WELLHEAD SYSTEM HAVING RESILIENT DEVICE TO ACTUATE A LOAD MEMBER AND ENABLE AN OVER-PULL TEST OF THE LOAD MEMBER

BACKGROUND

[0001] The invention relates generally to a tubular housing used to support an object within the hollow interior of the tubular housing. In particular, the invention relates to a system having a tubular housing, such as a wellhead, to support an assembly, such as a casing hanger, within the tubular housing via a load member that is actuated to extend between the housing and the assembly.

[0002] In the oil and gas industry, pipes and tubing are used to transport oil and/or gas. In a well, pipe and/or tubing may be supported by a tubular housing. For example, a wellhead and a casing hanger disposed within the wellhead may be used to support pipe, known as casing, within a wellbore. Casing is strong steel pipe that is used in an oil and gas well to ensure a pressure-tight connection from the surface to the oil and/or gas reservoir. However, casing can be used to serve many purposes in a well. For example, the casing can be used to protect the wellbore from a cave-in or from being washed out. The casing can also be used to confine production to the wellbore, so that water does not intrude into the wellbore from a surrounding formation or, conversely, so that drilling mud does not intrude into the surrounding formation from the wellbore. The casing can also provide an anchor for the components of the well.

[0003] Several sections of casing joined together end-to-end are known as a "casing string." Because casing serves several different purposes in a well, it is typical to install more than one casing string in a well. Casing strings typically are run in a concentric arrangement, similar to an upside-down wedding cake, with each casing string extending further downward into the ground as the center of the arrangement of concentric casing strings is approached. For example, the casing string with the greatest diameter typically is the outermost casing string and the shortest, while the casing string with the smallest diameter typically is at the center and extends the deepest.

[0004] The casing hanger typically supports the casing string from a wellhead or a similar structure located near the seafloor. The casing hanger rests on a landing shoulder inside the wellhead. Multiple casing hangers may supported within a single wellhead. However, another method that may be used to support a casing hanger, rather than by using a shoulder of the wellhead, is to use a load ring to support the casing hanger. The load ring may be actuated to extend between the casing hanger and a recess in the wellhead to support the casing hanger.

[0005] Unfortunately, problems may occur when engaging the load ring and installing the seal. For example, the load ring may not properly engage the wellhead. Furthermore, subsea oil and gas wells are being developed at ever increasing seawater depths. These greater ocean depths make it difficult for an operator on the surface to obtain a positive indication that a load ring, or any other such device, has been actuated in a subsea well.

[0006] Therefore, an improved technique for actuating a device in a subsea well is desired. The techniques described below may solve one or more of the problems described above.

BRIEF DESCRIPTION

[0007] A wellbore system comprising a housing assembly and a hanger assembly. The hanger assembly comprises an actuation member that interacts with a portion of the housing assembly when the hanger assembly is positioned at a desired location in the housing assembly. The hanger assembly also comprises a load member that is adapted to extend between the hanger assembly and the housing assembly to enable the housing assembly to support the hanger assembly. The load member is carried into the wellbore in a retracted position. When the actuation member interacts with the housing assembly at the desired location, the actuation member actuates the load member to expand outward to extend between the hanger assembly and the housing assembly. The actuation member is adapted to transfer a lifting force from the surface

to the load member to enable an over-pull test of the hanger assembly to be performed.

DRAWINGS

[0008] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0009] FIG. 1 is a cross-sectional view of a wellhead system comprises a casing hanger installed within a high pressure wellhead, in accordance with an exemplary embodiment of the present technique;

[0010] FIG. 2 is a detailed cross-sectional view of a portion of the wellhead system, taken generally along line 2-2 of FIG. 1, in accordance with an exemplary embodiment of the present technique;

[0011] FIG. 3 is a cross-sectional view of the casing hanger of FIG. 1, in accordance with an exemplary embodiment of the present technique;

[0012] FIG. 4 is a detailed cross-sectional view of a portion of the casing hanger, taken generally along line 4-4 of FIG. 3, in accordance with an exemplary embodiment of the present technique;

[0013] FIG. 5 is a cross-sectional view of the wellhead of FIG. 1, in accordance with an exemplary embodiment of the present technique;

[0014] FIG. 6 is a detailed cross-sectional view of a portion of the wellhead system, taken generally along line 6-6 of FIG. 5, in accordance with an exemplary embodiment of the present technique;

[0015] FIGS. 7-10 are a series of Figures illustrating the installation of the casing hanger into the wellhead; in accordance with an exemplary embodiment of the present technique;

[0016] FIG. 7 is a cross-sectional view of the casing hanger disposed in the wellhead as a load shoulder of an actuation member lands on a tag shoulder of the wellhead, in accordance with an exemplary embodiment of the present technique;

[0017] FIG. 8 is a detailed cross-sectional view of the casing hanger disposed in the wellhead as the load shoulder of the actuation member lands on the tag shoulder of the wellhead, in accordance with an exemplary embodiment of the present technique;

[0018] FIG. 9 is a cross-sectional view of the casing hanger disposed in the wellhead after the actuation member has been elastically deformed by the weight of the casing hanger string and the casing hanger has moved axially relative to the actuation member and, thereby, actuated a load ring, in accordance with an exemplary embodiment of the present technique;

[0019] FIG. 10 is a detailed cross-sectional view of the actuation member, casing hanger, and wellhead, taken generally along line 10-10 of FIG. 9, in accordance with an exemplary embodiment of the present technique; and

[0020] FIG. 11 is a chart of weight supported from the surface versus time, in accordance with an exemplary embodiment of the present technique.

DETAILED DESCRIPTION

[0021] Referring now to FIG. 1, the present invention will be described as it might be applied in conjunction with a technique for supporting a first device within the hollow interior of a second device. In the illustrated embodiment, the technique is used in a wellhead system, as represented generally by reference numeral 20, comprising a high pressure wellhead 22 and a casing hanger assembly 24. However, the technique may be used in systems other than a wellhead system. A string of casing (not shown) is connected to bottom of the casing hanger assembly 24. The casing hanger assembly 24 and casing string are lowered into a bore 26 of the high pressure wellhead 22 by a setting tool (not shown). The setting tool is supported by a string of pipe extending from a derrick or crane located on a platform, such as a drilling ship. Instruments on

the surface provide an operator with an indication of the weight supported by the derrick or crane, i.e., the weight of the casing, casing hanger, and the string of pipe supported from the surface.

[0022] Referring generally to FIGS. 1 and 2, the casing hanger assembly 24 is supported in the high pressure wellhead 22 by engagement between a load member 28 and the high pressure wellhead 22. In particular, engagement between the load member 28 and an opposite portion 30 of the surface profile 32 of the bore 26 of the high pressure wellhead 22. In the illustrated embodiment, the load member 28 is an inwardly-biased expandable ring, such as a C-ring, that is carried by the casing hanger assembly 24 into the wellhead 22. However, the load member 28 may be an outwardly-biased ring held in place by shear pins or a series of dogs disposed around the casing hanger assembly. The outer surface of the load member 28 has a toothed profile 34 in this embodiment. In addition, the opposite portion 30 of the surface profile of the high pressure wellhead 22 has a corresponding toothed profile so that it can receive and support the toothed profile 34 of the load member 28. However, profiles other than a toothed profile may be used by the load member 28 and the wellhead 22.

[0023] In the illustrated embodiment, the expansion of the load member 28 into engagement with the surface profile 32 of the high pressure wellhead 22 is actuated by engagement between an actuation member 36 carried by the casing hanger assembly 24 and a portion 38 of the high pressure wellhead 22. In this embodiment, the actuation member 36 is a ring that is disposed around the casing hanger assembly 24. However, the actuation member 36 may be several devices spaced around the circumference of the casing hanger assembly 24. In this embodiment, the portion 38 of the high pressure wellhead 22 that engages the actuation member 36 is a tag shoulder 38. In the illustrated embodiment, downward movement of the actuation member 36 is blocked by the tag shoulder 38 in the surface profile 32 of the bore 26 of the high pressure wellhead 22. However, another type of device or member may be used to engage the actuation member 36. In the illustrated embodiment, the tag shoulder 38 is contacted by a shoulder 39 of the actuation member 36.

[0024] The load member 28 is expanded outward by lowering the main body 40 of the casing hanger assembly 24 with the actuation member 36 blocked by the tag shoulder 38 of the high pressure wellhead 22. The main body 40 of the casing hanger assembly 24 has angled surfaces 42 on the outer circumference of the casing hanger assembly 24 opposite corresponding angled surfaces 44 on the inner circumference of the load member 28. These angled surfaces 42, 44 create a mechanical advantage that urges the load member 28 outward, and slightly upward, when there is relative movement between the main body 40 of the casing hanger assembly 24 and the load member 28. The slight upward movement of the load member 28 produces a gap 45 between the load member 28 and the actuation member 36 in this embodiment.

[0025] The actuation member 36 has an elastically-deformable portion 46 that blocks relative movement of the main body of the casing hanger assembly in a first direction relative to the actuation member 36 during the process of lowering the casing hanger assembly 24 into the wellhead 22 from the surface. In this embodiment, the elastically-deformable portion 46 of the actuation member 36 comprises an inward-facing protrusion 48 located on an extension 50. The main body 40 of the casing hanger assembly 24 has a corresponding outward-facing protrusion 52. As will be discussed in more detail below, engagement between the inward-facing protrusion 48 of the actuation member 36 and the outward-facing protrusion 52 on the main body 40 of the casing hanger assembly 24 causes the actuation member 36 to be urged upward to drive the load member 28 outward when a lifting force is applied to the casing hanger assembly 24 during an over-pull test to ensure that the load member 28 is engaged with the wellhead 22.

[0026] The wellhead system 20 has a number of other features. For example, the casing hanger assembly 24 has a series of ports 56 that extend around the main body 40 of the casing hanger assembly 24 to enable well fluids and/or cement to pass upward through the casing hanger assembly 24. In addition, the casing hanger assembly 24 also has a nose ring 58 that is used to guide and centralize the casing hanger assembly 24 through the bore 26 of the wellhead 22. Finally, the wellhead 22 has several sets of wickers 60 that may be used to form seals with corresponding wickers on casing hanger seal assemblies.

[0027] Referring generally to FIGS. 3 and 4, an exemplary embodiment of a casing hanger assembly 24 is presented. As noted above, the load member 28 initially is maintained in a retracted position to minimize inadvertent engagement with other wellhead components, which might cause the casing hanger assembly 24 to land in the wrong place. In addition, the actuation member 36 is carried on the casing hanger assembly 24 with the actuation member 36 oriented so that the actuation member protrusion 48 is positioned below the casing hanger protrusion 52. This orientation enables the actuation member 36 to support the main body 40 of the casing hanger assembly 24 after the actuation member 36 engages the tag shoulder 38 of the wellhead 22.

[0028] Referring generally to FIGS. 5 and 6, an exemplary embodiment of the wellhead 22 is presented. The toothed portion 30 of the surface profile 32 of the wellhead 22 and the wickers 60 are illustrated in FIG. 5. In addition, tag shoulder 38 is illustrated in FIG. 6.

[0029] Referring generally to FIGS. 7-10, the process for installing the casing hanger assembly 24 in the wellhead 22 is presented. As noted above, a setting tool supported by a string of pipe extending from the surface may be used to lower the casing hanger assembly 24 and casing string into the wellhead 22.

[0030] Referring generally to FIGS. 7 and 8, initially, the casing hanger assembly 24 is lowered from the surface into the wellhead 22. Eventually, the actuation member 36 engages the wellhead 22 at a desired location in the wellhead 22. In this embodiment, the engagement is comprised of landing the actuation member 36 on the tag shoulder 38 of the wellhead 22. At this point of the installation process, the actuation member protrusion 48 of the actuation member 36 is oriented below the casing hanger protrusion 52. This orientation enables the actuation member protrusion 48 of the actuation member 36 to support the casing hanger protrusion 52 of the casing hanger assembly 24 when the actuation member 36 is landed on the tag shoulder 38 of the wellhead 22. A reduction in the weight on the string of pipe will be indicated on the surface.

[0031] Referring generally to FIGS. 9 and 10, additional weight is transferred from the surface to the wellhead 22 as the operator attempts to lower the casing hanger assembly 24 further into the wellhead 22. The additional weight is transmitted to the actuation member protrusion 48 by the casing hanger protrusion 52. Eventually, the additional weight supported by the actuation member 36 causes the elastically-deformable portion 46 of the actuation member 36 to deform. In this embodiment, the extension 50 of the actuation member 36 is deformed radially outward, as represented by arrow 64. The deformation of the elastically-deformable portion 46 of the actuation member 36 removes the actuation member protrusion 48 as an impediment to axial movement of the casing hanger protrusion 52 and, therefore, the main body 40 of the casing hanger assembly 24. As a result, the main body 40 of the casing hanger assembly 24 is lowered further into the wellhead 22, as represented generally by reference numeral 62. Eventually, the casing hanger protrusion 52 is lowered below the actuation member protrusion 48, enabling the extension 50 to return the actuation member protrusion 48 to its un-deformed position, as represented by arrow 66. At this point of the installation process, now the actuation member protrusion 48 of the actuation member 36 is oriented above the casing hanger protrusion 52.

[0032] In the illustrated embodiment, the casing hanger protrusion 52 and the actuation member protrusion 48 are configured so that the elastically-deformable portion 46 deforms when the elastically-deformed portion 46 supports a defined weight. For example, the bottom surface of the casing hanger protrusion 52 and the top surface of the actuation member protrusion 48 are angled to enable the actuation member protrusion 48 to support the casing hanger protrusion 52, but also to enable sliding engagement between the two surfaces as the actuation member extension 50 is deflected outward. Similarly, the length of the extension 50 may be established so that the elastically-deformable portion 46 deforms when the elastically-deformed portion 46 supports a defined weight. In addition, the material composition of the actuation member 46 may be selected so that the elastically-deformable portion 46 deforms when the elastically-deformed portion 46 supports a defined weight.

[0033] As the operator attempts to lower the casing hanger assembly 24 further into the wellhead 22, the load member 28 is driven against the actuation member 36.

Because downward movement of the load member 28 is opposed by the actuation member 36, the angled surfaces 42, 44 of the casing hanger 24 and load member 28 produce a mechanical advantage that urges the load member 28 outward, as represented by arrow 68. In this view, the load member 28 has been driven outward into engagement with the surface profile 32 of the bore 26 of the wellhead 22. The toothed profile 34 of this embodiment of the load member 28 is engaged with the corresponding toothed profile 30 of this embodiment of the wellhead 22. The weight of the casing string and casing hanger assembly 24 are supported by the high pressure wellhead 22 via the load member 28. A casing hanger seal assembly may be installed to seal the annulus between the casing hanger 24 and the high pressure wellhead 22.

[0034] Before a casing hanger seal assembly is installed, it may be desired to perform an over-pull test to ensure that the load member 28 is engaged with the wellhead 22. To perform an over-pull test, a lifting force, as represented by arrow 70, is applied to the main body 40 of the casing hanger assembly 24. When the lifting force 70 is applied to lift the casing hanger assembly 24, the load member 28 retracts, as represented by arrow 72, due to its inward bias until lower surface 74 of load member 28 contacts upper surface 76 of the actuation member 36, closing gap 45. Further inward travel of the load member 28 is now restrained by contact between the actuation member protrusion 48 and the casing hanger protrusion 52. When the over-pull force exceeds total casing weight, the entire casing hanger assembly 24 will travel axially upward, as represented by arrow 78, and the load member 28 will expand outward and upward, as represented by arrow 80, until the upper surfaces 82 of the load member 28 contact the upper surfaces 84 of the load profile 30 in the wellhead bore 32. This contact will produce an opposing force to the lifting force on the casing hanger assembly 24 and reflect an increase in string weight by the operator. However, if the casing hanger assembly 24 is not properly positioned, the load member 28 will not be driven into engagement with the toothed profile 30 of the high pressure wellhead. In addition, no opposing force to the lifting force will be produced if the load member 28 is not properly positioned and the casing hanger assembly 24 will be lifted from its position in the wellhead 22.

[0035] Referring generally to FIG. 11, an exemplary embodiment of a plot 86 of weight versus time during the final portions of the installation process of the casing hanger assembly 24 is presented. In FIG. 11, the x-axis 88 represents the weight supported from the surface, such as by a pipe string supported by a derrick, and the y-axis 90 represents "time." In the first portion 92 of the plot 86, the weight supported from the surface comprises the casing string hanging from the casing hanger assembly 24, the casing hanger assembly 24, and a string of drill pipe used to lower the casing string and casing hanger assembly 24 into the wellhead 22 from the surface.

[0036] The point of the installation process where the actuation member 36 engages the tag shoulder 38 of the wellhead 22 is represented on plot 86 by arrow 94. From this point, the actuation member 36 and wellhead 22 begin to assume some of the weight of the casing string and casing hanger assembly 24. In particular, the casing hanger protrusion 52 is supported by the actuation member protrusion 48. This is reflected on the plot 86 as a reduction in the weight supported from the surface, represented generally by arrow 96.

[0037] When a defined amount of weight is supported by the actuation member 36, the elastically-deformable portion 46 of the actuation member 36 deforms. This is represented by point 98 on plot 86. In the illustrated embodiment of the actuation member 36, the extension 50 of the actuation member 36 is deformed outward, removing the actuation member protrusion 48 as support for the casing hanger protrusion 52. The weight of the casing string and casing hanger assembly 24 that had been transferred to the actuation member 36 and wellhead 22 are transferred back to the surface, as represented by arrow 100, as the main body 40 of the casing hanger assembly 24 lowers in the wellhead 22.

[0038] The point of the installation process when the load member 28 engages the wellhead 22 is represented generally by arrow 102. The weight of the casing string and casing hanger assembly 24 begins to be transferred to the wellhead 22 via the load member 28. This is represented on plot 86 generally by arrow 104 as a reduction in the weight supported from the surface. Eventually, all of the weight of the casing string and casing hanger assembly 24 is supported by the wellhead 22 via the load

member 28. Thus, the weight supported from the surface is the drill string weight, represented generally by arrow 106. The setting tool may be disengaged from the casing hanger assembly 24 and returned to the surface or the tool may be used to install a casing hanger seal.

[0039] Typically, an over-pull test is performed after installation to ensure that the load member 28 has engaged the wellhead 22 and the casing hanger assembly 24 is installed within the wellhead 22. As noted above, the casing hanger protrusion 52 and the elastically-deformable portion 46 of the actuation member 36 are utilized during the over-pull test. During the over-pull test, a lifting force is applied to lift the casing hanger assembly 24. The lifting force on the casing hanger assembly 24 causes the casing hanger protrusion 52 to drive the actuation member protrusion 48 upward. This, in turn, causes the actuation member 36 to drive the load member 28 into greater engagement with the toothed profile 30 of the high pressure wellhead 22 if the casing hanger assembly 24 is properly positioned in the high pressure wellhead. The engagement of the load member 28 with the toothed profile 30 of the wellhead will produce an opposing force to the lifting force from the casing hanger assembly 24. This opposing force will be reflected on the surface as an increase in the weight supported from the surface, represented generally by arrow 108. However, if the load member 28 and the toothed profile 30 of the high pressure wellhead 22 are not engaged, the weight supported from the surface will not increase.

[0040] The casing hanger protrusion 52 and the elastically-deformable portion 46 of the actuation member 36 are configured such that a defined safe over-pull weight may be provided before the elastically-deformable portion 46 of the actuation member 36 is deformed. The safe over-pull weight represents an operating limit for the opposing force created by the engagement between the load member 28 and the wellhead 22. This safe over-pull weight is represented in region 110 of the plot 86. In the illustrated embodiment, the casing hanger protrusion 52 and the actuation member protrusion 48 are configured so that the elastically-deformable portion 46 does not deform before a desired lifting force is applied. For example, the top surface of the casing hanger protrusion 52 and the bottom surface of the actuation member

protrusion 48 are angled to enable the actuation member protrusion 48 to block upward movement of the casing hanger protrusion 52.

[0041] To remove the casing hanger assembly 24 from the wellhead 22, a lifting force is applied to cause the elastically-deformable portion 46 of the actuation member 36 to deform from below. This force is represented on plot 86 at reference point 112. The casing hanger protrusion 52 is driven above the actuation member protrusion 48, which enables the load member 28 to retract into the main body 40 of the casing hanger assembly 24. The top surface of the casing hanger protrusion 52 and the bottom surface of the actuation member protrusion 48 are angled to enable sliding engagement between the two surfaces when the lifting force deflects the actuation member extension 50 outward. As a result, the weight of the casing hanger assembly 24 is transferred from the wellhead 22 to the surface via the pipe string, as represented by the portion of the plot 86 represented by arrow 114.

[0042] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS:

1. A wellhead system (20), comprising:

a first wellhead assembly (22); and

a second wellhead assembly (24), comprising:

a load member (28) adapted to be actuated to engage the first wellhead assembly (22) to enable the first wellhead assembly (22) to support the second wellhead assembly (24); and

a resilient actuation member (36) adapted to actuate the load member (28) at a desired position relative to the first wellhead assembly (22).

2. The wellhead system (20) as recited in claim 1, wherein the resilient actuation member (36) is adapted to engage a portion (38) of the first wellhead assembly (22).

3. The wellhead system (20) as recited in claim 2, wherein the actuation member (36) comprises a first engagement portion (48) and the second wellhead assembly (24) comprises a second engagement portion (52), the first and second engagement portions (48, 52) being adapted to cooperate to restrict axial movement of a main body (40) of the second wellhead assembly (24) in a first direction relative to the actuation member (36).

4. The wellhead system (20) as recited in claim 3, wherein the resilient actuation member (36) is adapted to block movement of the load member (28) in the first direction after the resilient actuation member (36) engages the portion of the first wellhead assembly (22).

5. The wellhead system (20) as recited in claim 4, wherein the resilient actuation member (36) is configured to elastically deform to enable axial movement of the main body (40) of the second wellhead assembly (24) in the first direction relative to the actuation member (36) when a sufficient force is applied to the actuation member (36).

6. The wellhead system (20) as recited in claim 4, wherein the second wellhead assembly (24) is adapted to drive the load member (28) outward when the main body (40) is moved in the first direction and movement of the load member (28) in the first direction is blocked by the actuation member (36).

7. The wellhead system (20) as recited in claim 6, wherein the first engagement portion (48) and the second engagement portion (52) are adapted to cooperate to urge the resilient actuation member (36) in a second direction opposite the first direction when a force is applied to the main body (40) of the second wellhead assembly (24) in the second direction after the load member (28) has been actuated by the actuation member (36).

8. The wellhead system (20) as recited in claim 7, wherein the second wellhead assembly (24) is adapted to urge the load member (28) outward when the resilient actuation member (36) is urged to move in the second direction opposite the first direction after the load member (28) has been actuated by the resilient actuation member (36).

9. The wellhead system (20) as recited in claim 8, wherein the first engagement portion (48) and the second engagement portion (52) are configured so that the first engagement portion (48) elastically deforms when the force applied to the main body (40) of the second wellhead assembly (24) in the second direction exceeds a desired magnitude to enable axial movement of the main body (40) in the second direction relative to the resilient actuation member (36).

10. The wellhead system (20) as recited in claim 9, wherein the load member (28) is resilient.