

LOCKDOWN SYSTEM FOR USE IN A WELLHEAD ASSEMBLY

BACKGROUND

Field of Invention

[0001] The invention relates generally to a system and method for locking together tubulars in a wellhead assembly.

Description of Prior Art

[0002] Wellheads used in the production of hydrocarbons extracted from subterranean formations typically comprise a wellhead assembly attached at the upper end of a wellbore formed into a hydrocarbon producing formation. Wellhead assemblies usually provide support hangers for suspending production tubing and casing into the wellbore. The casing lines the wellbore, thereby isolating the wellbore from the surrounding formation. The tubing typically lies concentric within the casing and provides a conduit therein for producing the hydrocarbons entrained within the formation.

[0003] Wellhead assemblies also typically include a wellhead housing adjacent where the casing and tubing enter the wellbore, and a production tree atop the wellhead housing. The production tree is commonly used to control and distribute the fluids produced from the wellbore and selectively provide fluid communication or access to the tubing, casing, and/or annuluses between the tubing and casing. Valves assemblies are typically provided within wellhead production trees for controlling fluid flow across a wellhead, such as production flow from the borehole or circulating fluid flow in and out of a wellhead.

[0004] Seals are used between inner and outer wellhead tubular members to contain internal well pressure. The inner wellhead member may be a tubing hanger that supports a string of tubing extending into the well for the flow of production fluid. The tubing hanger lands in an outer wellhead member, which may be a wellhead housing, a production tree, or a tubing head. A packoff or seal seals between the tubing hanger and the outer wellhead member. Alternately, the inner wellhead member might be an isolation sleeve secured to a production tree. A seal or packoff seals between the isolation sleeve and a casing hanger located within the wellhead housing.

[0005] A variety of seals of this nature have been employed in the prior art. Prior art seals include elastomeric and partially metal and elastomeric rings. Prior art seal rings made entirely of metal for forming metal-to-metal seals are also employed. The seals may be set by a running tool, or they may be set in response to the weight of the string of casing or tubing. One type of prior art metal-to-metal seal has inner and outer walls separated by a conical slot. An energizing ring is pushed into the slot to deform the inner and outer walls apart into sealing engagement with the inner and outer wellhead members. The deformation of the inner and outer walls exceeds the yield strength of the material of the seal ring, making the deformation permanent. Sometimes a lockdown ring is provided in the annular space between the tubulars, which is put into a position that locks the tubulars to one another when the seal is set.

SUMMARY OF THE INVENTION

[0006] Provided herein is an example of a wellhead assembly. In one example, a wellhead assembly includes an axis, an outer tubular, an inner tubular inserted into the outer tubular and defining an annular space between the inner tubular and outer tubular, and a lock ring in the annular space that is moveable from an unlocked position into a locked position. The wellhead assembly of this embodiment also includes an activation ring having a profiled surface that is axially slidable against and in contact with the lock ring to define a contact interface that is offset an angle from the axis when the lock ring is in the locked position, and to define a contact interface that is offset an angle from the axis when the lock ring is in the unlocked position, so that the angle when the lock ring is in the locked position is less than the angle when the lock ring is in the unlocked position. Optionally, a portion of the profiled surface is curved that is in contact with the lock ring when the lock ring is in the unlocked position, and a portion of the profiled surface that is in contact with the lock ring when the lock ring is in the locked position is substantially linear. In one example embodiment, the lock ring is set radially inward from the outer tubular when in the unlocked position, and the lock ring comprises a protrusion that engages a depression formed in an inner radial surface of the outer tubular. Alternatively, the lock ring is set radially outward from the inner tubular when in the unlocked position, and the lock ring has a protrusion that engages a depression formed in an outer radial surface of the inner tubular. In an alternate embodiment, the wellhead further includes a seal assembly that transfers a downward axial force to an upper end of the activation ring and that is energized by an energizing force. The force applied to the activation ring that slides the activation ring along the lock ring may urge the lock ring from the unlocked position to the locked position, and the

energizing force can be greater than the force applied to the activation ring. In one example, the outer tubular is a wellhead housing and the inner tubular is a tubing hanger.

[0007] Also provided herein is a system for locking together tubulars that are disposed in a wellhead assembly. In this example the system includes a lock ring that axially rests on one of the tubulars and selectively engages an adjacent tubular thereby axially locking together the one of the tubulars and the adjacent tubular. Also included is an activation ring axially moveable to between the lock ring and the one of the tubulars and having a surface in sliding contact with the lock ring that transitions from a curved profile to a linear profile as the activation ring moves to between the lock ring and the one of the tubulars. In an example embodiment of the system, the activation ring contacts the lock ring along an interface that is offset from an axis of the wellhead assembly by an angle up to about 5 degrees when the lock ring is engagement with the adjacent tubular. Optionally, the activation ring contacts the lock ring along an interface that is offset from an axis of the wellhead assembly by an angle that ranges from at least about 5 degrees to about 30 degrees when the curved profile is in contact with the lock ring. The one of the tubulars can be a tubing hanger and the adjacent tubular can be a wellhead housing. In an alternate example, the one of the tubulars can be a wellhead housing and the adjacent tubular can be a tubing hanger. Optionally, an upper end of the activation ring is in axial contact with a seal assembly, where the seal assembly is energized with an axial force that exceeds a force applied to slide the activation ring from a position above the lock ring to a position adjacent the lock ring.

[0008] Yet further provided herein is a method of locking together tubulars in a wellhead assembly. One example embodiment of the method includes providing a lock ring on a lateral surface of one of the tubulars, applying a force onto the lock ring in a direction oblique with an

axis of the wellhead assembly to radially urge the lock ring towards an adjacent tubular, changing the direction of the force to be substantially perpendicular to the axis and engaging the lock ring with the adjacent tubular, and retaining the lock ring in engagement with the adjacent tubular by continuing to apply the force in a direction substantially perpendicular to the axis. The method may further include providing an activation ring having a contact surface that transitions from a curved portion to a linear portion. In one example, the step of applying a force onto the lock ring in a direction oblique with an axis of the wellhead assembly involves axially urging the activation ring so the curved portion slides against a side of the lock ring. In an optional embodiment, the step of applying a force onto the lock ring in a direction perpendicular to an axis of the wellhead assembly includes axially urging the activation ring so the linear portion slides against a side of the lock ring. In an example, the step of continuing to apply the force in a direction substantially perpendicular to the axis includes retaining the activation ring adjacent the lock ring so the linear portion is in contact with a side of the lock ring.

BRIEF DESCRIPTION OF DRAWINGS

[0009] Some of the features and benefits of the present invention having been stated, others will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

[0010] FIGS. 1A and 1B are side sectional views of an example of coupling together tubulars in a wellhead assembly in accordance with the present invention.

[0011] FIGS. 2A-2C are side sectional detailed views of operation of a locking mechanism of FIGS. 1A and 1B in accordance with the present invention.

[0012] FIG. 3 is a side partial sectional view of an example embodiment of the wellhead assembly of FIGS. 1A and 1B set over a wellbore in accordance with the present invention.

[0013] While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to that embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF INVENTION

[0014] The method and system of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments are shown. The method and system of the present disclosure may be in many different forms and should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey its scope to those skilled in the art. Like numbers refer to like elements throughout.

[0015] It is to be further understood that the scope of the present disclosure is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation. Accordingly, the improvements herein described are therefore to be limited only by the scope of the appended claims.

[0016] Figure 1A is a side sectional view of one example embodiment of a wellhead assembly 10 that includes a portion of a wellhead housing 12 adjacent a tubing hanger 14. The wellhead

housing 12 and tubing hanger 14 are generally tubular members that are spaced apart. An example of a seal assembly 16 is illustrated set within an annulus 18 that is between the tubing hanger 14 and wellhead housing 12. The embodiment of the seal assembly 16 includes an annular seal ring 20 insertable into the annulus 18. The seal ring 20 of Figure 1A has an inner leg 22, which as provided in the sectional view is an elongate member that extends generally parallel with an axis A_X of the wellhead assembly 10. The example of the seal ring 20 also includes an outer leg 24; which also extends substantially parallel with the axis A_X and is longer than the inner leg 22. The outer leg 24 is set radially outward from the inner leg 22 to define an annular space 26 set between the inner and outer legs 22, 24. The inner and outer legs 22, 24 are connected to one another on their respective lower ends by a cross piece that also defines a lower surface of the space 26. An energizing ring 28 is shown having a lower end inserted into an upper end of the space 26. In an example, axially urging the seal assembly 20 into annulus 18 then inserting energizing ring 28 into space 26 urges legs 22, 24 radially outward from one another thereby creating a pressure barrier in the annulus 18. A ring-like collar 30 is shown circumscribing a portion of the energizing ring 28 and threadingly engaged with an upper end of the outer leg 24.

[0017] Further illustrated in the example of the wellhead assembly 10 of Figure 1A is an annular activation ring 32, which is set in the annulus 18 below the seal assembly 20. In the example of Figure 1A, the lower end of the seal assembly 20 rests on an upper end of the activation ring 32. Below the activation ring 32 is a lock ring 34 for axially locking together the wellhead housing 12 and tubing hanger 14. Referring now to Figure 2A, illustrated in detailed sectional view is an example of the activation ring 32 and lock ring 34. In the example of Figures 1A and 2A, the lock ring 34 is in an unlocked configuration, thus the wellhead housing 12 and tubing hanger 14

may move axially with respect to one another. As shown in Figure 2A, a surface of the activation ring 32 facing axis A_X defines an inner surface 36 that is shown having a transition 38 where a radius of the surface 36 changes. Opposite the inner surface 36 is an outer surface 40 shown having a lower portion 42 that transitions into an upper portion 44. The transition 46 at the upper end of upper portion 44 defines where a change in length of radius of the outer surface 40 takes place.

[0018] Profiles 48 are shown formed on the outer surface 40 and above transition 46 to define a handle 50 for raising and lowering the activation ring 32 within the annulus 18 (Figure 1A). In the example of Figure 2A, a line L_1 is shown extending tangentially across upper portion 44 illustrating in the example of Figure 2A that the outer surface 40 is generally linear along upper portion in the axial direction. In contrast, outer surface 40 along lower portion 42 is curved and in some portions thereof maintains a consistent radius. A line L_2 is shown tangentially across a portion of an inner surface of the lock ring 34. In one example embodiment, the line L_2 is at about 20 degrees to about 35 degrees offset from axis A_X .

[0019] Still referring to Figure 2A, an outer surface 54 of the lock ring 34 is shown having protrusions 56 that extend radially outward and away from inner surface 52. Referring back to Figure 1A, the protrusions 56 are profiled to correspond to depressions 58 shown formed along an inner surface 60 of the wellhead housing 12 and adjacent lock ring 34. Further illustrated in Figure 1A are wickers 62, 64 shown respectively formed on the inner surface 60 of the wellhead housing 12 and an outer surface 66 of the tubing hanger 14. In an embodiment, the wickers 62, 64 are ridge-like members formed in the surfaces 60, 66, so that when the seal 20 is set in the annulus 18, the wickers 62, 64 deform respective outer surfaces of the inner leg 22 and outer leg for enhancing the sealing function of the seal assembly 20.

[0020] Figure 1B illustrates in side sectional view an example of the lock ring 34 set in a locked position and in engagement with the depressions 58 on the wellhead housing 12. Further illustrated in Figure 1B is that a lower end of the lock ring 34 rests on a shoulder 67 defined where the outer surface 66 of the tubing hanger 14 juts radially outward and away from axis A_X . Engaging the protrusions 56 with the depressions 58 axially retains the lock ring 34 in place. Also, by contacting the shoulder 67 with lower end of the block ring 34, the tubing hanger 14 is prevented from moving axially upward with respect to the wellhead housing 12 by the axially static lock ring 34. Further in the example of Figure 1B, the lock ring 34 engages the profiles 58 by being moved radially outward from axis A_X by downward axial movement of the activation ring 32. Thus, retaining the activation ring 32 in the position of Figure 1B, the tubing hanger 14 is axially constrained to the wellhead housing 12.

[0021] A detailed example of interaction between the activation ring 32 and lock ring 34 in the locked position is illustrated in side sectional view in Figures 2B and 2C. In Figure 2B, shown is an example of the activation ring 32 having a force F applied to its upper end thereby slidably urging the activation ring 32 to a position adjacent the lock ring 34 (Figure 2C). In one example, the activation ring 32 and lock ring 34 are substantially coaxial when the lock ring 34 is in the locked position. In the example of Figure 2B, the lower curved portion 42 of the activation ring 32 is in contact with the inner surface 52 of the lock ring 34. As such, a resultant force F_R is exerted against the lock ring 34 and shown being in a direction generally oblique to the axis A_X . With further downward movement of the activation ring 32, the direction of resultant force F_R rotates from its oblique orientation and to one that is close to being substantially perpendicular to axis A_X (Figure 2). In the example of Figure 2B, a portion of line L_3 extends along a contact interface between the activation ring 32 and lock ring 34. Similarly, line L_4 in Figure 2C is

drawn along a contact interface between the activation ring 32 and lock ring 34 when the activation ring 32 is substantially adjacent lock ring 34. As shown, line L_4 is at an offset angle from axis A_X that is less than an offset angle between L_3 and axis A_X (Figure 2B).

[0022] An advantage of the curved lower surface 42 is that the lock ring 34 may be urged radially outward into its locked configuration with the wellhead housing 12 by a stroke distance of the activation ring 32 that is shorter than a corresponding stroke distance in instances where the lower portion 42 is linear. Moreover, by transitioning the outer surface 40 of the activation ring 32 from a curved lower portion 44 to a linear upper portion 44, the resultant force F_R has a reduced axial component exerted from the lock ring 34 onto the activation ring 32. As such, more force from the lockdown system may be distributed towards retaining the tubing hanger 14 rather than maintaining the lock ring 34 in its locked position.

[0023] Figure 3 is a side partial sectional view of one example of the wellhead assembly 10 shown set over a wellbore 68, where the wellbore 68 extends through a formation 70. In the example of Figure 3, an example of a lockdown assembly 71 is schematically illustrated for locking the tubing hanger 14 to the wellhead housing 12. In the example of Figure 3, the lockdown assembly 71 includes examples of the activation ring and lockdown ring as described above. Further illustrated in Figure 3 is a string of tubing 72 that depends downward into the bore hole 68 from the tubing hanger 14.

[0024] An additional advantage of the lockdown assembly illustrated herein is that by transitioning the outer surface of the retaining ring 32, axial forces required for retaining the lockdown ring 34 in its locked position are reduced that in turn allows for higher preloads on a

seal assembly 20 (Figure 1A). Thus, the lock ring 34 can be set at an axial force below that which may initiate energizing of a seal set in the annulus 18.

[0025] The present invention described herein, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While a presently preferred embodiment of the invention has been given for purposes of disclosure, numerous changes exist in the details of procedures for accomplishing the desired results. These and other similar modifications will readily suggest themselves to those skilled in the art, and are intended to be encompassed within the spirit of the present invention disclosed herein and the scope of the appended claims.

CLAIMS

What is claimed is.

1. A wellhead assembly comprising:

an axis;

an outer tubular;

an inner tubular inserted into the outer tubular and defining an annular space between the inner tubular and outer tubular;

a lock ring in the annular space that is moveable from an unlocked position into a locked position;

an activation ring having a profiled surface that is axially slidable against and in contact with the lock ring to define a contact interface that is offset an angle from the axis when the lock ring is in the locked position, and to define a contact interface that is offset an angle from the axis when the lock ring is in the unlocked position, so that the angle when the lock ring is in the locked position is less than the angle when the lock ring is in the unlocked position.

2. The wellhead assembly of claim 1, wherein a portion of the profiled surface is curved that is in contact with the lock ring when the lock ring is in the unlocked position, and wherein a portion of the profiled surface that is in contact with the lock ring when the lock ring is in the locked position is substantially linear.

3. The wellhead assembly of claim 1, wherein the lock ring is set radially inward from the outer tubular when in the unlocked position, and wherein the lock ring comprises a protrusion that engages a depression formed in an inner radial surface of the outer tubular.
4. The wellhead assembly of claim 1, wherein the lock ring is set radially outward from the inner tubular when in the unlocked position, and wherein the lock ring comprises a protrusion that engages a depression formed in an outer radial surface of the inner tubular.
5. The wellhead assembly of claim 1, further comprising a seal assembly that transfers a downward axial force to an upper end of the activation ring and that is energized by an energizing force.
6. The wellhead assembly of claim 5, wherein a force applied to the activation ring that slides the activation ring along the lock ring and urges the lock ring from the unlocked position to the locked position, and wherein the energizing force is greater than the force applied to the activation ring.
7. The wellhead assembly of claim 1, wherein the outer tubular comprises a wellhead housing and the inner tubular comprises a tubing hanger.
8. A system for locking together tubulars that are disposed in a wellhead assembly comprising:

a lock ring that axially rests on one of the tubulars and selectively engages an adjacent tubular thereby axially locking together the one of the tubulars and the adjacent tubular;

an activation ring axially moveable to between the lock ring and the one of the tubulars and having a surface in sliding contact with the lock ring that transitions from a curved

profile to a linear profile as the activation ring moves to between the lock ring and the one of the tubulars.

9. The system of claim 8, wherein the activation ring contacts the lock ring along an interface that is offset from an axis of the wellhead assembly by an angle up to about 5 degrees when the lock ring is engagement with the adjacent tubular.

10. The system of claim 8, wherein the activation ring contacts the lock ring along an interface that is offset from an axis of the wellhead assembly by an angle that ranges from at least about 5 degrees to about 30 degrees when the curved profile is in contact with the lock ring.

11. The system of claim 8, wherein the one of the tubulars is a tubing hanger and the adjacent tubular is a wellhead housing.

12. The system of claim 8, wherein the one of the tubulars is wellhead housing and the adjacent tubular is a tubing hanger.

13. The system of claim 8, wherein an upper end of the activation ring is in axial contact with a seal assembly, where the seal assembly is energized with an axial force that exceeds a force applied to slide the activation ring from a position above the lock ring to a position adjacent the lock ring.

14. A method of locking together tubulars in a wellhead assembly comprising:

providing a lock ring on a lateral surface of one of the tubulars;

applying a force onto the lock ring in a direction oblique with an axis of the wellhead assembly to radially urge the lock ring towards an adjacent tubular;

changing the direction of the force to be substantially perpendicular to the axis and engaging the lock ring with the adjacent tubular; and

retaining the lock ring in engagement with the adjacent tubular by continuing to apply the force in a direction substantially perpendicular to the axis.

15. The method of claim 14, further comprising providing an activation ring having a contact surface that transitions from a curved portion to a linear portion.

16. The method of claim 15, wherein the step of applying a force onto the lock ring in a direction oblique with an axis of the wellhead assembly comprises axially urging the activation ring so the curved portion slides against a side of the lock ring.

17. The method of claim 15, wherein the step of applying a force onto the lock ring in a direction perpendicular to an axis of the wellhead assembly comprises axially urging the activation ring so the linear portion slides against a side of the lock ring.

18. The method of claim 15, wherein the step of continuing to apply the force in a direction substantially perpendicular to the axis comprises retaining the activation ring adjacent the lock ring so the linear portion is in contact with a side of the lock ring.