is attached to outer barrel clamp 39, imparts a tensile load to the outer barrel of the slip joint. This in turn is transmitted to the whole riser pipe string.

The tensioner may be hydraulically actuated and may reel the cable in and out in response to vertical motion of the vessel, thus maintaining a substantially constant tensile load on the riser. Generally, time delays are experienced with such tensioners and result in a variation in the tensile load applied to the riser on the order of ± 15 percent.

The inner barrel of the slip joint is pivotally connected to the drilling vessel by means of a gimbal or a system of cables 23 as shown. Since the riser string is pivotally connected at its upper end to the vessel and flexibly connected to the blowout preventer stack at its lower end, it is free to flex when the drilling vessel is displaced from the centerline of the wellbore, preventing failure of the riser.

As indicated above, it has been found that peak stresses normally occur at the upper end of the riser pipe. Curve A of FIG. 2 exemplifies the variation of stress with depth for a conventional riser string having no upper ball joint. This example is based on a typical semisubmersible drilling vessel drilling in water 400 feet deep. The riser has a 16.0-inch diameter, contains a 10.0 pound per gallon drilling fluid and is subjected to a 220,000-pound-tensile load by the tensioners. A one-knot current is assumed to act on the upper 10 percent of the riser, and a 0.5-knot current is assumed to act on the lower 90 percent. Wave height is 30 feet and the vessel is positioned directly above the centerline of the wellbore. Curve A of FIG. 2 shows that the maximum riser stress reaches a level of some 39,000 p.s.i. at 95 feet, which is just below the slip joint.

It has been found that peak riser stress can be reduced by placing a flexible joint in the riser string in close proximity to the lower end of the slip joint. The flexible joint increases riser flexibility at the base of the slip joint, substantially preventing the transfer of moments from the slip joint to the riser pipe. Large diameter ball joints have been found to make particularly effective flexible joints but any flexible joint that can withstand both tensile and compressive loads will do. It has been found desirable to use a pressure balanced ball joint in order to assure flexibility when the flexible joint must carry a very high tensile load during drilling operations.

Curves B and C of FIG. 2 illustrate the change in peak stress caused by placing a flexible joint in close proximity to the lower end of the slip joint. Curve B shows the stress distribution that results when such a flexible joint is added to the riser string of Curve A. All other conditions remain the same. The maximum riser stress shown in Curve B again occurs near the lower end of the slip joint, but the addition of the flexible joint has reduced the peak stress from 39,000 to 15,000 p.s.i. This reduction in peak stress substantially extends the depth capability of such a riser string. This is illustrated by Curve C of FIG. 2 which shows the stress distribution of a riser string like that in Curve A but with water depth increased from 400 to 1,200 feet. All other conditions are assumed to remain the same. Riser stress in Curve C again peaks near the lower end of the slip joint, but the maximum stress is only 17,000 p.s.i. This is well below the peak stress in the conventional riser in 400 feet of water (Curve A), despite the fact that the riser has been extended an additional 800 feet.

The stress reduction achieved by placing a flexible joint in the upper end of the riser string will also increase the fatigue

life of the riser. Fatigue life is a function of both the mean maximum riser stress and the magnitude of the cyclical stress variation from that mean stress. Fatigue life of the riser can be extended by reducing either the mean maximum riser stress or the magnitude of the cyclical variations. Cyclical stress variations are caused primarily by vessel motion and are influenced by the sea state to which the vessel is exposed. The magnitude of the cyclical stress variations is not substantially affected by changes in the configuration of the drilling riser but the mean maximum stress when an upper flexible joint is added will be substantially lower than that which would be experienced with a conventional riser. The mean maximum stress for Curve B will be seen to be only 34 percent of that for a conventional riser. The riser of the invention will therefore have a substantially longer fatigue life than a conventional riser.

What is claimed is:

1. Apparatus for use in an offshore well operation comprising:

- a. a substantially vertical riser;
- b. an extensible joint attached to the upper end of the riser;
- c. a flexible joint in said riser positioned below and in close proximity to the extensible joint;
- d. means for flexibly connecting the lower end of the riser to a subsea wellhead;
- e. means for pivotally connecting the extensible joint to a floating vessel; and
- f. means for applying tension to the riser.

2. Apparatus as defined by claim 1 wherein the flexible joint is a ball joint.

3. Apparatus as defined in claim 2 wherein the means for flexibly connecting the lower end of the riser to the subsea wellhead includes a ball joint.

4. Apparatus for use in a well operation conducted from a floating vessel comprising:

- a. a substantially vertical riser;
- b. a first flexible joint attached to the lower end of the riser;
- c. means for connecting the first flexible joint to a subsea wellhead;
- d. a second flexible joint in said riser near the upper end thereof;
- e. a slip joint attached to the upper end of the riser;
- f. means for pivotally connecting the slip joint to the vessel;
- g. means on the vessel for generating a tensile force; and
- h. means for transmitting said tensile force to said riser.

5. Apparatus as defined by claim 4 wherein the second flexible joint is a ball joint.

6. Apparatus as defined by claim 5 wherein the first flexible joint is a ball joint.

7. Marine riser apparatus comprising:

- a. a substantially vertical riser;
- b. a first ball joint attached to the lower end of the riser;
- c. means for connecting the ball joint to a subsea wellhead;
- d. a second ball joint attached to the upper end of the riser;
- e. a slip joint attached to the upper end of the second ball joint;
- f. means for pivotally connecting the slip joint to a floating vessel; and
- g. means for applying tension to the riser.