SPECIFICATION

Vertically Moored Platform Anchoring

Background of the Invention

Field of the Invention

This invention relates to a structure floating on a body of water. More particularly, the invention relates to a floating structure from which drilling wells and/or production of oil and gas or like operations, or both, are carried out. In its more specific aspects, the invention concerns a floating structure having buoyancy means to float the structure and in which the structure is anchored by a plurality of essentially parallel and vertical conduits commonly called "risers". More specifically, the invention concerns such a structure in which concentric casing strings, within riser pipes, form an important part of the anchoring system.

Setting

In recent years, it has become desirable to use a floating vessel from which to drill wells in marine locations. Many of these structures have been maintained on station by conventional spread catenary mooring lines, or by propulsion thruster units. One system of floating vessel receiving attention for drilling or production of wells in water is the Vertically Moored Platform, such as described in U.S. Patent 3,648,638, issued March 14, 1972, entitled "Vertically Moored Platform", Kenneth A. Blenkarn, inventor. A key feature of Vertically Moored Platforms is that the floating platform is connected to anchor means in the ocean floor only be elongated, parallel members which are preferred to be large diameter conduits, commonly called "riser pipes". These elongated members or riser pipes are held in tension by excess buoyancy of the platform.

Prior Art

This invention is an improvement over the anchoring system described in U.S. Patent 3,648,638, supra. This patent is considered the closest prior art and, as stated above, our present invention is an improvement thereon. Other patents dealing with Vertically Moored Platforms include U.S. 3,559,410; U.S. 3,559,411; U.S. 3,572,272; U.S. 3,976,021; U.S. 3,978,804; U.S. 3,983,828; U.S. 3,993,273; U.S. 4,062,313; and U.S. 3,154,039. There are prior patents and art which teach to have concentric strings of casing extending from an underwater well to a platform above the water. In this latter regard, attention is directed to U.S. Patent 3,971,576. U.S. Patent 3,705,623 shows concentric pipes 33 and 17 connected to a buoyancy member 19; however, those concentric pipes form no part of the anchoring system. None of these patents or art to our knowledge teach to anchor a Vertically Moored Platform by means of concentric tensioned casing strings within an outer tensioned riser pipe. No prior art is known to do this.

This invention concerns an anchoring system and method of connecting a vessel floating on a body of water to a subsea well having a first string of casing set and secured in a hole in the bottom of said body of water, and a second string of casing supported in the first string and extending deeper than said first string of casing and secured in said hole.

According to one aspect of the present invention there is provided a method of connecting a vessel floating on a body of water to a subsea well having a first string of casing set and secured in a hole in the bottom of said body of water and a second string of casing supported within said first string and extending deeper than said first string and secured in said hole which comprises:

connecting a first riser conduit at its lower end to said first string of casing in a sealing relationship so that said first riser conduit and said first string of casing form a fluid-tight conduit;

supporting the upper end of said first riser conduit from said vessel to apply tension thereto;

connecting the lower end of a second riser conduit to said second string of casing in a sealing relationship so that said second string of casing and said second riser conduit form a second fluid-tight conduit; and

supporting the upper end of said second riser conduit from said vessel and applying a tension to said second riser conduit from the buoyancy of said vessel.

In accordance with a preferred aspect of the invention in which a vessel floating on a body of water is anchored to a subsea well having a first string of casing set and secured in said hole and a third string of casing supported within said second string and extending deeper than said second string and secured in said hole, said method comprises:

connecting a first riser conduit at its lower end to said first string of casing in sealing relationship so that said first riser conduit and said first string of casing form a fluid-tight conduit;

supporting the upper end of said first riser conduit from said vessel to apply tension thereto;

connecting the lower end of a second riser conduit to said second string of casing;

applying tension to said second riser conduit from tension means supported by said vessel and connected to the upper end of said second string of casing;

securing the upper end of said second riser conduit while under tension to an upper portion of said first riser conduit;

disconnecting said second riser conduit from said tension means;

connecting the lower end of a third riser conduit to said third string of casing;

applying tension to said third riser conduit from tension means supported by said vessel and connected to the upper end of said third string of casing;

securing the upper end of said third riser conduit while under tension to an upper portion of said first riser conduit; and

disconnecting said third riser conduit from said tension means.

The invention further provides a system for anchoring a vessel floating on a body of water to a plurality of concentric casings anchored in the floor of the body of water which comprises:

a tensioned first riser conduit;

a vertical support bearing connecting an upper end portion of said first riser conduit to said vessel;

a horizontal bearing between an upper end portion of said first riser conduit and said vessel to transmit horizontal forces therethrough;

a tensioned riser casing string within said first riser conduit; and

support means supporting said riser casing string from said vessel.

Preferably said support means supports said riser casing string from said first riser conduit at a level above said vertical support bearing.

As indicated, in carrying out the method of the invention, a first riser conduit (commonly called a "riser pipe") is connected at its lower end to said first string of casing in a sealing relationship so that the first riser conduit and the first string of casing from a fluid-tight conduit. The upper end of said first riser conduit is supported from the vessel to apply a tension thereto. The lower end of a second riser conduit or riser casing is connected to the second string of casing in a sealing relationship so that said second string of casing and the second riser conduit form a second fluid-tight conduit. The upper end of the second riser conduit is supported from an upper portion of the first riser conduit such that a tension is applied to the second riser conduit when tension is applied to the first riser conduit.

The upper and lower ends of the first riser conduit (or riser pipe) may be provided with terminators which are really stiffened sections of the riser pipe to distribute curvature over a length or a portion of the length of the riser pipe. The second or inner riser conduits may be provided with centralizers within the outer or first riser conduit terminators. The upper and lower ends of the inner casing strings need no terminators.

The invention will now be described in more detail with particular reference to the accompanying drawings of which:

Figure 1 is a view of a Vertically Moored Platform.

Figure 2 illustrates, partly in cutaway view, one riser pipe means of one leg of the Vertically Moored Platform of Figure 1.

Figure 3 illustrates an enlarged cross-sectional view of the means of Figure 2 of connecting the top ends of the inner casing strings to the riser pipe.

Figure 4 shows one means of connecting the riser pipe to the string of casing anchored in the wellbore.

Reference is first made to Figure 1 which shows a side view of a Vertically Moored Platform. Shown therein is a platform 10 supported on a body of water 12 having a bottom 14. The structure 10 generally includes a float means 16 which supports a working deck 18 above the surface 20 of the body of water 12. It is to be noted that a Vertically Moored Platform is described in detail in prior U.S. Patent 3,648,638, supra. Float means 16 is, for example, composed of four bottle-shaped buoyant legs 22. Each leg 22 is anchored by a plurality of riser pipes 24 which are provided with spacers 26. Riser pipes 24 connect to casings 28 which are cemented in holes in the bottom of the body of water.

A template 30 is shown on the bottom 14 through which the wells for casings 28 were guided. Riser pipes 24 normally are made of high quality steel and typically are 20 inches in diameter. The riser pipes 24 are parallel and are held in tension by the vertical force exerted on the buoyant structure. The typical length of these riser pipes 24 may be from 500 feet up to several thousand feet from the base of the leg member 22 of the Vertically Moored Platform to the sea floor 14.

Attention is next directed to Figure 2 which illustrates an improved anchoring connection means between the Vertically Moored Platform and the sea floor. Shown thereon is leg 22 which is one of the four float members of the Vertically Moored Platform of Figure 1. For simplicity and ease of understanding, we have shown only one riser pipe means extending between the leg 22 and the sea bottom 14. A vertical passage 32 extends through the lower part or enlarged portion of leg 22. The upper end of riser pipe means 24 is provided with an upper riser terminator 34. As a word of explanation, it is known that if a tubular member is held under tension and subject to bending, stresses concentrated in the ends. One way of meeting this problem is to make the end section sufficiently strong to distribute the bending deformation which may concentrate therein over a longer length. This is what is done here and we call the strengthened portion "a terminator", in this case, "the upper riser terminator 34". Thus, a terminator is a stiffened section of riser pipe to distribute curvature over a selected portion of the riser pipe.

Upper horizontal bearings 36 and lower horizontal bearings 38 are provided between upper terminator 34 and the wall of passage 32 through jacket 22. Above the horizontal bearing 36 is a

vertical bearing means 40. Details of this vertical bearings 40 are shown in Patent 3,976,021, Figures 17 and 18. It includes primarily a jack 42, bracket 44, engaging shoulders 46 of the upper end of the upper riser terminator 34, and shims and bearings 48. The vertical force of the tension in riser pipe 24 is transmitted through vertical bearing 40 to the Vertically Moored Platform jacket 22.

The lower end of riser pipe 24 is connected to a lower terminator 50 which passes through a drive pipe 52 in template 30. A 20-inch conductor casing 54 is hung from drive pipe 52 through mudline suspension 56, which in reality may be a upwardly facing shoulder 58 on drive pipe 52, and a shoulder 60 having a downwardly facing shoulder attached to the outer wall of 20-inch conductor casing 54. If the bottom 14 is sufficiently soft, drive pipe 52 can be driven the required depth into the bottom 14; otherwise, a hole can be drilled through the guide tube. A hole can be drilled through drive pipe 52 and the 20-inch conductor casing 54 set and cemented in place using conventional sea-drilling equipment.

After the 20-inch casing has been cemented in place, a smaller diameter hole to accommodate the next smaller size of casing can be drilled in the bottom thereof. This may be a 13-5/8 inch casing, which is illustrated as casing 62, which is supported by mudline suspension 64, which is similar to mudline suspension 56. The second or 13-5/8 inch casing 62 is then run and cemented in place. Then, the 13-5/8 riser casing string 78 is run and connected to casing 62. After this, an additional hole is drilled to accommodate the next smaller size of casing, which may be 9-5/8. Again, the innermost casing string 66 is run and cemented in place and is suspended by mudline suspension 68. Any desired number of these casing strings may be set in place in drilled holes in a manner described above which is well known. The upper ends of each of casings 54, 62 and 66 are provided with a locking means, such as J-slots 70, 72 and 74.

The lower end of riser pipe 24 is connected to the upper end of casing conductor 54 by a J-lug 76 which fits into the J-slot 70. Sealing means are also provided so that a fluid-tight conduit is formed from the conductor or outer casing 54 upwardly to the floating structure as exemplified by jacket 22. Latching means, not shown, between casing string 54 and drive pipe 52 can be installed to restrain vertical movement between casing string 54 and drive pipe 52. A similar device can be installed for succeeding pairs of casing strings such as strings 62 and 66.

Within riser pipe 24 are shown two concentric strings of casing, an intermediate string 78 and the innermost string 80. Of course, any reasonable number of inner casing strings can be used. The lowermost end of intermediate string 78 is connected through J-slot 72 to the cemented casing string 62 in the borehole, and, likewise, the lower end of innermost casing string 80 is connected to the cemented casing string 66, which is shown as the smaller one in the drawing. Thus, we have a string of casing 62 and intermediate casing string 78 forming a fluidtight conduit extending from the bottom of the casing to the top of the intermediate casing 78; likewise, a smaller fluid-tight conduit is formed from the lower end of the innermost set casing 66 through casing string 80 to the top of the platform. If desired, intermediate casing string 78 can be run before the hole for the inner casing string 66 is drilled.

The connecting arrangement between the riser pipe and the casing set in the wellbore is shown in Figure 4. Shown thereon also is the J-slot 70 on the upper end of the enlarged end portion of casing 54 and a J-lug 76, which is on the lower end of riser 24. Seal means 82 are provided between the lower end of riser 24 and the enlarged portion of the upper end of casing string 54. Connection 72 for intermediate casing string 78 and cemented casing 62 and connection 74 for innermost casing string 80 and cemented casing 66 can be like that shown in Figure 4.

Attention is now directed to means for supporting the upper end of intermediate string 78 and innermost of riser conduit 80 to the upper end of the riser pipe such that the inner casing riser strings 78 and 80 form a part of the anchoring system. This is shown clearly in Figure 3. The upper end of riser pipe extension 24A is provided with a flange 81. A casing hanger spool 84 is provided to sit on top of flange 81. Means are provided to connect the casing hanger spool 84 to the intermediate casing string 78. This includes a slip means 86. Screw 88 is used to set a seal of the annulus between casing 78 and casing hanger spool 84. Thus, the upper end of casing 78 is supported from riser extension 24A through casing hanger spool 84. Casing hanger spool 84 has an upper flange 92 which supports casing hanger spool 94; thus, innermost casing string 80 is supported from riser extension 24A through casing hanger spools 84 and 94. Bolts 100, 102 and 104 with proper machining and sealing are provided to assure fluid-tight annular spaces 106 between riser extension 24A and riser casing conduit 78 and unnulus 108 between the two inner strings of casing 78 and 80. Plugs 110 and 112 may be removed and pressure gauges installed to determine the pressure in these annuli. Conventional valves and other equipment may be placed on extension 114 in which to produce the well drilled through these casings.

The preferred installation procedure is to first pre-tension the riser 24 to a predetermined value with the jack 42 and then shim it in place on bearing 48. The hole for the casing 62 is drilled. The casing 62 is run and cemented in. The riser casing 78 is run and latched to casing 62 at the J-slot 72; then, the casing riser 78 is tensioned with the draw work of the drilling rig to a predetermined value which is a function of the riser 24 tension. The locking means 86 is set, locking the upper end of casing riser 78 to casing hanger spool 84. Other inner strings are installed in a similar manner.

Within riser 24 and riser terminators 34 and 50, we have provided centralizers 35 between the riser 24 and terminators 34 and 50 and the first or intermediate string of casing 78 and centralizers 37 between casing strings 78 and 80. By thus doing so, we control the frictional wear caused by the relative motion between the two strings. Also, the casing string, being inside the riser, does not require a terminator.

By the system that we have just described, a substantial part of the mooring is by the inner casing strings 78 and 80. This provides a much stronger anchoring means for a given size of riser pipe and will afford more protection in the event of a very severe storm. The amount of mooring by the outer riser pipe 24 compared to the inner casing strings 78, 80, etc., is a function of the cross-sectional area or, more accurately, a function of their respective axial flexibility. The part of the mooring carried by the casing risers may vary from as low as about 25% to about 70% of the total mooring forces.

An example of where the casing risers carry 27% of the mooring force in calm water is:

Riser (24)	18-5/8" OD 0.625" W.T.	610 kips
Casing Riser (78)	9-5/8" OD 0.352" W.T.	128 kips
Casing Riser (80)	7" OD 0.272" W.T.	72 kips
Tubing Riser	2-7/8" OD 0.217" W.T.	23 kips

Note: A KIP is 1000 pounds.

An example of where the casing risers carry 45% of the mooring force in calm water is:

Riser	18-5/8" OD 0.625" W.T.	455 kips
Casing	13-3/8"OD 0.380" W.T.	144 kips
Casing	9-5/8" OD 0.472" W.T.	126 kips
Casing	7" OD 0.453" W.T.	86 kips
Tubing	2-7/8" OD 0.276" W.T.	21 kips

An example of where the casing risers carry 60% of the mooring force in calm water is:

Riser	18-5/8" OD 0.625" W.T.	460 kips
Casing Riser	13-3/8" OD 0.380" W.T.	208 kips
Casing Riser	9-5/8" OD 0.972" W.T.	239 kips
Casing Riser	7" OD 0.276" W.T.	194 kips
Tubing Riser	2x2-3/8" OD 0.190" W.T.	45 kips

An example of where the casing risers carry 67% of the mooring force in calm water is

Riser	18-5/8" OD 0.625" W.T.	460 kips
Casing Riser	13-3/8" OD 0.719" W.T.	383 kips
Casing Riser	9-5/8" OD 0.545" W.T.	271 kips
Casing Riser	7" OD 0.54" W.T.	231 kips
Tubing Riser	2x2-3/8" OD 0.218" W.T.	60 kips

These distributions are determined by the axial flexibility of the riser strings and by the expected temperature and pressure effect. They will change when the temperature and the pressure distribution between each string vary. They will also change when the total mooring force changes under the influence of the wind, the waves, and the current.

While the above embodiments have been described in great detail, it is possible to incorporate variations therein without departing from the spirit or scope of the invention.

Claims

1. A method of connecting a vessel floating on a body of water to a subsea well having a first string of casing set and secured in a hole in the bottom of said body of water and a second string of casing supported within said first string and extending deeper than said first string and secured in said hole which comprises:

connecting a first riser conduit at its lower end to said first string of casing in a sealing relationship so that said first riser conduit and said first string of casing form a fluid-tight conduit;

supporting the upper end of said first riser conduit from said vessel to apply tension thereto;

connecting the lower end of a second riser conduit to said second string of casing in a sealing relationship so that said second string of casing and said second riser conduit form a second fluid-tight conduit; and

supporting the upper end of said second riser conduit from said vessel and applying a tension to said second riser conduit from the buoyancy of said vessel.

2. A method as claimed in Claim 1 including supporting said second riser conduit from the upper

Within riser 24 and riser terminators 34 and 50, we have provided centralizers 35 between the riser 24 and terminators 34 and 50 and the first or intermediate string of casing 78 and centralizers 37 between casing strings 78 and 80. By thus doing so, we control the frictional wear caused by the relative motion between the two strings. Also, the casing string, being inside the riser, does not require a terminator.

By the system that we have just described, a substantial part of the mooring is by the inner casing strings 78 and 80. This provides a much stronger anchoring means for a given size of riser pipe and will afford more protection in the event of a very severe storm. The amount of mooring by the outer riser pipe 24 compared to the inner casing strings 78, 80, etc., is a function of the cross-sectional area or, more accurately, a function of their respective axial flexibility. The part of the mooring carried by the casing risers may vary from as low as about 25% to about 70% of the total mooring forces.

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These distributions are determined by the axial flexibility of the riser strings and by the expected temperature and pressure effect. They will change when the temperature and the pressure distribution between each string vary. They will also change when the total mooring force changes under the influence of the wind, the waves, and the current.

While the above embodiments have been described in great detail, it is possible to incorporate variations therein without departing from the spirit or scope of the invention.

Claims

1. A method of connecting a vessel floating on a body of water to a subsea well having a first string of casing set and secured in a hole in the bottom of said body of water and a second string of casing supported within said first string and extending deeper than said first string and secured in said hole which comprises:

connecting a first riser conduit at its lower end to said first string of casing in a sealing relationship so that said first riser conduit and said first string of casing form a fluid-tight conduit;

supporting the upper end of said first riser conduit from said vessel to apply tension thereto;

connecting the lower end of a second riser conduit to said second string of casing in a sealing relationship so that said second string of casing and said second riser conduit form a second fluid-tight conduit; and

supporting the upper end of said second riser conduit from said vessel and applying a tension to said second riser conduit from the buoyancy of said vessel.

2. A method as claimed in Claim 1 including supporting said second riser conduit from the upper

end of said first riser conduit at a point above the level on said first riser conduit at which said first riser conduit is supported from said vessel.

3. A method as claimed in Claim 1 or Claim 2 wherein the axial tension applied to all tensioned conduits within said first riser conduit is in the range of about 25% and about 70% of the total axial tension carried by said first riser conduit and all tensioned conduits within said first riser conduit.

4. A system for anchoring a vessel floating on a body of water to a plurality of concentric casings anchored in the floor of the body of water which comprises:

a tensioned first riser conduit;

a vertical support bearing connecting an upper end portion of said first riser conduit to said vessel;

a horizontal bearing between an upper end portion of said first riser conduit and said vessel to transmit horizontal forces therethrough;

a tensioned riser casing string within said first riser conduit; and

support means supporting said riser casing string from said vessel.

5. A system as claimed in Claim 4 in which a portion of the upper end of the riser conduit extending through the horizontal bearing is a terminator.

6. A system as claimed in Claim 4 or Claim 5 including a centralizer on said riser casing string within said terminator, the wall of said riser casing string being of about uniform thickness along its entire length.

7. A system for anchoring a vessel floating on a body of water to a plurality of concentric casings anchored in the floor of the body of water which comprises:

a tensioned first riser conduit;

a vertical support bearing connecting an upper end portion of said first riser conduit to said vessel;

a horizontal bearing between an upper end portion of said first riser conduit and said vessel to transmit horizontal forces therethrough;

a tensioned riser casing string within said first riser conduit; and

support means supporting said riser casing string from said first riser conduit at a level above said vertical support bearing.

8. A method of anchoring a vessel floating on a body of water to a subsea well having a first string of casing set and secured in a hole in the bottom of said body of water, a second string of casing supported within said first string and extending deeper than said first string and secured in said hole and a third string of casing supported within said second string and extending deeper than said second string and secured in said hole which comprises:

connecting a first riser conduit at its lower end to said first string of casing in sealing reationship so that said first riser conduit and said first string of casing form a fluid-tight conduit;

supporting the upper end of said first riser conduit from said vessel to apply tension thereto;

connecting the lower end of a second riser conduit to said second string of casing;

applying tension to said second riser conduit from tension means supported by said vessel and connected to the upper end of said second string of casing;

securing the upper end of said second riser conduit while under tension to an upper portion of said first riser conduit;

disconnecting said second riser conduit from said tension means;

connecting the lower end of a third riser conduit to said third string of casing;

applying tension to said third riser conduit from tension means supported by said vessel and connected to the upper end of said third string of casing;

securing the upper end of said third riser conduit while under tension to an upper portion of said first riser conduit; and

disconnecting said third riser conduit from said tension means.

9. A method connecting a vessel floating on a body of water to a subsea well, substantially as hereinbefore described.

10. A system for anchoring a vessel floating on a body of water substantially as hereinbefore described with particular reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1982. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.