

[54] **TELESCOPIC RISER TENSIONING APPARATUS**

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[52] U.S. Cl. **166/5; 175/7**

[51] Int. Cl. **E21b 43/01**

[58] Field of Search **175/5, 7; 166/5, .6**

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[57] **ABSTRACT**

Apparatus and method for applying tension to a string of casing extending from a vessel floating on the surface of a body of water to a wellhead operatively connected to a well borehole extending down into the bottom of the body of water. The casing includes an upper coupling connected at one end to the casing and at the other end to a lower coupling in a telescoping relationship. A tensioner is operatively connected to both couplings for telescoping the couplings in a manner applying tension to the casing. A drilling fluid is injected down the casing and into the well borehole and a portion thereof is diverted from the couplings to a pressure transducer which receives pressure from the weight of the fluid in the casing and applies the force generated thereby to the tensioner to thereby telescope the couplings and apply tension to the casing.

6 Claims, 12 Drawing Figures

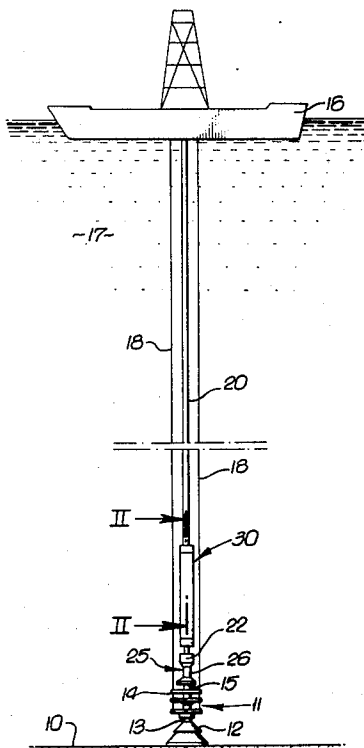


Fig. 9.

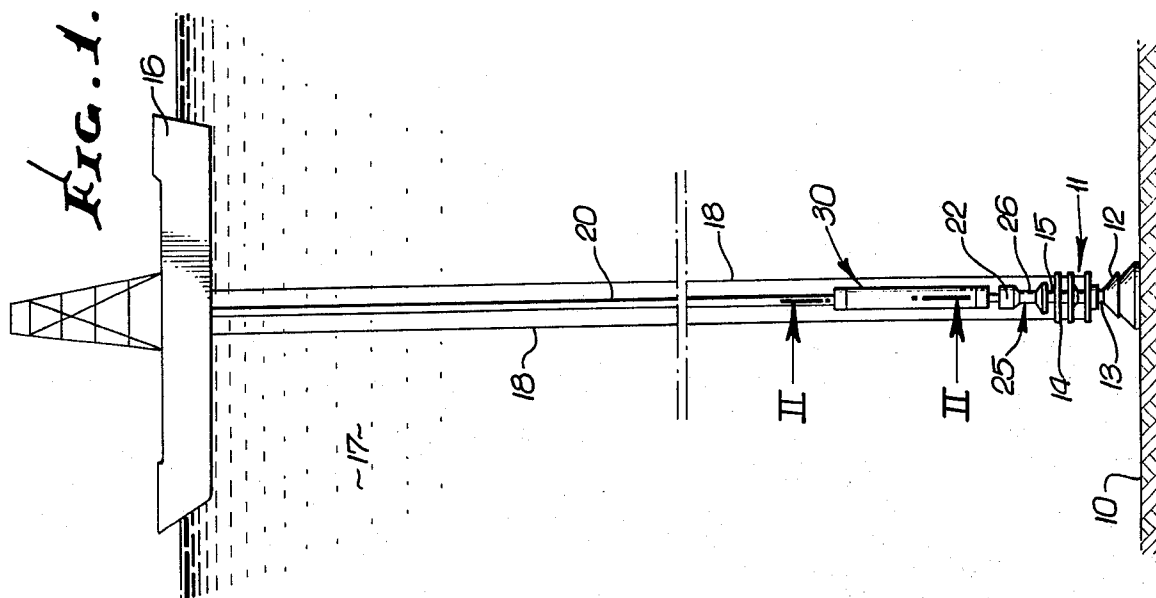
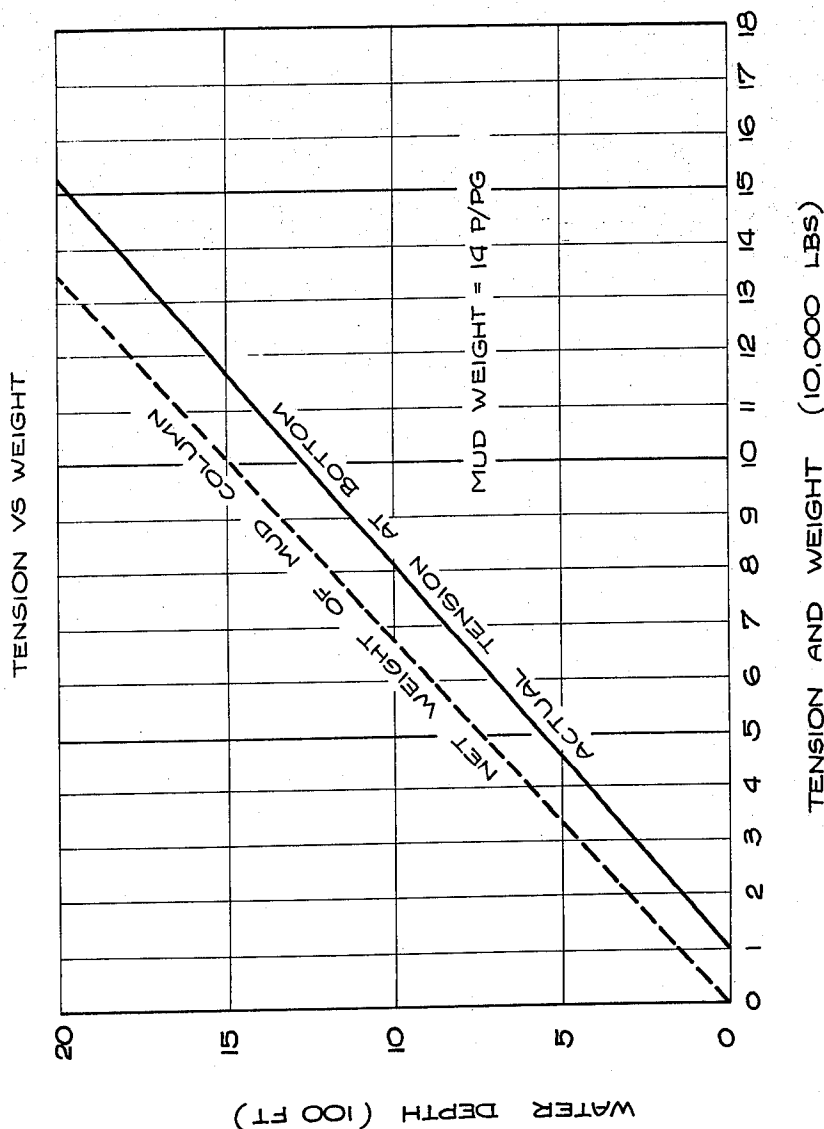


FIG. 2a.

FIG. 2b.

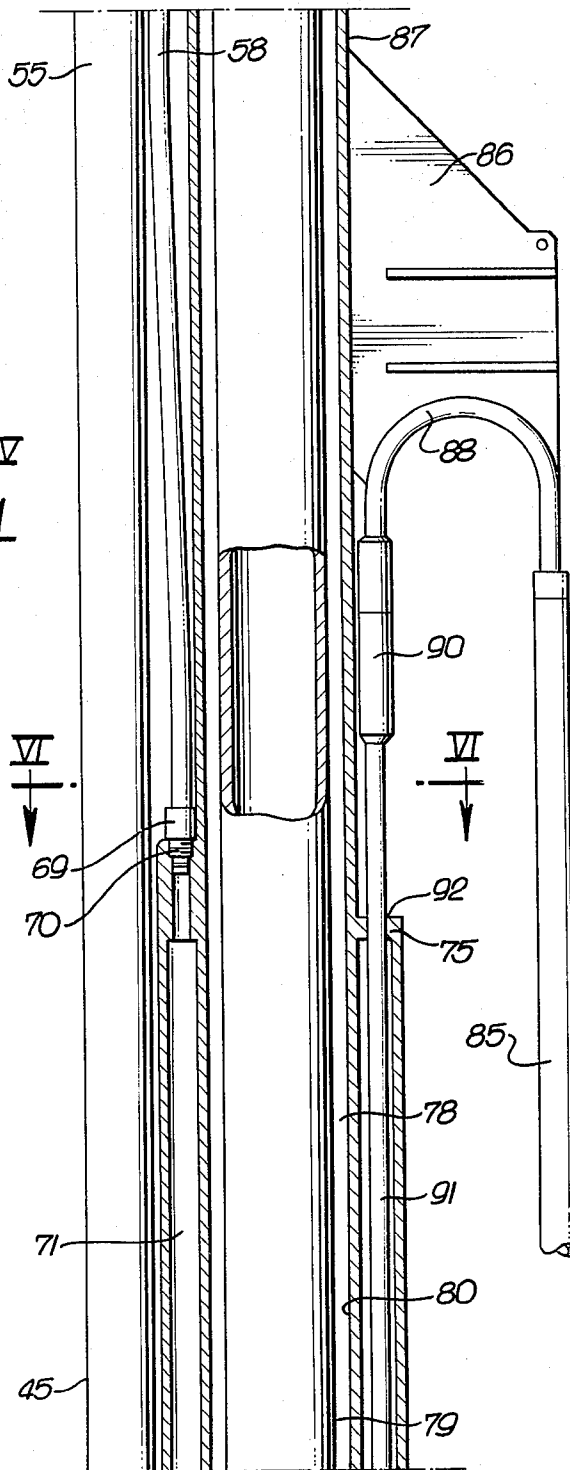
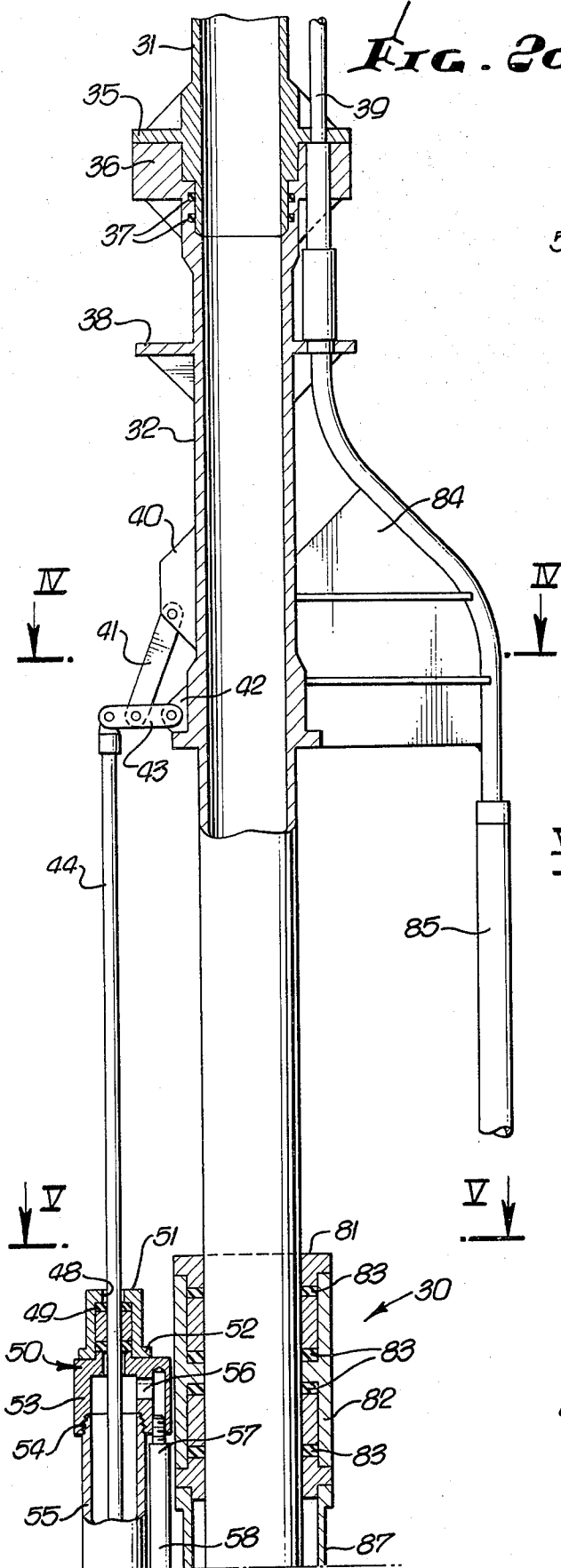


FIG. 2c.

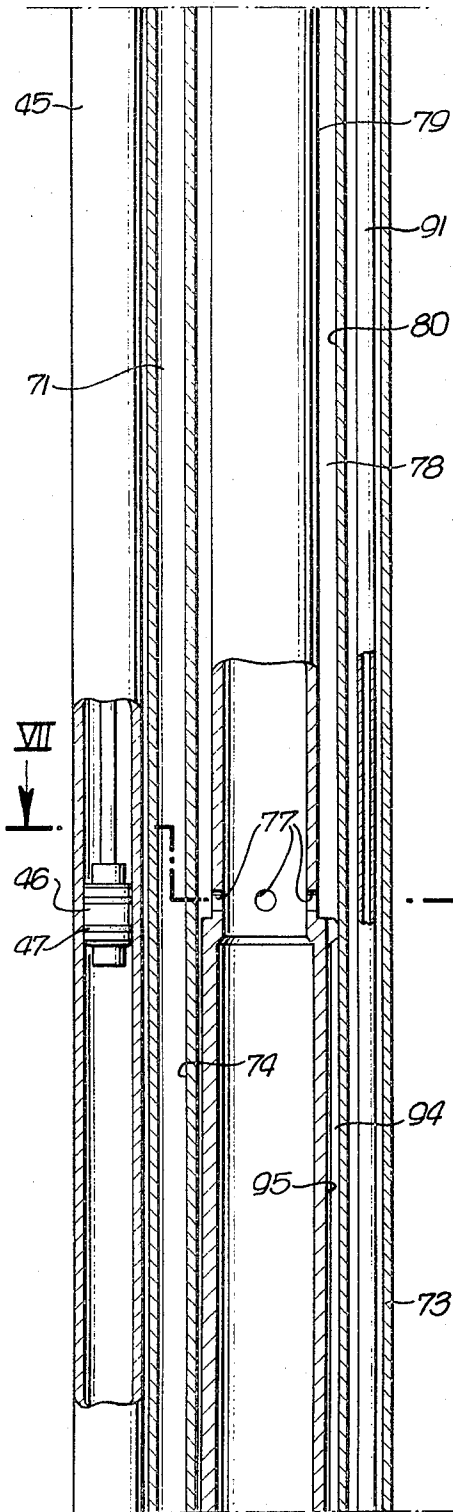


FIG. 2d.

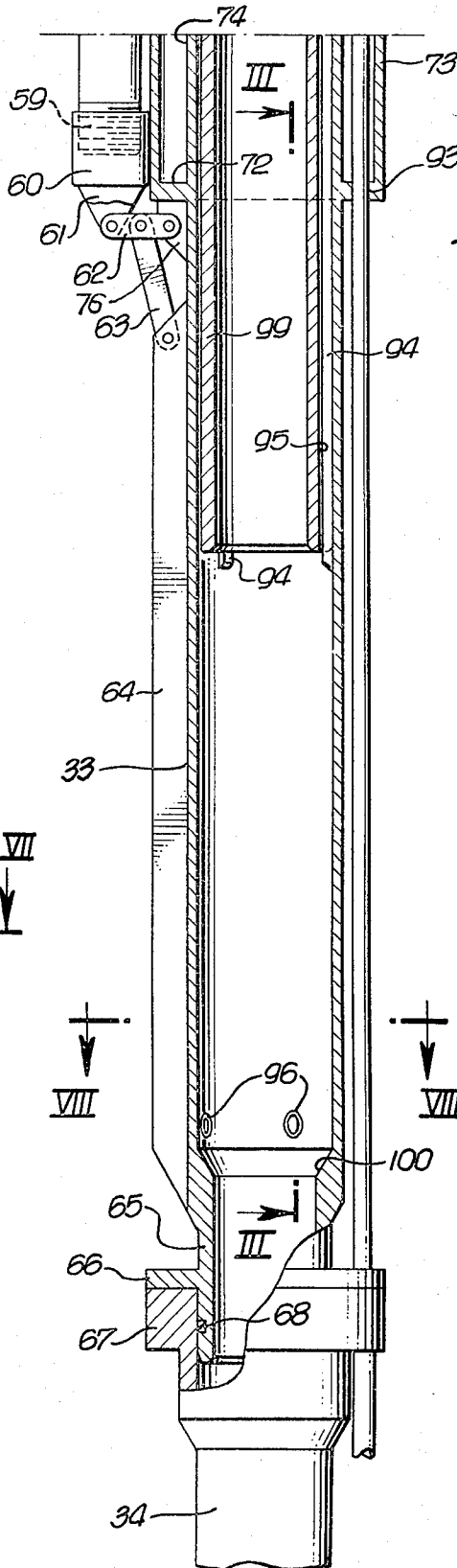


FIG. 3.

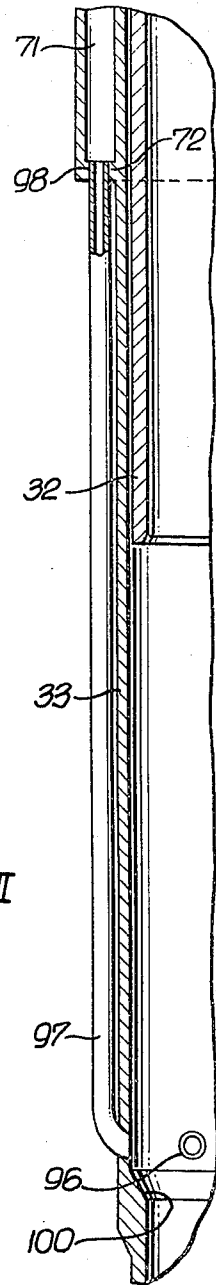


FIG. 4.

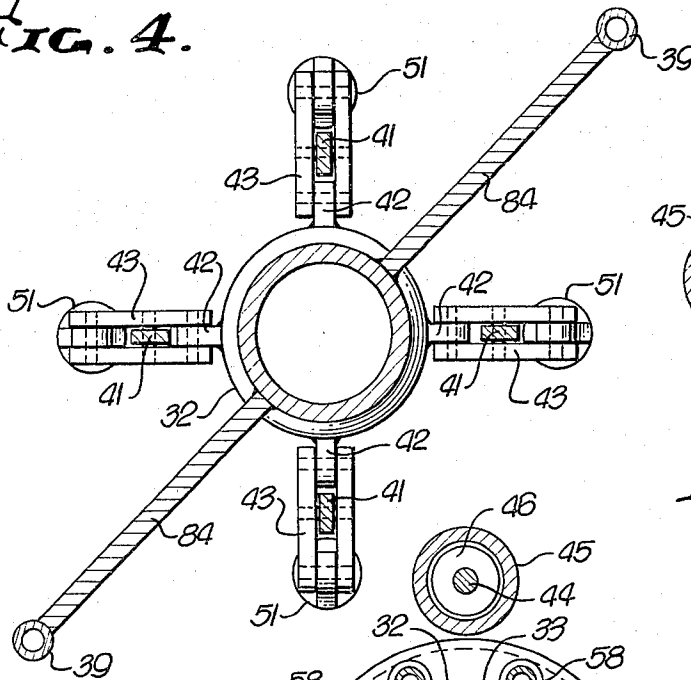


FIG. 7.

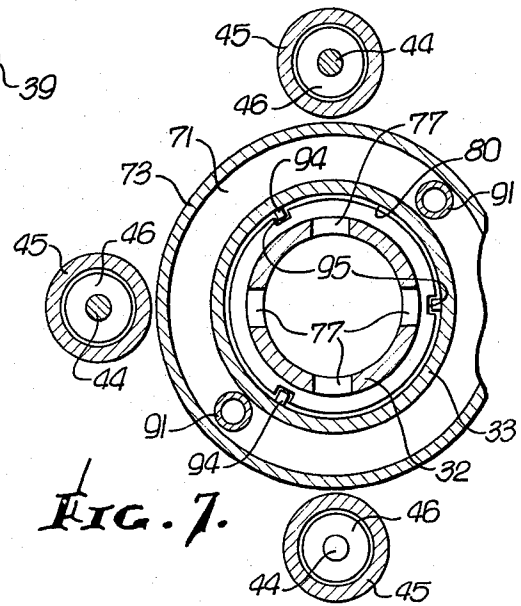


FIG. 6.

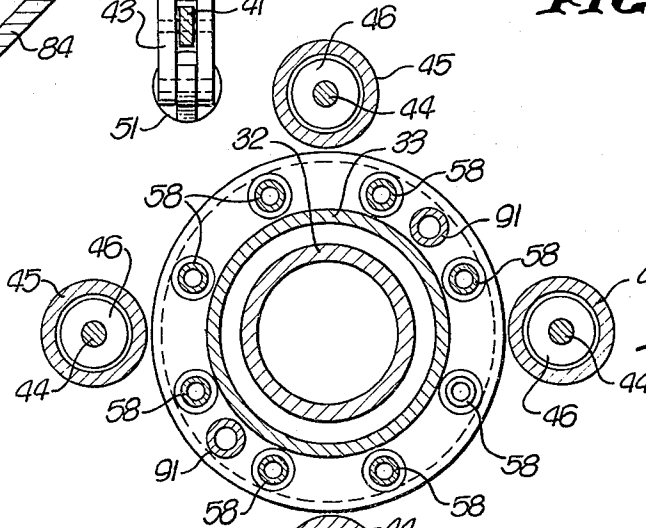


FIG. 5.

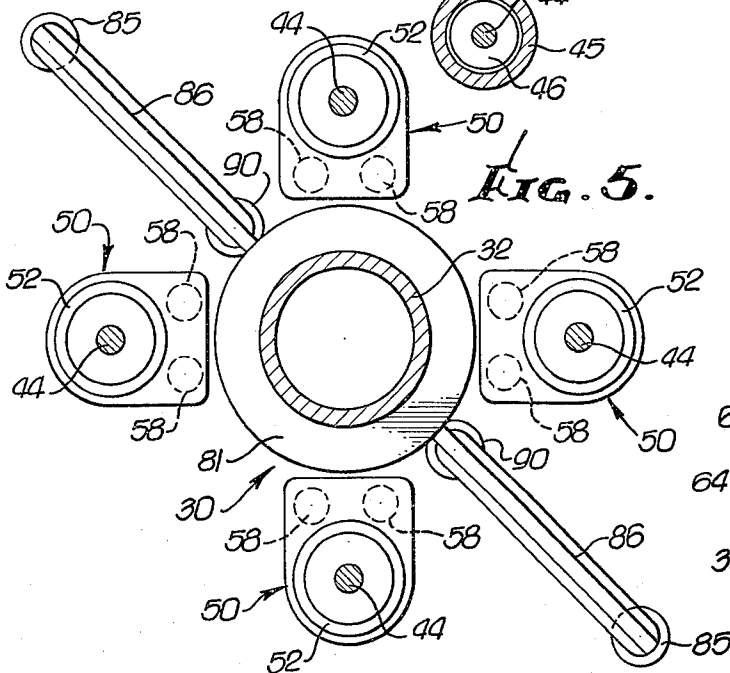
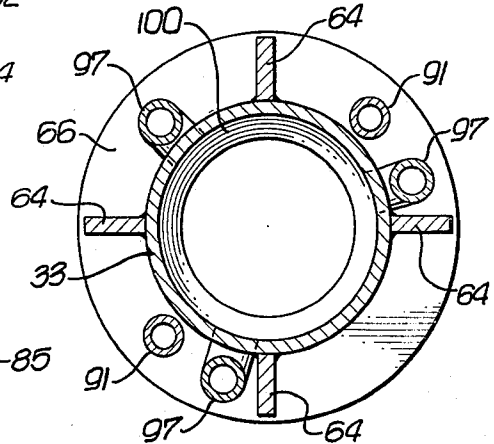


FIG. 8.



TELESCOPIC RISER TENSIONING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to subsea wells; and, more particularly, to apparatus for tensioning a string of casing extending from a vessel to the subsea well.

2. Description of the Prior Art

A typical subsea well has a wellhead located on the sea bottom over the well. The wellhead has a series of valves, called blowout preventers, which selectively open the well to the upper end of the wellhead. A vessel, such as a ship, barge, or the like, floats on the surface of the sea over the wellhead and is connected to the wellhead by guide lines. A hollow riser conduit string is run, via guide lines, from the vessel down to the wellhead for connection thereto.

As is well known in the subsea drilling art, the lower end of the riser conduit string has a riser connector thereto for connecting to the upper end of the wellhead. This connector has a conical downwardly opening cavity or skirt into which the upper end of the wellhead is received to center the connector thereon for mating connection therewith. The connector upon mating with the upper end of the wellhead is coaxially aligned therewith to snugly fit on the upper end and to facilitate the passage of tools, fluids, etc. through the wellhead and up the riser conduit string. Because the vessel moves about over the wellhead due to current, wind, etc., a ball joint is provided between the connector and the rest of the riser conduit string run to the vessel. In like manner, the upper end of the riser conduit string may be coupled to the vessel through a suitable riser and ball joint combination.

However, it is necessary to tension the conduit string in order to efficiently carry oil or the like from the subsea wellhead to the floating vessel. In the past, cumbersome and expensive tensioning devices were used to apply tension to such conduit strings. In addition, it has been suggested to mount buoyant material on the risers of such conduit strings to assist in such tensioning. Such material has inherent disadvantages and limitations.

In many applications, for example, the amount of tension required at the bottom of such risers may exceed 150,000 pounds. If tension of this magnitude was supplied by a weighted riser joint or joints, it would present a severe handling problem. Also, any angular displacement of the riser would impose a high bending moment on the joints and blowout preventers.

SUMMARY OF THE INVENTION

It is an object of this invention to provide subsea tensioning apparatus and method for a subsea wellhead installation.

It is a further object of this invention to provide a riser for a subsea wellhead installation having telescopic tensioning means associated therewith for tensioning a string of casing leading from a vessel to a subsea wellhead.

It is still another object of this invention to carry out the foregoing objects using the weight of the drilling mud rather than dead weight to apply tension to the casing.

These and other objects are preferably accomplished by providing a string of casing extending from a vessel floating on the surface of a body of water to a wellhead operatively connected to a well borehole extending

down into the bottom of the body of water. The casing includes an upper coupling connected at one end to the casing and at the other end to a lower coupling in a telescoping relationship. A tensioner is operatively connected to both couplings for telescoping the couplings in a manner applying tension to the casing. A drilling fluid is injected down the casing and into the well borehole and a portion thereof is diverted from the couplings to a pressure transducer which receives pressure from the weight of the fluid in the casing and applies the force generated thereby to the tensioner to thereby telescope the couplings and apply tension to the casing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a side elevational view of a subsea wellhead, a vessel on the surface of the sea and a string of casing extending between the vessel and the wellhead, with the casing, in accordance with this invention, having telescopic riser tensioning apparatus mounted thereon;

FIGS. 2a, 2b, 2c, 2d constitute a side elevational view partly in section, of exemplary telescopic riser tensioning apparatus in accordance with the invention;

FIG. 3 is a side elevational view, partly in section, of another orientation of a portion of the view of FIG. 2d;

FIG. 4 is a transverse sectional view taken along lines IV—IV of FIG. 2a;

FIG. 5 is a transverse sectional view taken along lines V—V of FIG. 2a;

FIG. 6 is a transverse sectional view taken along lines VI—VI of FIG. 2b;

FIG. 7 is a transverse sectional view taken along lines VII—VII of FIG. 2c;

FIG. 8 is a transverse sectional view taken along lines VIII—VIII of FIG. 2d; and

FIG. 9 is a graphical illustration showing a typical application of the apparatus in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 of the drawing, a typical subsea oil well assembly is shown indicating an ocean bottom 10 on which a conventional wellhead 11 is located. The wellhead 11 has a base 12 over the wellhole which extends down into the ocean bottom 10 and from which a tubular casing 13 rises. The casing 13 has a string of blowout preventers 14 terminating in an upper end 15. A vessel 16 floats on the surface of ocean 17 generally over wellhead 11. Guide lines 18 run from vessel 16 down to the wellhead 11 for guiding the insertion and removal of oil well tools such as a string of casing 20.

The casing 20 is shown extending from the vessel 16 to the wellhead 11 to be connected thereto to receive oil to be carried thereby to vessel 16. The string of casing 20 is made up of individual sections of hollow conduit joined by collars into a string. Adjacent the lower end of the casing 20, a ball joint 22 is provided for allowing the portion of casing 20 above joint 22 to pivot relative to the portion of casing 20 below joint 22. At the lower end of casing 20 is located a connector 25 for connecting the upper end 15 of wellhead 11 and a lower outwardly flared skirt 27 which contains a conical, downwardly opening hole. As the casing 20 is lowered on guide lines 18, the upper end 15 of wellhead 11 slides into the conical hole until the sides of the hole

are engaged. Such engagement centers and coaxially aligns the skirt 27 with the upper end 15 of wellhead 11, so that the upper end 15 will pass from the conical hole into the vertical bore of the upper part 26. The upper end 15 of wellhead 11 fits snugly into the bore of the upper part 26 to maintain connector 25 coaxially aligned therewith for receiving the oil to be carried to vessel 16.

As particularly contemplated within the present invention, telescopic riser tensioning means are provided for applying tension to casing 20. In the exemplary embodiment, such telescopic riser tensioning is indicated generally at 30 and connected to both casing 20 and joint 22. Such riser tensioning means is illustrated more particularly in FIGS. 2 through 8.

Thus, referring now more particularly to FIG. 2a, the riser tensioning means, indicated generally at 30, includes a lower conduit end 31 on string 20 above tensioning means 30, an upper generally tubular coupling 32 joined to the lower conduit end 31, a lower generally tubular coupling 33 telescopically receiving the upper coupling 32 therein (FIG. 2d), and an upper conduit end 34 on casing 20 below tensioning means 30.

Conduit end 31 includes a flange portion 35 (FIG. 2a) adapted to mate with a like flange portion 36 on upper coupling 32 and is secured thereto in a fluid-tight manner by any suitable means. Suitable O-rings 37 may be provided at the point of engagement of upper coupling 32 and lower conduit end 31. A like flange 38 may be provided on upper coupling 32 below flange portion 36. Suitable apertures may be provided in both flange portion 35 and flange 38 for receiving a pair of hoses or flow lines 39 (see FIG. 4) therethrough for reasons to be discussed further hereinbelow.

A plurality of plate or flanges 40 (see FIGS. 2a and 4) are disposed on upper coupling 32 below flange 38 and include links 41 fixedly connected at one end thereto. A like number of plates or flanges 42 are disposed below flanges 40 and also include links 43 fixedly connected at one end thereto. The other ends of links 41 are fixedly connected generally at the midpoint of links 43 while the other ends of links 43 are fixedly connected to piston rods 44. Four such linkage-rod arrangements are shown.

Rods 44 extend down into a like number of piston cylinders 45 which extend longitudinally along the outside of upper coupling 32 (see FIGS. 2a-2c and 6). Rods 44 terminate at their lower ends in pistons 46 (FIG. 2c) slidably mounted within cylinders 45. Suitable O-rings 47 or the like may be associated with each piston 46. The upper end of each rod 44 extends through suitable apertures 48 (FIG. 2a) in the upper ends 50 of cylinders 45 and suitable O-rings 49 or the like may also be associated with each rod 44 and the upper end 50 of each cylinder 45 below aperture 48.

The upper end 50 of each cylinder 45 may be comprised of a cap portion 51 having aperture 48 therein and O-rings 49 associated therewith. Each cap portion 51 includes a flange portion 52 secured in a fluid-tight manner to the top of a threaded member 53 threaded onto the upper end 54 of a main cylinder body portion 55.

An outlet port 56 is provided in each threaded member 53 in fluid communication with the upper end 57 of a plurality of tensioning pipe lines 58. Two such pipe lines 58 are associated with each cylinder 45 (see FIGS. 5 and 6). The lower end of each main cylinder body

portion 55 terminates in a threaded portion 59 threadingly received in a collar member 60 (FIG. 2d). Each collar member 60 terminates at its lower end in a flange 61 pivotally connected to one end of a link 62. Fluid communication with the ambient fluid surrounding means 30 may be provided in collar member 60. A second link 63 is fixedly connected to link 62 generally at the midpoint thereof. The other end of link 63 is fixedly connected to an elongated flange 64 extending along the outside of lower coupling 33.

The lower end 65 of lower coupling 33 includes a flange portion 66 secured in a fluid-tight manner to a like flange portion 67 on upper conduit end 34. Suitable O-rings 68 or the like may be provided at the point of engagement of lower coupling 33 and upper conduit end 34.

The lower ends 69 (FIG. 2b) of pipe lines 58 terminate in threaded portions 70 threadingly received in a surge chamber 71 formed in lower coupling 33 and surrounding upper coupling 32 as clearly shown in FIG. 7. Thus, chamber 71 is formed by providing an integral bottom wall 72 (FIG. 2d) extending about coupling 33, above links 62, 63 and having a generally cylindrical sidewall 73 extending upwardly therefrom (FIG. 2c) and spaced from the inner wall 74 of coupling 33 to form chamber 71. Sidewall 73 terminates in a top wall 75. The other end of each aforementioned link 62 is fixedly connected to a like number of flanges 76 mounted to bottom wall 72 and coupling 33 as shown.

As shown in FIG. 2c and more particularly in FIG. 7, a plurality of balancing ports or holes 77 are provided in lower coupling 32 in fluid communication with a space 78 formed between the outer wall 79 of upper coupling 32 and the inner wall 80 of lower coupling 33 as shown in FIG. 2.

The upper end 81 of lower coupling 33 terminates in a packing member 82 having a plurality of suitable O-rings 83 or the like associated therewith for sealing lower coupling 33 to the outer wall 79 of upper coupling 32 in a fluid-tight manner.

The aforementioned pair of flow lines 39 are braced by flanges 84 (FIG. 2a) secured to the outer wall 79 of upper coupling 32 and each line 39 includes a tubular member 85 extending downwardly generally parallel to upper coupling 32. A like pair of flanges 86 (FIG. 2b) are secured to the outer wall 87 of lower coupling 33 and curved pipe members 88 are secured thereto. Each pipe member 88 carries a portion of aforementioned tubular member 85 at one end and a connecting member 90 at the other end (see also FIGS. 5 and 6). That is, member 85 in FIG. 2b is a continuation of like member 85 in FIG. 2a. Connecting member 90 (FIG. 2b) is connected in a fluid-tight manner to an elongated pipe member 91 extending down through and within chamber 71; i.e., it extends through an aperture 92 in top wall 75, through chamber 71, out an aperture 93 in bottom wall 72, out of chamber 71 and down through suitable aligned apertures in flange portions 66, 67 as shown in FIGS. 2a through 2d.

As shown in FIGS. 2c and 2d and more particularly in FIG. 7, longitudinally extending splines 94 or the like may be provided at spaced locations on the inner wall 80 of lower coupling 33. These splines 94 are adapted to enter longitudinally extending keyways 95 formed on the outer wall 79 of upper coupling 32 to key upper coupling 32 to lower coupling 33 when assembled and

guide the same in its telescopic movement as will be described further hereinbelow.

Apertures or openings 96, similar to aforementioned holes 77, are provided at the bottom of lower coupling 33 as shown in FIG. 2d. As shown in FIGS. 3 and 8, a plurality of bottom pipe lines 97, as for example, three such spaced pipe lines, are in fluid communication at one end with each opening 96 and at the other end in fluid communication with chamber 71 via suitable apertures 98 in bottom wall 72. An internal shoulder 100 is formed at the bottom of lower coupling 33 above its point of connection to upper conduit end 34 to provide a stop for telescoping upper coupling 32.

The upper and lower couplings 32 and 33 thus form the riser portion of the telescopic riser tensioning means, indicated generally at 30. The cylinders 45 and the associated means for activating pistons 46 form the tensioning portion of the telescopic riser tensioning means, indicated generally at 30. Ports 77 are balancing ports which allows drilling fluid, such as mud or the like, present in couplings 32, 33 to exit therethrough and into the space 78 to fill space 78. This prevents any unbalanced pressures from being created on the upper coupling 32.

The lower portion 99 of upper coupling 32 is relatively long and heavy so as to stabilize the couplings 32 and 33 in their extended position and concentrate the initial required tension at the lowest possible point.

The telescopic riser tensioning means, indicated generally at 30, may be run down through a rotary table (not shown) mounted on vessel 16. The various couplings disclosed hereinabove may be quick couplings permitting the quick and easy attachment of the cylinders 45 and lines 39.

In operation, when the telescopic riser tensioning means, indicated generally at 30, is first lowered down into the ocean 17, chamber 71 is filled one-half with water and one-half with mud. This mixture may be placed in chamber 71 initially or the drilling mud or the like may displace water in chamber 71 and result in the one-half mixture. As drilling mud or the like is circulated down through the riser portion of means 30, i.e., through couplings 32 and 33, the mud exits from ports 77 into space 78 and fills space 78 to prevent the creation of unbalanced pressures as discussed hereinabove. Packing member 82 retains the mud within space 78.

As the mud is circulated, it exits from ports 96 in coupling 33, up pipelines 97 and into surge chamber 71. The mud thus displaces any water in chamber 71. The mud then exits from chamber 71 via the flexible couplings to the cylinders 45 (i.e., the tensioning pipelines 58). Since each pair of pipelines 58 are in fluid communication with a cylinder 45 via ports 56, the drilling mud enters each cylinder 45 and forces each piston 46 downwardly. Any fluid or mud below piston 46 would exit out of collar member 60 as discussed hereinabove.

As pistons 46 are moved downwardly, rods 44 are of course also moved downwardly. Since rods 44 are fixedly connected to both the upper and lower couplings 32 and 33 via the aforementioned linkage arrangements, the couplings 32 and 33 are telescoped and pull the lower conduit end 31 downwardly to thereby tension casing 20.

The flow lines 39 and tubular members 85 are sufficiently long and/or flexible to permit telescoping movement of couplings 32 and 33. These members 85 are

coupled to the conventional B.O.P. stacks 14 on well-head 11 and fluid may be injected down lines 39 from vessel 16 as is well known in the art.

The weight of the drilling mud present in casing 20 is thus used to apply tension to casing 20. By adjusting the size of tensioning cylinders 45, tensioning may be increased at a predetermined rate faster than the weight of the mud column present in casing 20. An initial tension of approximately 10,000 pounds is provided by the length and weight lower portion 99 of upper coupling 32.

Any suitable materials known in the drilling art may be used to carry out the techniques of my invention. The cylinders 45 may be sized so that only opposite pairs are in service at one time. These cylinders 45 are flexibly attached to surge chamber 71 which is concentric with respect to telescoping couplings 32 and 33. The volume of chamber 71 is preferably approximately twice the displacement of cylinders 45 to assist in keeping the drilling mud out of cylinders 45.

The foregoing is an example of telescopic riser tensioning means in accordance with my invention.

EXAMPLE

25 Dimensions for Upper and Lower Couplings 32, 33.

Maximum outside diameter of both couplings 32, 33=18 $\frac{3}{8}$ ".

Minimum inside diameter of both couplings 32, 33=17 $\frac{3}{8}$ ".

30 Wall area of the lower end of lower portion 99=35 sq. ft.

Inside cross-sectional area of lower end of lower portion 99=237 sq. ft.

35 Dimensions and Specifications for Cylinders 45.

Total area of all four cylinders=4(78.5 sq. ft.)=314 sq. ft.

Total area of all four rods=4(6.5 sq. ft.)=27 sq. ft.

40 Net tension area=total cylinder area-total rod area-wall area of lower portion 99=314 sq. ft.-27 sq. ft.-35 sq. ft.=252 sq. ft.

Initial tension on means 30=10,000 lbs.

Calculations

45 Depth of ocean 17=1,500 feet.

Weight of drilling mud=14 lb./gal.

Mud gradient=mud weight $\times$ 7.48 gal./sq. ft./ft. $\div$ 144 sq. ft./sq. ft.=14(7.48)/144=.728 psi./ft.

50 Water gradient=weight of water $\times$ 7.48 gal./sq. ft./ft. $\div$ 144 sq. ft./sq. ft.=8.337 lbs./gal./144(7.48)=.445 psi./ft.

Net gradient=mud gradient-water gradient=.728-.445=.283 psi./ft.

Hydraulic tension-net gradient $\times$ net tension area $\times$ water depth=.283 (252) (1,500)=107,000 lbs.

55 Total tension=hydraulic tension+initial tension or 107,000 lbs.+10,000 lbs.=117,000 lbs.

Mud column weight=net gradient $\times$ inside area $\times$ water depth or .283 (237) (1,500)=101,000 lbs.

60 The above information may be plotted on a graph such as that illustrated in FIG. 9 where tension and weight is plotted with respect to the water depth. It can be seen that, since the net tension area is 6 percent greater than the inside area, the effective working surface area of cylinders 45 is 6 percent greater than the area of the mud in the lower end of lower portion 99. Thus, the tension increases 6 percent faster than the weight of the mud column.

It can be seen from the foregoing that I have described a telescopic riser tensioning means utilizing the weight of the drilling mud to apply tension on casing 20. This tension automatically increases as the required tension increases. By adjusting the size of cylinders 45, tensioning may be increased at a predetermined rate faster than the weight of the mud column. The initial tension of approximately 10,000 lbs. is provided by the lower end 99 of upper coupling 32.

I claim:

1. In an apparatus for applying tension to a string of casing extending from a vessel floating on the surface of a body of water to a subsea wellhead and having a drilling fluid therein, said apparatus including:

- a hollow upper coupling member fixedly connected at one end to said string of casing in a fluid-tight manner and
- a hollow lower coupling member having one end telescopically receiving the other end of said upper coupling member in a fluid-tight manner and its other end fixedly connected to said wellhead in a fluid-tight manner thereby defining a bore extending through said string of pipe, said telescoping upper and lower coupling members and said wellhead, the improvement comprising the provision of:

tensioning means operatively connected to both said upper and lower coupling members for telescoping said coupling members to thereby apply tension to said casing, said tensioning means including pressure transducing means for receiving pressure from the weight of said fluid in said casing and applying the force generated thereby to said tensioning means to thereby telescope said coupling members and thus tension said casing,

said tensioning means including a surge chamber surrounding said coupling members and separated therefrom in a fluid-tight manner, said surge chamber being sealed off from ambient fluid surrounding said surge chamber,

said pressure transducing means including at least one cylinder having a piston slidably movable therein, said piston having a piston rod operatively connected to one of said coupling members, said cylinder being operatively connected to said surge chamber,

and said tensioning means further including means associated with said lower coupling member in fluid communication with said surge chamber, and said surge chamber being in fluid communication with the interior of said cylinders above said pistons.

2. The apparatus of claim 1 wherein at least four such cylinders are provided at spaced locations surrounding said surge chamber.

3. A telescopic riser tensioning apparatus for applying tension between upper and lower couplings of a telescopic joint in a subsea riser conduit run from a floating vessel to a subsea wellhead comprising:

- a surge chamber and means for connecting said chamber in fluid communication with the interior of said riser conduit, said surge chamber comprising an annular chamber and means for mounting it

about at least one of said couplings;

at least one or more piston and cylinder means connected across said joint for tensioning said upper and lower couplings toward one another upon introduction of fluid under pressure into each said piston and cylinder means; and

means for connecting said surge chamber to each said piston and cylinder means in fluid communication whereby fluid pressure within said riser conduit is transmitted via said surge chamber to said piston and cylinder means.

4. A telescopic riser tensioning apparatus for applying tension between upper and lower couplings of a telescopic joint in a subsea riser conduit run from a floating vessel to a subsea wellhead comprising:

- a surge chamber and means for connecting said chamber in fluid communication with the interior of said riser conduit;

at least one or more piston and cylinder means connected across said joint for tensioning said upper and lower couplings toward one another upon introduction of fluid under pressure into each said piston and cylinder means wherein said one or more piston and cylinder means are provided with an effective working surface area which is greater than the cross-sectional area of the bore of the riser conduit between said joint and said vessel whereby the tension in pounds force exerted by said tensioning apparatus increases at a faster rate than does the weight of a column of fluid within said riser conduit on lengthening of said riser conduit; and means for connecting said surge chamber to each said piston and cylinder means in fluid communication whereby fluid pressure within said riser conduit is transmitted via said surge chamber to said piston and cylinder means.

5. The telescopic riser tensioning apparatus of claim 4 wherein said working surface area of said piston and cylinder means is at least 6 percent greater than the cross-sectional area of the bore of said riser conduit.

6. A telescopic riser tensioning apparatus for applying tension between upper and lower couplings of a telescopic joint in a subsea riser conduit run from a floating vessel to a subsea wellhead comprising:

- a surge chamber and means for connecting said chamber in fluid communication with the interior of said riser conduit;

at least one or more piston and cylinder means connected across said joint for tensioning said upper and lower couplings toward one another upon introduction of fluid under pressure into each said piston and cylinder means;

means for connecting said surge chamber to each said piston and cylinder means in fluid communication whereby fluid pressure within said riser conduit is transmitted via said surge chamber to said piston and cylinder means; and

an elongated weighted portion on the upper coupling of said telescopic joint for providing an initial tensioning of the riser conduit thereabove in a predetermined amount greater than otherwise provided by said upper coupling.

* * * * *