MULTI-PIECE STACKED SEALING SYSTEM AND METHOD OF USING SAME

Abstract: Subsea wells have a variety of proprietary well head configurations that require sophisticated locking and sealing profiles that allow the well bore to be sealed off and the production of hydrocarbons to be safely controlled. A universal tubing hanger and lockdown assembly uses a sealing apparatus to annularly seal the well bore. When compressed, a multi-piece stacked sealing system employs rigid and elastic members to seal the well bore annulus in both the top-down and bottom-up directions. Top-down pressure containment is needed for appropriate well system testing and bottom-up pressure containment is necessary to control the internal pressure of the well.
— as to the applicant’s entitlement to claim the priority of the earlier application (Rule 4.17(iii))

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MULTI-PIECE STACKED SEALING SYSTEM
AND METHOD OF USING SAME

BACKGROUND OF THE INVENTION

1. **Field of the Invention.**

   This invention relates to a system and method of using same to seal a well bore such that the production of hydrocarbons may be safely controlled. More specifically, the invention relates to a multi-piece stacked sealing system and method for using same to seal the annulus between a production casing and a tubing hanger.

2. **Description of the Related Art.**

   A typical subsea wellhead assembly includes a wellhead housing installed at the sea floor. With a drilling blowout preventer (BOP) stack installed on the wellhead housing, the well bore is drilled while successively installing concentric casing strings in the well bore. Typically, each successive casing string is cemented at its lower end and includes a casing hanger sealed with a mechanical seal assembly at its upper end in the wellhead housing.

   In order to produce the cased well, a production tubing string and tubing hanger are typically run into the well bore through the BOP stack and the tubing hanger is landed, sealed and locked in the wellhead housing and/or casing hanger. Upon sealing the bore(s) extending through the tubing hanger, the BOP stack is removed and a Christmas tree is lowered onto the wellhead housing. A Christmas tree is an oilfield term understood to include the control valves and chokes assembled at the top of a well to control the flow of oil and gas. It is vitally important to the operation and safety of the well that the proper connections are remotely formed between the Christmas tree, the wellhead housing, and the tubing hanger.
In a conventional completed well system, the Christmas tree is connected to the top of the wellhead housing over the tubing hanger. The tubing hanger supports at least one production tubing string which extends into the wellbore. The tubing hanger provides a production bore within the tubing string and a conduit that communicates with the annulus surrounding the tubing string and inside the innermost or production casing string. In addition, the tubing hanger comprises at least one vertical production bore for communicating fluid between the tubing string and a corresponding production bore in the Christmas tree, and typically at least one vertical annulus bore for communicating fluid between the tubing annulus and a corresponding annulus bore in the Christmas tree. The tubing hanger may additionally include one or more service and control conduits for communicating control fluids and well chemicals through the tubing hanger or electrical power to devices or positions located in or below the tubing hanger.

A tubing hanger conventionally is sealed and rigidly locked into the wellhead housing or component in which it is landed. In a well having a conventional Christmas tree, the tubing hanger is landed in the wellhead housing. The tubing hanger typically includes an integral locking mechanism which, when activated, secures the tubing hanger to the wellhead housing or a profile in the casing hanger. The locking mechanism ensures that any subsequent pressure from within the well acting on the tubing hanger will not cause the tubing hanger to lift from the wellhead housing thereby resulting in an unsafe condition.

There are a limited number of subsea wellhead equipment manufacturers worldwide. Currently, the primary manufacturers of subsea wellhead housings are ABB Vetco Gray, Cooper Cameron Corp., Dril-Quip, FMC, and Kvaerner. Each of the primary manufacturers has its own proprietary wellhead housing and casing hanger designs, dimensions, and details.
Quite frequently, a well is completed on Manufacturer A's wellhead housing and casing hangers using a tubing hanger and/or Christmas tree from Manufacturer B. However, since Manufacturer A's housing and casing hanger design are proprietary, Manufacturer B may not be able to connect its Christmas tree to Manufacturer A's housing without a license from Manufacturer A at a fee in order to design Manufacturer B's equipment to properly interconnect and mate with Manufacturer A's wellhead housing and casing hanger. This results in a substantial amount of additional engineering and costs or additional equipment (such as a tubing spool) when electing to purchase Manufacturer B's equipment for use with Manufacturer A's wellhead housing. Since each wellhead housing/system manufacturer has multiple models of housings and casing hangers with different proprietary details, it is not practical or economical for other manufacturers to build up an inventory of equipment for installation on other manufacturers’ wellhead equipment. In addition to the added costs, it also increases, the delivery time which is often vitally important to the well owner.

A tubing hanger assembly adapted for positioning in the wellhead housing independently of any proprietary details of the wellhead housing has recently been disclosed by Broussard in U.S. Patent No. 7,419,001, which is incorporated herein by reference. The tubing hanger suspension assembly disclosed in U.S. Patent No. 7,419,001 includes a tubing hanger housing which is positioned in the wellhead housing and further includes a sealing and lockdown mechanism capable of providing sealing and load support of the production tubing in the production casing string.

Figure 1 shows a universal tubing hanger suspension assembly 80 according to a preferred embodiment of U.S. Patent No. 7,419,001. The tubing hanger suspension assembly 80 includes a string of production tubing 122 connected to a tubing hanger housing 124. The
production tubing 122 defines a production tubing bore 122a extending axially through the tubing 122. The tubing hanger housing 124 includes production bore 124a in fluid communication with the production tubing bore 122a. The production bore 124a extends substantially vertically through the tubing hanger housing 124. The production tubing string 122 typically extends down to the production zone Z. The production tubing string 122 includes a subsurface safety valve 126 at a desired depth with the well bore B. The tubing hanger housing 124 also includes an annulus passageway 124b extending through the tubing housing hanger 124. Included in the tubing housing assembly 124 is an annulus isolation valve 128 arranged and designed to seal and close off the annulus passageway 124b.

The universal tubing hanger suspension assembly 80 includes a tubing hanger lower assembly 82 at a lower end of the tubing hanger housing 124. The lower assembly 82 may be connected to or integral with the tubing hanger housing 124. The lower assembly 82 includes a sealing and lockdown assembly 134. The lower assembly 82 is preferably a tubular member having a throughbore, such as a pipe or a mandrel having a bore therethrough. The tubing hanger lower assembly 82 extends around the production tubing string 122 with a production annulus 132a defined therebetween. While production string 122 preferably has a length such that its lower end extends approximately to the production zone Z, the tubing hanger lower assembly 82 preferably has a length substantially less than the length of the tubing string 122.

The sealing and lockdown assembly 134 is carried by the tubing hanger lower member 82. The sealing/lockdown assembly 134 is located near the lower end of the tubing hanger lower member 82. An enlarged view of the sealing/lockdown assembly 134 is shown in Figure IA. The sealing/lockdown assembly 134 includes an enlarged outside diameter

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tubular portion 136 which is slightly less than the inside diameter of the production casing 118. The sealing/lockdown assembly 134 includes a sealing apparatus 138 and a movement prevention locking apparatus or lockdown apparatus 140. The sealing apparatus 138 and the lockdown apparatus 140 may be contained within a unitary assembly or may be separate assemblies. In wells having a subsurface safety valve 126 (Figure 1), the sealing apparatus 138 is positioned in the casing string 118 above the subsurface safety valve 126 and the lockdown apparatus 140 will also be above the subsurface safety valve 126.

The lockdown apparatus 140 includes elements or slips, which may be metallic or nonmetallic, adapted to engage the interior of the production casing 118. When engaged, the lockdown apparatus 140 engages the interior of the casing 118 and "fixes" or prevents axial (i.e., vertical or up and down) movement of the tubing hanger suspension assembly 80 (Figure 1) relative to the production casing 118.

The sealing apparatus 138 includes a sealing element, which may be made of elastomers or other elastic materials (including composites) or a metal seal, adapted to form an annular seal between the production casing 118 and the tubular portion 136, as for example, by compression. The sealing apparatus 138 and the lockdown apparatus 140 may be independently activated or jointly activated. As shown in Figure IA, the activation and de-activation of the lockdown apparatus 140 and the sealing apparatus 138 is hydraulically controlled through ports 142a and 142b. However, the activation and de-activation may also be accomplished electronically, mechanically, or electrically.

The sealing and lockdown assembly 134 is activated, preferably hydraulically, via the hydraulic control lines to force the lockdown apparatus 140 into tight locked engagement with the production casing 118. The engaged lockdown apparatus 140 prevents or
substantially prevents relative vertical movement between the lower tubular member 82 and the production casing 118. The sealing and lockdown assembly 134 may comprise a set of slips having metal elements which grip the production casing 118. An elastomeric or other elastic-type seal is compressed by the set slips to form a fluid-tight seal. Typically, the sealing and lockdown assembly 134 is a modified packer assembly of the type conventionally used in wells to isolate production zones, etc. However, disclosed hereinafter are implementations of a multi-piece stacked sealing system designed to be used in place of the sealing apparatus 138 disclosed in U.S. Patent No. 7,419,001, to compliment the tubing hanger lockdown and seal assembly 134 disclosed therein, or to provide independent annular sealing between tubulars, i.e., in a well bore. U.S. provisional patent application number 61/176,441, upon which this application is based, is incorporated herein by reference.
BRIEF SUMMARY OF THE INVENTION

A multi-piece stacked sealing system (i.e., a multi-piece stacked seal system) arranged and designed to seal the annulus between tubular members, and more preferably, between production casing (i.e., outer tubular) and a tubing hanger (i.e., inner tubular) is disclosed. The system is preferably carried by a tubing hanger assembly and can either be a stand alone system or comprise a part of a sealing and locking mechanism assembly typically associated with a tubing hanger assembly. However, the system may also be used to seal annular spaces between a variety of tubulars. In a preferred implementation, the system comprises a plurality of rigid members (i.e., tapered rings composed of a rigid material), a plurality of elastic members (i.e., tapered rings composed of an elastic or elastomeric material), an upper support ring, and a lower support ring, each positioned around the circumference of the tubing hanger assembly. The plurality of rigid members are preferably stacked between the upper and lower support rings with the plurality of elastic members interposed therebetween such that the tapered surfaces of the rigid members, the elastic members, and the upper and lower support rings compliment each other.

The system is activated by applying an axial downward force on the upper support ring by several methods including, but not limited to, hydraulic, mechanical, electronic, or electrical methods. This compressive force in turn compresses the spaces between the rigid members (i.e., rigid tapered rings) stacked around the tubing hanger and further compresses the elastic members (i.e., elastic tapered rings) disposed there in between. Compression of the elastic members causes their temporary deformation and forces the elastic members into sealing contact with the inner wall of the production casing, thereby sealing the annulus between the tubing hanger and the production casing. Once compressed, the rigid members
are physically stopped by each other \((i.e., \text{they will not travel past each other})\), therefore, the
system cannot be over-compressed. Similarly, the compressed elastic members are
prevented from being extruded through any space between the inner wall of the production
casing and the rigid members during activation/compression of the system by the
counteracting compression forces that are imparted to the elastic members disposed between
adjacent rigid members. De-activation of the system may be accomplished by removing or
reducing the downward axial force applied to the upper support ring.
BRIEF DESCRIPTION OF THE DRAWINGS

By way of illustration and not limitation, the invention is described in detail hereinafter on the basis of the implementations represented in the accompanying figures, in which:

Figure 1 is a schematic sectional elevation view illustrating a universal tubing hanger suspension assembly comprising a tubing hanger lower assembly which carries a sealing and lockdown assembly;

Figure 1A is an enlarged schematic sectional elevation view of the sealing and lockdown assembly of the tubing hanger suspension assembly of Figure 1;

Figure 2 is an enlarged schematic sectional elevation view illustrating a preferred implementation of the multi-piece stacked sealing system, in an non-actuated or non-sealing state, carried by the tubing hanger lower assembly and disposed between the tubing hanger lower assembly and production tubing;

Figure 3 is an enlarged schematic sectional elevation view illustrating a preferred implementation of the multi-piece stacked sealing system of Figure 2 in which the multi-piece stacked sealing system has been actuated to seal the annulus between the tubing hanger lower assembly and the production tubing; and

Figure 4 illustrates an enlarged schematic sectional view of the multi-piece stacked sealing system of Figure 2 illustrating the elastic member disposed adjacent to a top rigid member.
DETAILED DESCRIPTION OF THE INVENTION

As generally shown in Figure 2, a preferred implementation of the invention is a multi-piece stacked sealing system 10 (i.e., a multi-piece stacked seal system) carried by a tubing hanger lower assembly 82 of a universal tubing hanger suspension assembly 80 (Figure 1). The multi-piece stacked sealing system 10 is preferably arranged and designed to seal the annulus between the tubing hanger lower assembly 82 and the production casing 118. The multi-piece stacked sealing system 10 preferably comprises a plurality of rigid rings or members 20, a plurality of elastic rings or members 40, 44, 46, coiled springs 60, 62, an upper support ring 22 carrying a U-cup seal 70, and a lower support ring 24 carrying a U-cup seal 70. The plurality of rigid members 20, the upper support ring 22, and the lower support ring 24 are preferably composed of a metallic material such as, but not limited to, steel; however various rigid nonmetallic and composite/mixed composition materials known to those of skill in the art may also be used.

Each of the rigid members 20 is a ring-like structure designed with an inner wall 26 having an inner diameter slightly larger than the outer diameter of the tubing hanger lower assembly 82 such that the rigid members 20 may be carried by the tubing hanger lower assembly 82. The rigid members 20 preferably have an outer diameter slightly smaller than the inner diameter of the production casing 118; however, the outer diameter of the rigid members 20 may be designed to contact the inner wall 92 of the production casing 118 regardless of whether the multi-piece stacked sealing system 10 is actuated or as a direct result of the actuation of the multi-piece stacked sealing system 10. Rigid members 20 are preferably designed such that in cross-section, as shown in Figure 2, the members 20 have a generally triangular shape (i.e., tapered on its top (upper) and bottom (lower) sides to form an
outwardly distal apex/vertex) with each vertex preferably being flat (i.e., not pointed).

The rigid members 20 are preferably stacked or disposed around the tubing hanger lower assembly 82 between an upper support ring 22 and a lower support ring 24 such that the inner wall 26 of the rigid members 20 is disposed adjacent to the outer surface 86 of the tubing hanger lower assembly 82. The rigid members 20 are preferably designed to move/slide axially about the outer surface 86 of the tubing hanger lower assembly 82. As previously discussed, the rigid members 20 have a generally triangular shape in cross-section and it is preferred to have the rigid members 20 oriented about the tubing hanger lower assembly 82 such that the apex 28 of this generally triangular shape in cross section is disposed towards the production casing 118. In other words, rigid rings or members 20 each have a top (upper) surface and a bottom (lower) surface that are tapered toward a common circular (i.e., circumferential) apex 28. When viewed in cross-section, this apex 28 may have a shape that is pointed (not shown) or flat (Figures 2-4). There are two rigid members 20 shown in Figure 2, however, additional rigid members (not shown) may be stacked above or below but between the upper 22 and lower 24 support rings. A space 30 is preferably disposed between each of the rigid members 20 and between the rigid members 20 and the upper 22 and lower 24 support rings.

The upper support ring 22, positioned around the circumference of the tubing hanger lower assembly 82 (i.e., inner tubular), has a U-cup seal 70 disposed in its inner wall 32 (Figure 4), which is arranged and designed to seal between the upper support ring 22 and the tubing hanger lower assembly 82. Similarly, the lower support ring 24, also positioned around the circumference of the tubing hanger lower assembly 82 (i.e., inner tubular), has a U-cup seal 70 disposed in its inner wall 34, which is arranged and designed to seal between
the lower support ring 24 and the tubing hanger lower assembly 82. These top and bottom U-cup seals 70 are preferably interchangeable and replaceable. While a U-cup seal is one preferred type of seal, other types of seals well known to those skilled in the art, including but not limited to O-ring and polypack seals, may also be preferably used. When viewed in cross-section (Figures 2-3), the upper support ring 22 preferably has a tapered lower surface and the lower support ring 24 preferably has a tapered upper surface. As viewed in cross-section, the respective vertices of the upper and lower support rings, which are adjacent to the outer surface 86 of the tubing hanger lower assembly 82 and elastic member 44, 46, are preferably flat (i.e., not pointed) so as to compliment the vertices of the elastic members 44, 46.

The elastic members 40, 44, 46 are preferably composed of a thermoplastic elastomer such as, but not limited to, an engineering thermoplastic elastomer. The thermoplastic elastomer is selected such that: (1) it is rigid under no axial loading and has a durometer between Shore 30D to 82D, more preferably between Shore 40D and 60D and most preferably between Shore 52D to 55D, and (2) under axial loading greater than approximately 50,000 lbf, but more preferably under axial loading greater than approximately 15,000 lbf, it becomes more fluid-like and capable of being deformed. Engineering thermoplastic elastomers composed, at least in part, of polyester, such as DuPont Hytrel® (thermoplastic polyester elastomer), and more specifically Dupont Hytrel® 5555HS, are a preferred material for constructing the elastic members 40, 44, 46. However, other thermoplastic polyester elastomers may also be used. A preferred material may also have some or all of the following characteristics:
An advantage of using a preferred elastomeric material is that the multi-piece stacked sealing system 10 may be activated or energized to deform the elastic members 40, 44, 46 at a much lower axial compression force.

As shown in Figure 2, the elastic members 40, 44, 46 are ring-like structures designed with an outer wall 42 having an outer diameter slightly smaller than the inner diameter of the inner wall 92 of the production casing 118. The elastic members 40, 44, 46 are preferably designed such that in cross-section, as shown in Figure 2, the elastic members 40, 44, 46 have a generally triangular shape (i.e., tapered on its top and bottom sides to form an inwardly distal apex). It is preferred to have the elastic members 40, 44, 46 oriented about the tubing hanger lower assembly 82 such that the apex 48 of this generally triangular shape in cross section is disposed towards the tubing hanger lower assembly 82. In other words, elastic rings or members 40, 44, 46 each have a top (upper) surface and a bottom (lower) surface that are tapered toward a common circular (i.e., circumferential) apex 48. When viewed in cross-section, this apex 48 may have a shape that is pointed (not shown) or flat.
(Figures 2-4). While the elastic members 40, 44, 46 are interposed to compliment the tapered surfaces of the rigid members 20 and the upper 22 and lower 24 support rings, the elastic members 40, 44, 46 are preferably designed not to be flush with the tubing hanger lower assembly 82 so as to provide the space 30 previously described. As shown, the elastic members 40, 44, 46 are designed to be interposed between rigid members 20 and between the rigid members 20 and the upper 22 and lower 24 support rings, such that the elastic members 40, 44, 46 are also carried by the tubing hanger lower assembly 82. Preferably, the plurality of rigid members 20 are stacked between the upper 22 and lower 24 support rings (and around the circumference of the tubing hanger) with the plurality of elastic members 40, 44, 46 interposed therebetween such that the tapered surfaces of the rigid members 20 and the elastic members 40, 44, 46 compliment each other.

The ring-like elastic member 44 disposed adjacent to the upper support ring 22 has an upper spring 60 that is shaped in the form of a ring and disposed therein preferably within a notch or recessed groove 64 formed in an upper most surface 52. Similarly, the ring-like elastic member 46 disposed adjacent to the lower support ring 24 has a lower spring 62 that is shaped in the form of a ring and disposed therein preferably within a notch or recessed groove 66 formed in a lower most surface 54. An enlarged schematic sectional elevation view of the elastic member 44 disposed adjacent to the upper support ring 22 is shown in Figure 4. The notch 64 formed in the upper most surface 52 of the elastic member 44 provides integral structures to elastic member 44, similar to lips, on either side of the notch 64. As shown in Figure 4, the integral structure of the elastic member 44 closest to the tubing hanger lower assembly 82 forms an upper inner lip 58 and the integral structure of the elastic member 44 closest to the production casing 118 forms an upper outer lip 56. An
unactuated, ring-shaped spring 60 is disposed in the notch 64. The upper spring 60 is designed to move radially outwardly in response to pressure applied axially to the upper support ring 22. The outward radial movement of the spring 60 is further designed to apply pressure and thereby move the upper outer lip 56 radially outwardly and into sealing contact with the inner wall 92 of production casing 118. While a close-up illustration of the elastic member 46 disposed adjacent to the lower support ring 24 is not shown, one skilled in the art will recognize that it would appear similar to that shown in Figure 4 except flipped top to bottom.

In a preferred method of using the invention, a universal tubing hanger suspension assembly 80 (Figure 1) is placed within the wellhead housing such that the multi-piece stacked sealing system 10 carried by the tubing hanger lower assembly 82 is positioned proximate to the portion of the production tubing 118 (i.e., outer tubular) to be annularly sealed. Figure 2 shows the multi-piece stacked sealing system 10 prior to activation and Figure 3 shows the multi-piece stacked sealing system 10 after activation. The multi-piece stacked sealing system 10 may be activated/actuated hydraulically by applying hydraulic fluid into a cavity (not shown) arranged and designed to exert a downward axial force against the upper support ring 22, e.g., through downward axial movement of ring-like member 76. As shown in Figures 2-4, ring-like member 76 is representative of a hydraulically-actuated piston-type device. Such hydraulic mechanisms and actions are well known to those skilled in the art and several hydraulic actuators are known that may be equally employed to activate/actuate the multi-piece stacked sealing system 10. Those skilled in the art will readily recognize that activation/actuation may also be effected electronically, mechanically, or electrically through a variety of methods and devices arranged and designed to apply a
downward axial force upon the multi-piece stacked sealing system 10.

Starting with Figure 2, upon activation/actuation, the upper support ring 22 of the multi-piece stacked sealing system 10 is forced downwardly in an axial direction by the downward axial movement of ring-like member 76 toward the rigid members 20 and the lower support ring 24, thereby compressing the upper support ring 22, the rigid members 20, and the lower support ring 24 together. The compression of these members 20 and rings 22, 24 closes the spaces 30 therebetween such that they contact each other but are positively stopped by each other (i.e., there is no over travel). Thus, the multi-piece stacked sealing system 10 is preferably activated or energized (and unlocked) by axially moved internal components but the system 10 cannot be over compressed. It should be noted that lower support ring 24 is preferably designed to move/slide axially about the outer surface 86 of the tubing hanger lower assembly 82. However, as shown in Figures 2 and 3, the downward axial movement of lower support ring 24 is stopped by tubing hanger lower assembly 82. This permits the members 20 and rings 22, 24 to be compressed together via the downward axial force applied to upper support ring 22, e.g., by ring-like member 76. Alternatively, but not shown, the downward axial movement of lower support ring 24 may be stopped by an actuated element or slip of lockdown apparatus 140, such as that shown in and described in relation to Figures 1 and 1A. Further still, lower support ring 24 may be coupled to tubing hanger lower assembly 82 so as to prevent any downward axial movement.

As shown in Figure 3, the compression of these member(s) 20 and rings 22, 24 also compresses the plurality of elastic members 40, 44, 46 interposed therebetween, which in turn forces these elastic members 40, 44, 46 to deform into sealing contact with the inner wall 92 of the production casing 118. This deformation and general outward radial
movement of elastic members 40, 44, 46, caused by their compression between the tapered surfaces of the rigid members 20 (and upper/lower support rings 22, 24), creates the spaces 38 as shown in Figure 3. The composition of the elastic members 40, 44, 46 is selected to ensure deformation of the elastic members 40, 44, 46 into sealing contact with the inner wall 92 of production casing 118, including production casing having an irregular surface, such as one marred, gashed, pitted, or out of round. The elastic member 44 adjacent to the upper support ring 22 is prevented from being extruded downwardly between the inner wall 92 of production casing 118 and the rigid member 20 by an equal or near equal counter force provided by the compressed, adjacently positioned elastic member 40. Similarly, the elastic member 46 adjacent to the lower support ring 24 is prevented from being extruded upwardly between the inner wall 92 of production casing 118 and the rigid member 20 by an equal or near equal counter force provided by the compressed, adjacently positioned elastic member 40. While Figures 2 and 3 show only one elastic member 40 between rigid members 20, additional elastic members 40 could be positioned between additional rigid members 20 in a similar alternating arrangement. The compression of these additional elastic members (not shown) would similarly prevent, by providing an equal or near equal counter force, the extrusion of adjacently positioned elastic members between the inner wall 92 of production casing 118 and the additional rigid members (not shown).

As best shown in Figure 3, compression of elastic member 44 by upper support ring 22 causes upper inner lip 58 (Figure 4) to compress and move upper spring 60 radially outward toward the inner wall 92 of the production casing 118. The radial outward movement of spring 60 forces upper outer lip 56 (Figure 4) into sealing contact with the inner wall 92 of the production casing 118. An advantage of the spring 60 is that it stores the
kinetic energy of the axial compression of multi-piece stacked sealing system 10; thereby retaining the compression force against upper outer lip 56 (Figure 4) in sealing contact with the inner wall 92 and preventing or minimizing further deformation or creep of the elastic member 44. As best shown in Figure 3, compression of elastic member 46 by lower support ring 24 causes lower inner lip 59 to compress and move lower spring 62 radially outward toward the inner wall 92 of the production casing 118. The radial outward movement of spring 62 forces lower outer lip 57 into sealing contact with the inner wall 92 of the production casing 118. The spring 62 also retains the compression force against lower outer lip 57 in sealing contact with the inner wall 92; thereby preventing or minimizing further deformation or creep of the elastic member 46. As will be readily apparent to one skilled in the art, when additional axial pressure is applied to the multi-piece stacked sealing system 10 either upwardly or downwardly, the compression of the elastic members 40, 44, 46 between the inner wall 92 of the production casing 118 and the tubing hanger lower assembly 82 increases, thereby improving the leak resistance of the multi-piece stacked sealing system 10.

As will be readily recognized by those skilled in the art, deactivation or unlocking of the multi-piece stacked sealing system 10 is accomplished by removing the downward axial force caused to be exerted upon the upper support ring 22, e.g., by member 76. The absence of this downward axial force will allow the elastic members 40, 44, 46 to resume their former shape, thereby expanding the rigid members 20 (and upper support ring 22) axially. While the previous implementations generally describe the activation/actuation of the system 10 using an axial downward force applied to the upper support ring 22 with the lower support ring 24 held stationary, an alternative implementation may activate/actuate the system 10 using an axial upward force applied to the lower support ring 24 with the upper support ring
22 held stationary. Based on the disclosure herein, such alternative implementation is within
the knowledge of those skilled in the art.

The Abstract of the disclosure is written solely for providing the United States Patent
and Trademark Office and the public at large with a means by which to determine quickly
from a cursory inspection the nature and gist of the technical disclosure, and it represents
solely a preferred implementation and is not indicative of the nature of the invention as a
whole.

While some implementations of the invention have been illustrated in detail, the
invention is not limited to the implementations shown; modifications and adaptations of the
above implementations may occur to those skilled in the art. Such modifications and
adaptations are in the spirit and scope of the invention as set forth in the claims:
WHAT IS CLAIMED IS;

1. A system (ID) for sealing an annular space between well bore tubulars, said system comprising:

   a plurality of rigid rings (20) having a tapered upper surface and a tapered lower surface and arranged and designed to be stacked around an inner tubular (82), said plurality of rigid rings each having an outside diameter smaller than an inside diameter of an outer tubular (118);

   a plurality of elastic rings (40, 44, 46) having a tapered upper surface and a tapered lower surface and arranged and designed to be stacked between said plurality of said rigid rings such that said tapered upper and lower surfaces of said rigid rings compliment said tapered upper and lower surfaces of said elastic rings, said plurality of elastic rings each having an outside diameter smaller than an inside diameter of said outer tubular;

   an upper support ring (22) disposed above said plurality of rigid rings and having one (44) of said plurality of elastic rings interposed therebetween, said upper support ring having a tapered lower surface to compliment said tapered upper surface of said one of said plurality of elastic rings and having an outside diameter smaller than an inside diameter of said outer tubular, said upper support ring arranged and designed to be disposed around said inner tubular;

   a lower support ring (24) disposed below said plurality of rigid rings and having another (46) of said plurality of elastic rings interposed therebetween, said lower support ring having a tapered upper surface to compliment said tapered lower surface of said another of said plurality of elastic rings and having an outside diameter smaller than an inside diameter of said outer tubular, said lower support ring arranged and designed to be disposed around...
said inner tubular;

an upper spring (60) disposed in an upper recessed groove (64) in an upper surface (52) of said one of said plurality of elastic rings, said upper recessed groove (64) forming an upper outer lip (56) within said one of said plurality of elastic rings, said upper spring arranged and designed to transfer axial force acting upon said upper support ring to said upper outer lip; and

a lower spring (62) disposed in a lower recessed groove (66) in an lower surface (54) of said another of said plurality of elastic rings, said lower recessed groove (66) forming a lower outer lip (57) within said another of said plurality of elastic rings, said lower spring arranged and designed to transfer axial force acting upon said lower support ring to said lower outer lip.

2. The system of claim 1 wherein,

said upper support ring carries within an inner surface (32) thereof a seal arranged and designed to seal between said upper support ring and said inner tubular, and

said lower support ring carries within an inner surface (34) thereof a seal arranged and designed to seal between said lower support ring and said inner tubular.

3. The system of claim 1 wherein,

said inner tubular is a tubing hanger (82) and said outer tubular is production casing (118).

4. The system of claim 1 wherein,

said plurality of elastic rings are at least in part composed of a thermoplastic elastomer.
5. The system of claim 4 wherein,
said thermoplastic elastomer is at least in part composed of a polyester.

6. The system of claim 1 wherein,
said system is arranged and designed to be carried by a tubing hanger assembly (80).

7. A method of sealing an annular space between well bore tubulars, said method comprising the steps of:

    carrying a sealing system (10) on an inner tubular (82), said sealing system having a plurality of rigid rings (20) tapered on an upper surface and a lower surface and stacked around said inner tubular, said plurality of rigid rings each having an outside diameter smaller than an inside diameter of an outer tubular (118), said sealing system further having a plurality of elastic rings (40, 44, 46) tapered on an upper surface and a lower surface and stacked between said plurality of said tapered rigid rings such that said upper and lower surfaces of said rigid rings compliment said upper and lower surfaces of said elastic rings, said plurality of elastic rings each having an outside diameter smaller than an inside diameter of said outer tubular, said sealing system further having an upper support ring (22) disposed above said plurality of rigid rings with one (44) of said plurality of elastic rings interposed therebetween, said upper support ring having a tapered lower surface to compliment said upper surface of said one of said plurality of elastic rings and having an outside diameter smaller than an inside diameter of said outer tubular, said upper support ring disposed around said inner tubular, said sealing system further having a lower support ring (24) disposed below said plurality of rigid rings with another (46) of said plurality of elastic rings interposed therebetween, said lower support ring having a tapered upper surface to compliment said lower surface of said another of said plurality of elastic rings and having an...
outside diameter smaller than an inside diameter of said outer tubular, said lower support ring arranged and designed to be disposed around said inner tubular, said sealing system further having an upper spring (60) disposed in an upper recessed groove (64) in an upper surface (52) of said one of said plurality of elastic rings, said upper recessed groove (64) forming an upper outer lip (56) within said one of said plurality of elastic rings, said upper spring arranged and designed to transfer axial force upon said upper support ring to said upper outer lip, and said sealing system further having a lower spring (62) disposed in a lower recessed groove (66) in an lower surface (54) of said another of said plurality of elastic rings, said lower recessed groove (66) forming an lower outer lip (57) within said another of said plurality of elastic rings, said lower spring arranged and designed to transfer axial force upon said lower support ring to said lower outer lip;

positioning said sealing system carried by said inner tubular within an outer tubular at a position for sealing an annular space between said outer tubular and said inner tubular using said sealing system; and

applying an axial force on said sealing system such that said upper support ring, said plurality of rigid rings, and said lower support ring are moved closer together, thereby compressing and deforming said plurality of elastic rings into sealing contact with said outer tubular.

8. The method of claim 7 wherein,

said upper support ring carries a seal arranged and designed to seal between said upper support ring and said inner tubular, and

said lower support ring carries a seal arranged and designed to seal between said lower support ring and said inner tubular.
9. The method of claim 7 wherein,
said axial force is produced by hydraulic fluid acting on said sealing system.

10. The method of claim 7 wherein,
said inner tubular is a tubing hanger (82) and said outer tubular is production casing

11. The method of claim 7 wherein,
said plurality of elastic rings are at least in part composed of a thermoplastic elastomer.

12. The method of claim 11 wherein,
said thermoplastic elastomer is at least in part composed of a polyester.
INTERNATIONAL SEARCH REPORT

A CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 33/1.2 (2010 0.01)
USPC - 166/387

According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - E21B 23/06, 33/03, 33/12, 33/1295 (2010 01)
USPC - 166/387

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patent

C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 3,335,800 A (MYERS) 15 August 1967 (15 08 1967) entire document</td>
<td>1-12</td>
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D Further documents are listed in the continuation of Box C

*Special categories of cited documents
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Date of the actual completion of the international search
25 June 2010

Date of mailing of the international search report
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