APPARATUS FOR CARRYING OUT UNDERWATER WELLHEAD OPERATIONS


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References Cited

UNITED STATES PATENTS
3,556,231 1/1971 Henderson 175/27 X
3,208,728 9/1965 Parks 175/27 X
3,369,600 2/1968 Bohlmann 175/27 X

ABSTRACT

Apparatus for carrying out underwater operations between a wellhead on the ocean bottom and a vessel floating on the water surface wherein the vessel is subject to wave motion. Interconnection means are suspended from the floating vessel adapted to operatively engage the wellhead to thereby provide fluid communication between the vessel and the wellhead. Hydropneumatically controlled wave motion cancelling means operatively engage the interconnection means to compensate for any wave motions acting on the vessel and thereby maintain the interconnection means in operative position.

8 Claims, 5 Drawing Figures
APPROATUS FOR CARRYING OUT UNDERWATER WELLHEAD OPERATIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention
   This invention relates to apparatus for carrying out operations, such as, for example, drilling, completion and production operations, with respect to underwater wellheads from a floating vessel. More particularly, the invention relates to apparatus for compensating for wave motion which, acting on the vessel, is normally transmitted to interconnecting means between the vessel and the underwater wellhead.

2. Description of the Prior Art
   In an attempt to locate new oil fields, an increasing amount of well-drilling has been conducted at offshore locations, such as, for example, off the coast of California, Louisiana and Texas. As a general rule, the strings of casing in a well, together with the tubing strings or string, extend to a point above the surface of the water where they are closed in the conventional manner that is used with respect to on-shore wells, with a conventional wellhead assembly being attached to the top of the casing. Such arrangements constitute a hazard to navigation, and recently methods and apparatus have been developed for drilling, completing and performing maintenance operations on wells wherein both the well casing head and subsequently the wellhead assembly and casing closure device are located underwater at depths sufficient to allow ships to pass over them.

In the case of these latter underwater installations, some means must be provided to carry out the various required operations with respect to the underwater well and the wellhead assembly associated therewith. This problem becomes especially difficult when the underwater well site is at such a distance below the surface of the ocean or other body of water so as to preclude the use of human divers. Accordingly, a wide variety of special tools and components have been devised and utilized to remotely carry out the desired underwater operations from vessels floating on the surface of the water over a well site. These tools and components are lowered from the vessel to the location of the well, by any one of a variety of methods, well known in the art, such as by means of pipe strings and/or guidelines extending downwardly from the floating vessel.

In the event pipe strings or their equivalent are used to carry out these operations, some means must be employed to prevent buckling and/or breakage thereof of equipment depending therefrom due to the rise and fall of the vessel on the surface of the water and a consequential variation in the distance between the vessel and the underwater installation. Those familiar with the art have accordingly long since recognized the need for wave cancelling apparatus to compensate for movement of the floating vessel with respect to the underwater well. As a consequence, various devices for accomplishing this end have been developed, but such devices have been characterized by their complexity and have been prone to mechanical failure. In addition, prior art devices of this type have normally been of such specialized construction as to preclude their use on the wide variety of styles and types of drilling or service vessels without extensive alteration or modification.

SUMMARY OF THE INVENTION
   It is therefore a primary object of the present invention to provide apparatus whereby operations may be carried out with respect to an underwater wellhead from a floating vessel.

It is a further object of the present invention to provide apparatus for performing operations with respect to an underwater wellhead, such apparatus including means for compensating for wave motion acting on a floating vessel which is normally transmitted to pipes or other interconnecting means between the vessel and the wellhead.

It is a still further object of the present invention to provide wave compensation apparatus that is simple in construction and operation and is readily adaptable for use with a wide variety of drilling or service vessels without alteration or modification and is a compatible supplement to commonly used wellhead equipment.

These and other objects are preferably accomplished by suspending interconnection means from a vessel floating on a water surface subject to wave motion, the interconnection means being adapted to operatively engage a wellhead on the ocean floor to thereby provide fluid communication between the vessel and the wellhead. Hydro-pneumatically controlled wave motion cancelling means operatively engage the interconnection means to compensate for any wave motions acting on the vessel and thereby maintain the interconnection means in operative position.

BRIEF DESCRIPTION OF THE DRAWING
   FIG. 1 is a diagrammatic elevational view illustrating apparatus according to the present invention utilized with a conductor pipe depending from a floating vessel and operatively associated with an underwater wellhead;

   FIG. 2 is an enlarged side view in partial cross-section illustrating the wave arrester assembly according to the present invention;

   FIG. 3 is an enlarged view taken along the line 3—3 in FIG. 2;

   FIG. 4 is a schematic presentation of the hydro-pneumatic control assembly utilized in the present invention; and

   FIG. 5 is a detailed view of a portion of the apparatus of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT
   Referring to FIG. 1 of the drawing, a floating vessel or platform is generally represented by numeral 11. The vessel or platform 11 is of any suitable type, preferably one, as illustrated, floating at the surface 10 of a body of water 12 and substantially fixedly positioned over a preselected location on the ocean floor or sea bed 13 by suitable vessel-positioning means or by being anchored to the ocean floor by suitable anchors (not shown) connected to the anchor lines 14 and 15. Equipment of this type may be used when carrying out operations with respect to underwater wells, in water depths varying from about 100 to about 1,500 feet or more. Vessel 11 is equipped with conventional drilling or workover equipment, such as a derrick (not shown) as well as other auxiliary equipment, such as a conventional hoist system including traveling block 16 and pipe elevator 17 depending therefrom. Mounted on work floor 18 of vessel 11 is a conventional rotary machine 19 which is positioned over a well or slot 20 which extends vertically through the vessel 11 in a-
ventiona1 manner. When using the equipment of the present invention, the slot 20 of the vessel 11 may be centrally located or extend in from one edge. However, drilling operations may be carried over the side of the vessel or platform 11 without the use of a well or slot, as from a portion of the work floor 18 which may be cantilevered out over one end of vessel 11.

Depending from vessel 11 is at least one pipe string 22 which cooperates at its lowermost end with an under-water wellhead structure 23 which is affixed to ocean floor 13 in the usual manner. Since a wide variety of under-water wellhead structure designs may be utilized in conjunction with the present invention and since such devices are well-known in the art, under-water wellhead structure 23 and its associated well bore 24 have been illustrated only in a somewhat schematic fashion. It should, of course, be understood that in the event a producing well is having operations carried out with respect thereto, a production wellhead assembly permitting such operations would be the type of under-water wellhead structure utilized. One under-water wellhead assembly suitable for this purpose is disclosed in U. S. Pat. No. 3,067,734. Of course, the apparatus according to the present invention may also be utilized in the performance of certain well drilling operations conducted from a floating vessel, such as fishing jobs, landing pipe, setting packers, connecting flow lines, etc. In this latter situation, wellhead structure 23 would be a drilling assembly, which may be of any known type.

Pipe string 22 is supported by the wave arrester assembly (indicated generally by numeral 25) in a manner that will be described in greater detail below. Wave arrester assembly 25, on the other hand, is supported by floating vessel or platform 11 and extends through slot 20 of the vessel in the manner illustrated. More specifically, wave arrester assembly 25 extends through rotary machine 19 and is prevented from falling there-through by means of any suitable device, as, for example, by a spider member 26 which is mounted on top of the rotary machine 19. Spider member 26 includes a lower base member 27 and a plurality of arms 28 which are swivel-mounted on the base member and adapted to move to the positions illustrated in FIG. 1 to cooperate with the wave arrester assembly 25 in a manner that will be described in greater detail below. Rather than using a spider for this purpose, any equivalent mechanism, such as slips, may be used for this purpose. Also disposed on board vessel 11 is hydro-pneumatic control unit 30. Hydro-pneumatic control unit 30 cooperates with wave arrester assembly 25 through control hose 31 in a manner to be described below. Control hose 31 may include suitable conduits (not shown) in fluid communication between unit 30 and assembly 25 all in the manner to be discussed further hereinbelow with particular regard to FIG. 4.

Referring now to FIG. 2, the wave arrester assembly 25, according to the present invention, is shown in detail. The wave arrester assembly 25 includes a cylindrical body element 33 having an outer shell 34 and an inner shell 35 which is concentrically disposed with respect thereto. Although, in relatively short or normal stroke assemblies, these shells are single lengths of suitable size pipe, in long stroke assemblies they may include several sections that are joined together as by means of a coupling 36, the latter element being circumferentially welded to the shells 34 and 35 as shown. This construction not only serves to connect the shell sections in an end-to-end manner, but, in addition, assists in maintaining the concentric relationship between the inner and outer shells at fixed intervals. Attached to the lowermost sections of outer shell 34 and inner shell 35 as by means of welding is a skirt member 37. Skirt member 37 defines a downwardly- and outwardly-flared opening 38 with the inner wall of the skirt member 37 defining the opening 38 serving as a guide for tool-joints and the like as they enter the lower end of the wave arrester assembly 25. Skirt member 37 includes an upwardly facing flange portion 39 of a diameter sufficient to accommodate tapped holes 40 for receiving downwardly extending piston rods 41 as will be described hereinbelow.

The upper end 42 of body element 33 forms a slip bowl 43 in the shape of an upwardly and outwardly truncated conical bore 44 of a size and dimension sufficient to receive rotary slips 45 (FIG. 1) for the purpose of supporting the pipe string 22 from the wave arrester assembly 25. As can be seen in FIG. 5, slips 45 are preferably removable, a removable arrangement which land on surface 43 to wedge and grip pipe string 22. Slip bowl 43 (FIG. 2) further includes an outwardly extending flange 46, the upper face of which provides a seating surface 47 for supporting from assembly 25 a travelling work platform 48 or the like (also shown in dotted lines in FIG. 1), if desired. The lower face of flange 46 includes a seating surface 48a for supporting wave arrester assembly 25 from vessel 11 when the assembly 25 is being inactively employed as a wave cancelling apparatus. Work platform 48 includes an L-shaped flange 49 for bolting platform 48 to bowl flange 46 through a nut 50 and bolt 50a or the like.

A plurality of hydraulic cylinders 51 are preferably circumferentially spaced about body element 33 and are in axial relationship thereto. These cylinders 51 are preferably even in number and arranged with one-half of the cylinders 51 (i.e., cylinders 51a as shown in FIGS. 2 and 3) having their piston rods 52 disposed in an upwardly directed position and the other half of the cylinders 51 (i.e., cylinders 51b as shown in FIG. 3) being situated in inter-adjacent relationship with the latter piston rods 53 (FIG. 2) arranged in a downwardly directed position. The downwardly directed piston rods 53 are threaded in tapped holes 40 of skirt member 37 and fastened thereto through means of jam nuts 54.

In order to retain cylinders 51 in fixed relationship, upper end plate 55 and lower end plate 56 (plate 55 also being shown in FIG. 3) slidably encompass body element 33 as can best be seen in FIG. 3. Plates 55 and 56 are attached to each other by means of tie rods 57 or the like, rods 57 being intermittently secured to end plates 55 and 56 by nuts 58 and jam nuts 59. Aperture means 60 (FIG. 3), formed in end plates 55 and 56, are coaxial with cylinders 51 and are substantially smaller in diameter than the outside diameter of cylinders 51, yet large enough to allow free movement of piston rods 52 and 53 passing therethrough (see also FIG. 4). Aperture means 60 are preferably counterbored (FIG. 4) to register depth on the cylinder side of the end plates 55 and 56 so as to receive the end portions of the cylinders 51 when in assembly.

A bushing 61 is slidably mounted on body element 33 and disposed below slip bowl 43 and above the hydraulic cylinders 51. Tapped holes 62, corresponding to the
upwardly extending threads of piston rods 52, are provided in the lower face 63 of bushing 61 so that, when threaded together and locked with jam nut 64, the bushing 61 is fixedly secured to rods 52. The upwardly facing surface 65 of bushing 61 coacts with the downwardly facing surface 46 of bowl flange 46 so as to limit upper movement of the respective elements.

An annular shoulder abutment 67 is formed on the outer periphery of bushing 61 to serve as a supporting seating surface 68 for the arms 28 of spider member 26 (Fig. 1). Thus assembled, the bushing 61 is supported from vessel 11 through spider member 26 which bushing 61 in turn supports the wave arrestor assembly 25 by shoulder engagement of abutment 67 and seating surface 48. Such support is accomplished only as long as there is insufficient pressure in the piston rods 52 and 53 to support the combined weight of the load of suspended pipe string 22, the wave arrestor assembly 25, etc., other than the weight of the bushing 61 and upper piston rods 52. By application of cylinder pressure sufficient to overcome this weight combination, the wave arrestor assembly 25 and its supported pipe string 22 move upwardly thus transferring the load from the bushing 61 to the hydraulic cylinders 51.

In operation, when it is desired that wave arrestor assembly 25 function as a wave cancellation means, sufficient fluid volume is applied to cylinders 51 to elevate assembly 25 to a point where, in operation, shoulder engagement of abutment 67 and seating surface 48 does not take place. This operation requires hydraulic pressure in the system of sufficient magnitude to over come the weight loads of the pipe string 22, assembly 25, etc. The volume of fluid in cylinders 51 must be delicately maintained so that vertical motion of vessel 11 is not translated into motion on pipe string 22. This may be accomplished by providing a gas balancing cushion to the hydraulic fluid in hydro-pneumatic control unit 30 as will be discussed further hereinbelow.

Referring now to FIG. 4, unit 30 and wave arrestor assembly 25 are shown schematically. The piston rod 41 of pressure side of the hydraulic cylinder control hose 31 interconnecting the wave arrestor assembly 25 to unit 30 is essentially connected to the hydraulic fluid side 73 of the surge cylinder 68 of unit 30. This closed cylinder 68 is provided with a piston 69 having an attached rod 70 passing through packing gland 71 at the hydraulic fluid side 73 of cylinder 68. Piston 69 also includes a rod marker 72 at its outer end for reasons to be discussed further hereinbelow. A compressible gas, such as air, is contained in cylinder 68 in the opposing side 74 of the piston 69.

In the operable position of the wave arrestor assembly 25, the pressure air side 74 of surge cylinder 68 is adjusted to balance the weight of pipe string 22 with the arrestor assembly 25 positioned at the desired elevation with respect to vessel 11. A surge chamber 75, having an air or the like chamber 76 therein, supplements the displacement of air or the like chamber 68 to reduce the air or gas pressure differential as the non-compressible hydraulic fluid acting on the piston 69 causes piston 69 to stroke within cylinder 68. A high pressure reserve tank 77, having an air or the like chamber 78 therein, and an air or gas compressor 79 coupled thereto, is provided for charging and maintaining the air (or gas) pressure within the surge chamber 75 and the air or gas side 74 of surge cylinder 68. A suitable air or gas compressor 79 is any compressor characterized by relatively low volumetric displacement for adequate pressure requirements. The reserve tank 77 acts as an immediate reserve to adjust pressure in the surge portion of unit 30.

Thus, as can be seen in FIG. 4, the pressure or piston rod side of cylinders 51 are all in connected communication through suitable conduits 82 and 83, i.e., conduit 31 in FIG. 1, to the fluid side 73 of surge cylinder 68. In a preferred adjustment, the system is closed, i.e., charged with sufficient volume so that, with cylinders 51 fully extended, the limit of discharge in the surge cylinder 68 is effected. When the displacement of cylinder 68 is set equal to that of cylinders 51, the stroke limits in each are synchronized.

A hydraulic pump 84, together with a conventional accumulator 85, is preferably coupled to conduit 83 as shown for initially charging the hydraulic portion of the system and to replenish the volume of the hydraulic fluid in the event of leakage. The fluid side of the system also includes a reservoir tank 86 for both supplying fluid to the system and serving as a surge tank for the non-pressure side of cylinders 51. The operation of the remaining components of the system (i.e., unit 30 and assembly 25) such as block valves 87 through 90, motor 97, three-way control valve 91, three-way valve 92, relief valve 93, gauge 94, and valve actuators 95 and 96, will become apparent from the following description of operation of the system.

To Charge the Hydraulic System

With the valves positioned as follows:

(89) open
(90) closed
(91) all ports blocked
(88) open
(92) surge chamber vented to atmosphere
(87) closed

First, wave arrestor assembly 25 is extended to maximum stroke limit (the arrestor assembly 25 being supported from the bushing 61). Surge cylinder piston 69 is moved to the limit of its stroke on the fluid side 73 of cylinder 68.

Second, motor 97 is actuated and pump 84 is started and valve 91 is positioned to slowly allow fluid to enter the wave arrestor cylinders 51 and the fluid side of the surge cylinder piston 69. Fluid pressure from the pump 84 causes the wave arrestor cylinders 51 to close and the piston 69 of the surge cylinder 68 to be moved to the gas side 74 of the cylinder 68.

Third, valve 90, the highest point in the system, is opened and all gases purged from the fluid side of the surge cylinder 68.

Fourth, valve 90 is closed and surge piston 69 is moved to its maximum limit of stroke towards the fluid side 73 of cylinder 68. This expels all fluid from surge cylinder 68 into reservoir 86.

Fifth, wave arrestor assembly 25 is extended to maximum stroke limit. All fluid in the arrestor cylinders 51 is transferred to the fluid side 73 of the surge cylinder 68 causing piston 69 to be forced to the extreme gas side 74 of surge cylinder 68.

To Charge the Pneumatic System

With the valves positioned as follows:

(89) open
(90) closed
(91) surge cylinder open to wave arrestor assembly 25—pump port unlocked
(88) closed
(92) all ports blocked
First, valve 88 is opened to equalize the predetermined gas pressure between surge cylinder 68 and surge chamber 75.

Second, valve 91 is opened to introduce high pressure fluid to the wave arresting cylinders 51 from the reserve fluid accumulator 85. The above operation causes the wave arresting cylinders 51 to close. The closing of the wave arresting cylinders 51 to their desired position is continued, preferably at 100 percent stroke.

Third, with the cylinders 51 of the wave arresting assembly 25 approximately 100 percent closed and with piston 69 or surge cylinder 68 at maximum limit of stroke on the fluid side 73 of cylinder 68, slips 45 on pipe string 22 are placed at the upper end of arrestor assembly 25 and elevator 17 is removed from pipe string 22 (as shown in FIG. 1). The weight of pipe string 22 on wave arrestor assembly 25 causes wave arresting assembly 25 and surge piston 69 to move to the mid-position of their respective strokes as gas in the gas side 74 of the cylinder 68 is compressed to its predetermined volume. Both wave arresting assembly 25 and cylinder piston 69 are now in a condition to move freely to accommodate for vertical vessel motion. To adjust the Spacing of the Wave Arrestor Assembly (under constant load)

To raise or lower a pipe riser supported by the wave arrestor assembly 25, such as would be necessary to connect or disconnect the riser from an ocean floor structure, valve 91 is manipulated to add or subtract fluid from the cylinders 51. With constant axial load on the wave arrestor assembly 25, piston 69 remains in a fixed position as the cylinders 51 are opened or closed.

To Adjust Axial Pull of the Wave Arrestor Assembly

With the wave arrestor assembly 25 dynamically supporting the upper end of a pipe riser and with the lower end fixed to the ocean floor, it is possible to vary the axial pull applied to the riser by the wave arrestor assembly 25 by increasing or decreasing the gas pressure in the surge cylinder 68 and the surge chamber 75. This is readily accomplished by manipulating valve 92 to admit high pressure gas to the accumulator 85 from reserve tank 77 or by venting the surge chamber 75 to atmosphere.

To Adjust the Spacing of the Surge Cylinder Piston

With the wave arrestor assembly 25 supporting a riser that is connected to the ocean floor, it may be necessary from time to time to reposition the surge piston 69 to the midpoint of its stroke within the surge cylinder 68. It is essential in order to maintain proper flow of fluid to the wave arrestor assembly 25 that the surge cylinder piston 69 be confined within its limit of travel in the surge cylinder 68.

Positioning of the surge piston 69 may be accomplished by manipulating valve 91 to add or subtract fluid from the surge cylinder 68 to the reservoir sump 86 causes the piston 69 to shift to the fluid side 73 of the cylinder 68. Alternatively, by moving valve 91 to add fluid to the surge cylinder 68, the piston 69 moves to the gas side 74 of the cylinder 68.

In addition, automatic positioning of the surge piston 69 may be accomplished by use of travel indicating paws 80 and 81 slidably mounted on the surge cylinder mount 98. The indicating paws may be used in coordination with rod marker 72 to electrically, hydraulically, or pneumatically signal valve actuators 95 and 96 to automatically position valve 91 as required to keep piston 69 in proper position.

In summary, apparatus has been described for carrying out underwater operations between a wellhead on the ocean floor and a vessel floating on the water surface wherein the vessel is subject to wave motion. A pipe string or other interconnecting means is provided between the vessel and the wellhead with the support for the interconnecting means being provided by a wave arresting assembly. The interconnecting means extends through the wave arresting assembly and is held in supportive engagement therewith by means of slips. The portion of the wave arresting assembly which is interconnected to the interconnecting means is biased in an upward direction and is relatively movable with respect to a support and guide bushing. The support and guide bushing provide means whereby the wave arresting assembly may be supported from the vessel, as upon a conventional rotary table mounted on the vessel. The wave arresting assembly includes a plurality of piston-cylinder arrangements interconnected to the hydro-pneumatic control unit which are effective to maintain the wave arresting assembly in the desired operational condition. The wave arresting assembly may be adapted to accommodate a travelling work platform to assist in the performance of the desired operations with respect to the underwater wellhead.

We claim as our invention:

1. Apparatus for carrying out underwater operations between a wellhead on the ocean bottom and a vessel floating on the water wherein said vessel is subject to wave motion, said apparatus comprising:
   interconnection means suspended from said floating vessel and adapted to operatively engage said wellhead to thereby provide fluid communication between said vessel and said wellhead; and
   hydropneumatically controlled wave motion canceling means adapted to compensate for any wave motion acting on said vessel, said interconnection means extending through said wave motion canceling means and being operatively coupled to said wave motion canceling means; and
   said wave motion canceling means in addition being releasably carried by said floating vessel and including a downwardly and outwardly flared opening at its lowermost end.

2. Apparatus for carrying out underwater operations between a wellhead on the ocean bottom and a vessel floating on the water wherein said vessel is subject to wave motion, said apparatus comprising:
   interconnection means suspended from said floating vessel adapted to operatively engage said wellhead to thereby provide fluid communication between said vessel and said wellhead; and
   hydropneumatically controlled wave motion canceling means operatively engaging said interconnection means, said wave motion canceling means including a substantially cylindrical body element and plurality of hydraulic cylinders slidably and outwardly engaging said body element, at least some of said cylinders having their piston rods disposed in an upwardly directed position and at least some of said cylinders having their piston rods disposed in a downwardly directed position; the upper and lower ends of all of said cylinders lying substantially in the same plane; and
upper and lower plate means abutting the upper and lower ends of all of said cylinders, respectively, for retaining said cylinders therebetween, said plate means having apertures therein for passing all of said piston rods slidably therethrough.

3. The apparatus of claim 2 including a bushing member fastened to the free ends of the upwardly directed piston rods, said bushing member being slidably mounted on said cylindrical body element; and the free ends of the downwardly directed piston rods being fixedly secured to approximately the lowermost end of said body element.

4. The apparatus of claim 2 wherein said bushing member includes abutment means thereon adapted to releasably retain slip means connected to said vessel to thereby releasably retain said wave motion cancelling means in fixed position with respect to said vessel.

5. The apparatus of claim 4 wherein said body element includes bushing member limit means at its upper end adapted to be engaged by said bushing member to limit the upper movement thereof with respect to said body element.

6. The apparatus of claim 5 wherein said hydropneumatically controlled wave motion cancelling means includes hydraulic fluid supply means coupled to said cylinders for selectively supplying sufficient hydraulic fluid thereto to selectively release and transfer the load to and from said bushing member to said cylinders.

7. The apparatus of claim 6 wherein said hydropneumatically controlled wave motion cancelling means further includes hydraulic fluid supply control means operatively engaging said hydraulic fluid supply means for maintaining sufficient hydraulic fluid under pressure in said cylinders so that vertical motion on said vessel is not translated into motion on said interconnecting means.

8. The apparatus of claim 7 wherein said hydraulic fluid supply control means includes a surge cylinder having a compressible pressure gas side and a non-compressible hydraulic fluid side, the pressure gas side being adapted to be adjusted to balance the weight of the interconnection means when the hydropneumatically controlled wave motion cancelling means is positioned at its desired elevation with respect to said vessel.

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