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SEALING DEVICES AND RELATED METHODS FOR OIL AND GAS APPLICATIONS

Abstract

A sealing device includes a first ring that is fixedly attached to a pipe segment, a second ring that is movably secured to the pipe segment and spaced axially apart from the first ring in an initial configuration of the sealing device, and a third ring that axially overlaps a first wall portion of the first ring and a second wall portion of the second ring, wherein the third ring is expandable radially to accommodate a third wall portion of the first ring and a fourth wall portion of the second ring within an interior region of the third ring.

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Background/Summary

TECHNICAL FIELD

[0001] This disclosure relates to sealing devices for oil and gas applications, such as annular sealing devices with an expandable ring that provides metal-to-metal sealing with a surrounding pipe segment.

BACKGROUND

[0002] In oil and gas settings, casing strings may be cemented in place within a well to anchor the strings and provide barriers to uphole migration of fluids (e.g., gases and liquids) within the annular regions between the strings. If the cement job is of a low quality, then channels can form leak paths in the cement, which can result in annular fluid pressure building between the casing strings over time. For example, gas can therefore, undesirably, travel to the surface and cause the well to be suspended for safety reasons, as produced fluids are supposed to travel to the surface only through a production tubing (e.g., an innermost pipe segment).

[0003] Leak paths within the cement are difficult to fix (e.g., especially between casing strings located radially far from the production tubing) and require removal of the casing strings that are adjacent to the leak to provide access to the respective annuli. Such operations are expensive, complex, and technically difficult to perform. Packers may be employed within the annuli to block such leak paths. Conventional inflatable packers often require a fluid delivery port to be provided in the casing string, but such port is subject to failure over time. Conventional swelling packers are formed from elastomers, which have a finite life span and are therefore also subject to failure during the expected life of the well. Such failures compromise the integrity of the well and should be prevented when possible.

SUMMARY

[0004] This disclosure relates to sealing devices for oil and gas applications, such as annular sealing devices with an expandable ring that provides metal-to-metal sealing with a surrounding pipe segment. For example, such sealing devices are installed within an annular region between inner and outer pipe segments of a casing string and include a fixed ring, a movable ring, and an expandable ring. The expandable ring can expand radially outward to accommodate a width of the fixed and movable rings within an interior region of the expandable ring. In some embodiments, one or more of all of the rings are made entirely of metal.

[0005] The details of one or more embodiments are set forth in the accompanying drawings and description. Other features, aspects, and advantages of the embodiments will become apparent from the description, drawings, and claims.

Description

DESCRIPTION OF DRAWINGS

[0006] FIG. **1** is a side perspective view of an example casing string that is equipped with an example sealing device in an annular region.

[0007] FIG. **2** is a side cross-sectional view of the casing string of FIG. **1**, with the sealing device in a pre-set configuration.

[0008] FIG. **3** is a side cross-sectional view of the casing string of FIG. **1**, with the sealing device in a post-set configuration.

[0009] FIG. **4** is an enlarged, side cross-sectional view of a portion of the casing string of FIG. **1**, with the sealing device in a post-set configuration.

[0010] FIG. **5** is an enlarged, side cross-sectional view of a portion of the casing string of FIG. **1**, with the sealing device in a post-set configuration.

[0011] FIG. **6** is a side cross-sectional view of a latch mechanism of the sealing device of FIG. **1**, with the sealing device in a post-set configuration

[0012] FIG. **7** is a side perspective view of an inner pipe segment of the casing string of FIG. **1**,

equipped with the sealing device in a pre-set configuration.
[0013] FIG. **8** illustrates a side perspective view of a fixed ring and a movable ring of the sealing device of FIG. **7** in a pre-set configuration of the sealing device.
[0014] FIG. **9** illustrates a side perspective view of the fixed ring and the movable ring of the sealing device of FIG. **7** in the post-set configuration of the sealing device.
[0015] FIG. **10** illustrates a side perspective view the fixed ring, the movable ring, and an expandable ring of the sealing device of FIG. **7** in the post-set configuration of the sealing device.
[0016] FIG. **11** illustrates an exploded side perspective view of the fixed ring, the movable ring, and the expandable ring of the sealing device of FIG. **7**.
[0017] FIG. **12** illustrates a side cross-sectional view of the fixed, movable, and expandable rings of FIG. **11**.
[0018] FIG. **13** illustrates a side perspective view of circumferential sealing elements along an inner pipe segment of the casing string of FIG. **1**.
[0019] FIG. **14** illustrates a side cross-sectional view of the sealing device, within the casing string of FIG. **1**, in a pre-set configuration of the sealing device during a weight-set operation.
[0020] FIG. **15** illustrates a side cross-sectional view of the sealing device, within the casing string of FIG. **1**, in a post-set configuration of the sealing device during a weight-set operation.
[0021] FIG. **16** illustrates a side cross-sectional view of the sealing device, within the casing string of FIG. **1**, in a pre-set configuration of the sealing device during a tension-set operation.
[0022] FIG. **17** illustrates a side cross-sectional view of the sealing device, within the casing string of FIG. **1**, in a post-set configuration of the sealing device during a tension-set operation.
[0023] FIG. **18** illustrates a top cross-sectional view of the sealing device, within the casing string of FIG. **1**, in a pre-set configuration of the sealing device.
[0024] FIG. **19** illustrates a top cross-sectional view of the sealing device, within the casing string of FIG. **1**, in a post-set configuration of the sealing device.
[0025] FIG. **20** is a flow chart illustrating an example method of sealing an annular region using the example sealing device of FIG. **1** or the example sealing device of FIG. **21**.
[0026] FIG. **21** is a perspective view of an inner pipe segment of the casing string of FIG. **1**, equipped with an example sealing device that includes an automated locking mechanism.
[0027] FIG. **22** is a cross-sectional view of the inner pipe segment and the sealing device of FIG. **21**.
[0028] FIG. **23** is a side view of the inner pipe segment and the sealing device of FIG. **21**, with certain components removed to expose latching pins of the sealing device.
[0029] FIG. **24** is a side perspective view of the inner pipe segment and the sealing device of FIG. **21**, with a cover removed to expose an actuation module of the sealing device.
[0030] FIG. **25** is a perspective view of the inner pipe segment and the sealing device of FIG. **24**, illustrating a pressor sensor along an end of the actuation module.
[0031] FIG. **26** is a schematic view of the actuation module of FIG. **24** in a deactivated state of the locking mechanism for which a latch of the sealing device is restrained.
[0032] FIG. **27** is a schematic view of the actuation module of FIG. **24** in an actuated state of the locking mechanism for which a latch of the sealing device is released.

DETAILED DESCRIPTION

[0033] FIGS. **1-3** illustrate an example casing string **105** that includes an inner pipe segment **101** (e.g., a first casing joint or a production tube) and an outer pipe segment **111** (e.g., a second casing joint) that surrounds the inner pipe segment **101** within a well of a rock formation. The inner pipe segment **101** defines an interior channel **129** through which fluids or other components may be flowed or dropped into the inner pipe segment **101**. The casing string **105** is equipped with an example sealing device **100** that is located within an annular region **103** formed between the pipe segments **101**, **111**. In some embodiments, the sealing device **100** is a packer that is designed to seal radially against both pipe segments **101**, **111** to close the annular region **103**.

[0034] Referring to FIGS. **2** and **3**, the outer pipe segment **111** includes a wall **107** that defines an interior grove **109** (e.g., a machined groove or recess). The groove **109** extends around an inner circumference of the pipe segment **111** and is formed to accommodate a portion of the sealing device **100**. For example, the groove **109** is formed as a seat that includes a substantially cylindrical portion **113** and a tapered (e.g., substantially frustoconical) portion **115**. The inner pipe segment **101** includes a wall **117** and an exterior stopping element **119** (e.g., a stop collar) that axially positions the sealing device **100** along the pipe segment **101**. The inner pipe segment **101** defines a central axis **121**. Both pipe segments **101**, **111** are made of one or more metals, such as steel. The inner pipe segment **101** is illustrated in a pre-set position with respect to the outer pipe segment **111** in FIG. **2** and illustrated in a post-set position with respect to the outer pipe segment **111** in FIG. **3**.
[0035] Referring to FIGS. **2-7**, the sealing device **100** surrounds the inner pipe segment **101** and includes a fixed ring **102** (e.g., a static ring), a movable ring **104** (e.g., a dynamic ring), and an expandable ring **106**. The fixed ring **102** is located in a fixed axial position with respect to the inner pipe segment **101**. For example, the fixed ring **102** is positioned against the exterior stopping element **119**. The fixed ring **102** includes a main wall portion **108** (e.g., a substantially cylindrical wall portion) and an end wall portion **110** (e.g., including both a tapered portion and a cylindrical portion). The movable ring **104** includes a main wall portion **112** (e.g., a substantially wall cylindrical portion) and an end wall portion **114** (e.g., including both a tapered portion and a cylindrical portion). In a pre-set (e.g., initial) configuration of the sealing device **100** (shown in FIG. **2**), the movable ring **104** is secured to the inner pipe segment **101** at an initial axial position by one or more set screws **139** (e.g., grub screws). In an operational configuration of the sealing device **100**, the movable ring **104** is movable axially with respect to the inner pipe segment **101** from the initial axial position to a final axial position that corresponds to a post-set configuration (e.g., a final or functional configuration) of the sealing device **100** (shown in FIG. **3**).
[0036] The expandable ring **106** includes a main wall portion **116** (e.g., a substantially cylindrical wall portion), a first end wall portion **118** (e.g., including both a tapered portion and a cylindrical portion), and a second end wall portion **120** (e.g., including both a tapered portion and a cylindrical portion). In the pre-set configuration of the sealing device **100** (shown in FIGS. **2** and **7**), the end wall portions **118**, **120** respectively overlap the end wall portions **110**, **114** such that the end wall portions **110**, **114** determine an axial position of the expandable ring **106**. Owing to the tapered portions of the end wall portions **110**, **114**, a circumferential gap **122** is disposed between the rings **104**, **106**, **108** in the pre-set configuration.
[0037] Referring to FIGS. **4-9**, during a setting operation, the movable ring **104** is moved axially into the gap **122** along the inner pipe segment **101** until the wall portions **110**, **114** either contact each other or are separated by a small, optional gap **148**. For example, adequate sealing can be achieved even when the small gap **148** is present between the rings **102**, **104**, as illustrated. In embodiments for which no gap exists such that the movable ring **104** ultimately contacts the ring fixed ring **102**, the maximum travel distance of the movable ring **104** will have been reached. In some embodiments, such contact between the rings **102**, **104** in this manner maximizes the possible sealing area.
[0038] Referring to FIGS. **3-5**, **10**, and **12**, as the movable ring **104** moves axially, the expandable ring **106** expands radially outward to accommodate a width of the main wall portions **108**, **112** of the fixed and movable rings **102**, **104** within a cylindrically-shaped interior region **146** of the expandable ring **106**. While expanding, the expandable ring **106** slides axially over the end wall portions **110** of the fixed ring **102** to contact the main wall portion **108**, and the movable ring **104** slides axially interiorly within the expandable ring **106** such that the expandable ring **106** contacts the main wall portion **112**. The expandable ring **106** is permitted to slide along the fixed ring **102** until a shoulder **124** of the expandable ring **106** abuts a stopping element **126** (e.g., a protrusion) of the fixed ring **102**. In this post-set configuration of the sealing device **100**, the expandable ring **106** is positioned as illustrated in FIGS. **3-5** and **10**.

[0039] In some embodiments, the fixed ring **102** and the movable ring **104** are formed from one or more metals, such as steel. In some embodiments, the expandable ring **106** is formed from one or more expandable metals that can withstand high differential pressures for VO gas qualification, such as specially treated steel. In some embodiments, one or more of all of the rings **102**, **104**, **106** are made entirely of metal. In some embodiments, the fixed ring **102** has a length in a range of about 0.1 meters (m) to about 0.3 m. In some embodiments, the movable ring **104** has a length in a range of about 0.5 m to about 5 m. In some embodiments, the expandable ring **106** has a length in a range of about 0.4 m to about 5.5 m. In some embodiments, the sealing device **100** has total a length in a range of about 1 m to about 12 m in the pre-set configuration of sealing device. In some embodiments, the sealing device **100** has total a length in a range of about 0.4 m to about 7 m in the post-set configuration of sealing device. In some embodiments, the movable ring **104** has moved a total distance of about 0.3 m to about 5 m with respect to the inner pipe segment **101** between the pre-set and post-set configurations of the sealing device **100** (e.g., during a complete operation of the sealing device **100**).

[0040] Referring to FIGS. **11-13**, the inner pipe segment **101**, the movable ring **104**, and the expandable ring **106** include multiple circumferential sealing elements (e.g., sealing rings or sealing ribs) that are machined into their exterior wall surfaces. Some of the sealing elements are also visible in FIG. **4**. The sealing elements are formed to radially engage (e.g., bite radially into) material of the adjacent components to enhance a sealing effect between these concentrically arranged components. The sealing elements of the device components that experience or undergo significant relative sliding (e.g., the inner pipe segment **101** and the dynamic ring) have progressively increasing heights (e.g., standoffs), as indicated by the lines **128** in FIG. **13**. For example, on each of the inner pipe segment **101** and the movable ring **104**, the sealing element with the smallest height is the first to engage the surrounding sliding component, such that each successive sealing element causes increasing radial expansion of the surrounding component.

[0041] The inner pipe segment **101** includes sealing elements **130***a*, **130***b*, **130***c* of respective heights that progressively increase in a first direction, and the movable ring **104** includes sealing elements **132***a*, **132***b*, **132***c* of respective heights that increase in an opposite, second direction. The expandable ring **106** includes sealing elements **134** of the same height since no component of the sealing device **100** surrounds the external surface of the expandable ring **106**. While each of the inner pipe segment **101**, the movable ring **104**, and the expandable ring **106** are illustrated as including three sealing elements, in general, any of these components may include less than three or more than three such sealing elements.

[0042] In some embodiments, the sealing elements **130***a*, **130***b*, **130***c* have heights in a range of about 0.2 centimeters (cm) to about 0.5 cm. In some embodiments, the sealing elements **132***a*, **132***b*, **132***c* have heights in a range of about 0.2 cm to about 0.5 cm. In some embodiments, the sealing elements **134** have heights in a range of about 0.2 cm to about 0.5 cm. In some embodiments, the sealing elements along any of the inner pipe segment **101**, the movable ring **104**, and the expandable ring **106** may be spaced axially (e.g., equidistantly or non-equidistantly) apart by a distance of about 0.02 m to about 0.2 m.

[0043] Referring to FIGS. **6**, **7**, **11**, and **12**, the movable ring **104** also includes one or more latch mechanisms **136** that fixes a position of the movable ring **104** with respect to the outer pipe segment **111** during a setting operation. The latch mechanisms **136** also serve as centralizers that radially center the sealing device **100** (e.g., and accordingly, the inner pipe **101** to which the sealing device **100** is installed) within the outer pipe segment **111**. The latch mechanisms **136** are aligned with an end **138** of the main wall portion **112** and, in part, extend through respective openings **138** in the main wall portion **112**. Each latch mechanism **136** includes a radially oriented spring **140** and a latch **142** (e.g., a latching dog) positioned adjacent and radially outward of the spring **140**. The spring **140** and the latch **142** are positioned in a receptacle **144** defined by the inner pipe segment **101** and an opening **138** in the main wall portion **112**. The latch mechanism **136** also includes a housing **150** that is secured to an exterior surface of the main wall portion **112** to secure the latch **142** to the movable ring **304** within the receptacle **144**.

[0044] With the latch **142** spring-loaded (e.g., biased) in a radially outward direction, the latch **142** pushes outwardly against an inner surface of the outer pipe segment **111** while the inner pipe segment **102** is moved axially within the outer pipe **111**. When the latch **142** reaches the groove **109** (e.g., such that the latch **142** is radially unobstructed), a portion of the latch **142** extends radially outward through an opening in the housing **150** and into the groove **109** to prevent the movable ring **142** from moving axially.

[0045] FIGS. **14** and **15** respectively illustrate pre-set and post-set configurations of the sealing device **100** during a weight-set operation for installing (e.g., cementing) the casing string **105** in a well of a rock formation **127**. The groove **109** of the outer pipe segment **111** is at a known depth based on the prior installation of the outer pipe segment **111**. The sealing device **100** is then securely installed to the inner pipe segment **101** (e.g., at an axial position that will enable the latch mechanisms **136** of the sealing device **100** to engage the groove **109** of the outer pipe segment **111** before a downhole end (e.g., a shoe) of the inner pipe segment **101** reaches the bottomhole end of the well. For example, since the latch mechanisms **136** will engage the groove **109** as the inner pipe segment **101** is run into the well, it is important to appropriately, axially position the the inner pipe segment **101** to prevent the shoe from contacting the bottomhole before the sealing device **100** reaches the seat, while also leaving enough space to allow the sealing device **100** to complete its stroke length.

[0046] The inner pipe segment **101**, equipped with the sealing device **100**, is advanced into the well and through the outer pipe segment **111** to an axial position at which the latch mechanism **136** is located above and spaced apart from the groove **109**. In cases for which a primary cement job is planned, the cement exits the casing string **105** from the bottom (e.g., the shoe) and travels in an uphole direction **123** within the annular region **103**. For example, the sealing device **100** can be axially positioned anywhere in the casing string **105** above the shoe, and the cement will travel past the sealing device **100** such that sealing is effected before the cement sets. In cases for which a secondary cement job is planned, an inflatable packer may be set and ports opened in the casing to allow cement to flow out of the annular region **103** above the location of the packer. The sealing device **100** will then be run below the 2-stage cement tool (e.g., a DV tool). In such cases, the primary cement may not reach the sealing device **100** either by design or due to circumstance, but the sealing device **100** can still be set in the same manner. The inner pipe segment **101**, equipped with the sealing device **100**, is then advanced further in the downhole direction **125** until the latch **142** engages (e.g., is received within) the groove **109** to prevent any further advancement of the inner pipe segment **101** within the outer pipe segment **102**.

[0047] With the latch **142** securely retained within the groove **109**, an uphole hold or grip on the inner pipe segment **101** can be released to allow the sealing device **100** to set between the inner and outer pipe segments **101**, **111**. For example, upon such release, the weight of the inner pipe segment **101**, carrying the fixed ring **102** in fixed relation, will overcome the resistance of the set screw **139**s (e.g., thereby breaking the set screws **139**) to move with respect to the movable ring **104** in the downhole direction **125**. Such movement thereby moves the fixed ring **102** axially towards the movable ring **104** and accordingly forces the expandable ring **106** radially outward to surround the main wall portions **108**, **112** of the rings **102**, **104**. In this post-set configuration of the sealing device **100**, the expandable ring **106** forms an outer metal-to-metal seal with the outer pipe segment **111** and forms an inner metal-to-metal with the fixed and movable rings **102**, **104**. Furthermore, the movable ring **104** forms a metal-to-metal seal with the inner pipe segment **101**.

[0048] In some implementations, the weight-set operation may be performed when the groove **109** of the outer pipe segment **111** is oriented as illustrated in FIGS. **14** and **15** (e.g., with the cylindrical portion **113** located downhole of the tapered portion **111**). In other implementations, the groove **109** may be positioned in a reverse orientation, with the cylindrical portion **113** located uphole of the tapered portion **111**, as illustrated in FIGS. **16** and **17**. In such cases, the sealing device **100** may be set according to a tension-set operation.

[0049] FIGS. **16** and **17** respectively illustrate pre-set and post-set configurations of the sealing device **100** during such a tension-set operation for installing (e.g., cementing) the casing string **105** in a well of the rock formation **127**. The outer pipe segment **111** is advanced (e.g., run) into the well along the downhole direction **125** until the groove **109** reaches a desired depth. The sealing device **100** is then securely installed to the inner pipe segment **101** (e.g., at an axial position that will enable the latch mechanism **136** of the sealing device **100** to pass the groove **109** of the outer pipe segment **111** before the downhole end of the inner pipe segment **101** reaches the bottomhole end of the well so that the sealing device **100** can set in the reverse direction (e.g., the uphole **123** direction).

[0050] The inner pipe segment **101**, equipped with the sealing device **100**, is advanced into the well and through the outer pipe segment **111** to an axial position at which the latch mechanism **136** is located below and spaced apart from the groove **109**. Cement may travel within the casing string **105** as already described above with respect to a weight-set operation for a primary or secondary cement job. During the presently described operation (e.g., a tension-set operation), cement may or may not end up above the latch mechanism **136** upon setting, depending on a design of the cement job and various operational factors. The inner pipe segment **101**, equipped with the sealing device **100**, is then moved in the uphole direction **123** (e.g., raised) until the latch **142** engages (e.g., is received within) the groove **109** to prevent any further movement of the inner pipe segment **101** within the outer pipe segment **102**.

[0051] With the latch **142** securely retained within the groove **109**, the inner pipe segment **101** can be pulled further to allow the sealing device **100** to set between the inner and outer pipe segments **101**, **111**. For example, such pulling can cause the weight of the inner pipe segment **101**, carrying the fixed ring **102** in fixed relation, to overcome the resistance of the set screws **139** (e.g., thereby breaking the set screws **139**) to allow the ring **102** to move in the uphole direction **123** with respect to the movable ring **104**. Such movement thereby moves the fixed ring **102** axially towards the movable ring **104** and accordingly forces the expandable ring **106** radially outward to surround the main wall portions **108**, **112** of the rings **102**, **104**. In this post-set configuration of the sealing device **100**, the expandable ring **106** forms an outer metal-to-metal seal with the outer pipe segment **111** and forms an inner metal-to-metal with the fixed and movable rings **102**, **104**. Furthermore, the movable ring **104** forms a metal-to-metal seal with the inner pipe segment **101**.

[0052] FIGS. **18** and **19** respectively illustrate the annular region **103** for both pre-set and post-set configurations of the sealing device **100** (e.g., irrespective of the type of setting operation that has been employed). In the pre-set configuration, the annular region **103** is open for cement or fluids to pass. In contrast, in the post-set configuration, the annular region **103** has been sealed (e.g., blocked or closed off) by the sealing device **100**. (In the example of FIGS. **18** and **19**, the outer pipe segment **111** is illustrated interiorly of another annular region **152** located between the outer pipe segment **111** and yet another, surrounding pipe segment (e.g., another casing string joint, not shown). A total number of pipe segments of the casing string **105** may depend on several operational parameters.)

[0053] The sealing device **100** advantageously prevents gas migration to the surface through the annular region **103** in a manner that is relatively easy to effect. For example, given that the sealing device **100** does not require the presence of any fluid ports or elastomeric materials within the well, the sealing device **100** reduces the likelihood of leak generation and/or movement within the annular region **103** and is designed to remain effective throughout an expected life of the well in which it is deployed. This is made possible, at least in part, by the all-metal construction of the sealing device **100**.

[0054] FIG. **20** is a flow chart illustrating an example method **200** of sealing an annular region (e.g., the annular region **103**). In some embodiments, the method **200** includes a step **202** for moving a first pipe segment (e.g., the inner pipe segment **101**) within a second pipe segment (e.g., the outer pipe segment **101**) to a first downhole position, the first and second pipe segments defining the annular region therebetween, and the first pipe segment carrying a sealing device (e.g., the sealing device **100**, **300**) that includes a first ring (e.g., the fixed ring **102**) that is fixedly attached to the first pipe segment, a second ring (e.g., the movable ring **104**, **304**) that is movably secured to the first pipe segment, and a third ring (e.g., the expandable ring **106**) that axially overlaps a first wall portion (e.g., the end wall portion **110**) of the first ring and a second wall portion (e.g., the end wall portion **114**) of the second ring. In some embodiments, the method **200** includes a step **204** for delivering cement to the annular region. In some embodiments, the method **200** includes a step **206** for moving the first pipe segment within the second pipe segment to a second downhole position at which a latch (e.g., the latch **142**, **314**) of the second ring is retained within a groove (e.g., the groove **109**) of the second pipe segment. In some embodiments, the method **200** includes a step **208** for expanding the third ring radially outward to contact the second pipe segment and seal the annular region.

[0055] While the sealing device **100** has been described and illustrated with respect to certain dimensions, sizes, shapes, arrangements, materials, and methods **200**, in some embodiments, a sealing device that is otherwise similar in construction and/or function to the sealing device **100** may include one or more different dimensions, sizes, shapes, arrangements, configurations, or materials, or be operated according to different methods.

[0056] For example, in some embodiments, a sealing device that is otherwise substantially similar to the sealing device **100** may include one or more smart latch mechanisms (e.g., automated locks) that can be automatically controlled to engage with or disengage with the groove **109** of the outer pipe segment **111** during a setting operation. Referring to FIGS. **19-21**, a sealing device **300** includes multiple hydraulic latch mechanisms **336** instead of the mechanical latch mechanisms **136** of the sealing device **100**. The sealing device **300** further includes a support ring **302** to which the latch mechanisms **336** are secured. The latch mechanisms **336** and the support ring **302** together provide a locking assembly **306**. In addition to providing a locking functionality to the sealing device **300**, the latch mechanisms **336** also serve as centralizers that radially center the sealing device **300** and the inner pipe **101** (e.g., to which the sealing device **300** is installed) within the outer pipe segment **111**.

[0057] The sealing device **300** also includes a movable ring **304** that interfaces with the latch mechanism **336**, but that is otherwise substantially similar in construction and function to the movable ring **104**. Furthermore, the sealing device **300** is otherwise substantially similar in construction and function to the sealing device **100** and accordingly includes the fixed ring **102**, the expandable ring **106**, and other components and features described above with respect to the sealing device **100**.

[0058] Still referring to FIGS. **21-23**, each latch mechanism **336** includes a main housing **308** that is positioned on the support ring **302** and a latch housing **310** that is positioned on the movable ring **304**. The latch mechanism **336** further includes a radially oriented spring **312** and a latch **314** positioned adjacent and radially outward of the spring **312**. The spring **312** and the latch **314** are positioned in a receptacle **344** formed by the inner pipe segment **101** and an opening in a main wall portion of the movable ring **304**. The latch housing **310** is secured to the exterior surface of the main wall portion to secure the latch **314** to the movable ring **304** within the receptacle **344**.

[0059] The latching mechanism **336** includes a latch pin **316** that is movable axially in a first direction over an end portion of the latch **314** to maintain the latch **314** directly against the inner pipe segment **101** (e.g., in a retracted radial position). The latch pin **316** is also movable axially in a second, opposite direction off of the latch **314** to allow the spring-loaded latch **314** to extend radially outward (e.g., to an extended position) from the latch housing **310** to engage the groove **109** of the outer pipe segment **111**.

[0060] Referring to FIGS. **25-27**, the latch mechanism **336** includes an actuation module **340** that is disposed within the main housing **308** and protected by a cover **318**. The actuation **340** module includes electronics **322**, an on-board battery **324** that powers the actuation module **340**, a fluid tank **326**, a valve **328**, a valve actuator **330**, a piston housing **332**, hydraulic fluid **334**, a fluid line **346**, a fluid tank **326**, a piston **338** positioned within the piston housing **332**, and the latch pin **316**, which extends from the piston **338**. The piston **338** is equipped with seals **342** that prevent leakage of the fluid **334** circumferentially along the piston **338**. In some embodiments, the electronics **322** includes one or more built-in sensors. The latch mechanism **336** also includes a communication cable **348** that delivers one or more of sensor, control (e.g., actuation or deactivation), and other data signals to the electronics **322**. The communication cable **348** may also receive data from the electronics **322**.

[0061] Referring to FIG. **26**, in a pre-operative position, wellbore hydrostatic pressure acting on a surface of the piston **342** pushes the piston **342** inward into the housing **332**. The piston **342** is hydraulically locked because the valve **328** is closed. In turn, the latch pin **316** is maintained in engagement with the latch **314** such that the latch **314** is flush with the latch housing **310**.

[0062] Referring to FIG. **27**, when the electronics **322** receives and processes a latch actuation signal, the electronics **322** controls the valve actuator **330** to operate (e.g., open) the valve **328** to allow fluid **334** to flow out of the piston housing **332** and into the fluid tank **336**. Movement of the fluid **334** to the fluid tank **326** allows the piston **338** to retract within the piston housing **332** and accordingly allows the latch pin **316** to retract within the piston housing **332** and off of the latch **314**. Such movement off of the latch **314** allows the latch **314**, under action of the spring **312**, to move radially outward to the extended position to engage the groove **109** of the outer pipe segment **111**.

[0063] Referring to FIG. **25**, in some embodiments, the latch mechanism **336** also includes a pressure sensor **320** that is positioned along the latch housing **310** (e.g., at an end of the housing **310** or at another location along the housing **310**). The pressure sensor **320** is located to detect a fluid pressure in the annular region **103** between the inner and outer pipe segments **101**, **111**. A pressure signal reflecting the fluid pressure is delivered to and processed by the electronics **322**. The electronics **322** can control the valve actuator to operate the valve **328** based on one or both of the pressure signal and a control signal delivered from the communication cable **348**.

[0064] In some implementations, the sealing device **300** advantageously allows automatic, smart retraction (e.g., deactivation) of the latch **314** so that the sealing device **300** is able to freely move in the uphole and downhole directions **123**, **125** until an operator decides on a point of no return for the sealing device **300** within a well. For example, problems sometimes arise while running an inner pipe segment within the well, which necessitates removal of the inner pipe segment before the inner pipe segment is cemented in place. If the sealing device has already passed the outer pipe segment when a problem arises, it will not be possible to retrieve the inner pipe segment without first setting the sealing device, which itself prevents its removal. Circulation of fluid within the annular region between inner and outer pipe segments would also not be possible since the sealing device will have closed off the annular region. Smart retraction of the latch **314** enables free uphole and downhole movement of the sealing device **300** until the operator decides on the point of no return.

[0065] In some embodiments, actuation of the latch **314** occurs via use of radio frequency identification (RFID) tags or other media that may be pumped into the interior channel **129** of the inner pipe segment **101** from the surface. In some embodiments, such devices may carry an encoded command that sends a control signal to the actuation module **340**. Corresponding sensors (e.g., as part of the electronics **322**) in the actuation module **340** are powered by the battery **324**. In some embodiments, a sealing device that is otherwise substantially similar in construction and/or function to the sealing device **300** may alternatively include an actuation mechanism provided by a solenoid, a motor and gears, downlinking from the surface, or another method.

[0066] In some embodiments, downlinking from the surface involves manipulation of the fluid pressure within the annular region. For example a rig pump may be used to manipulate the pressure in an annular region to send a signal to the actuation module of a sealing device. Circulating fluid through the casing prior to cementing is typical and is performed to clean the well of any remaining cuttings and debris or to displace fluid. Pumping rates can vary during this operation. Pressure losses in the annular region are related to the flow rate, which affects the equivalent circulating density (ECD), where the ECD will be higher than the equivalent static density (ESD). Turning the pumps on and off or up and down according to a set pattern during a defined time period will cause the actuation module to experience pressure fluctuations that may be detected at a pressure sensor and interpreted as a command. In some embodiments, a sealing device includes pressure sensors (e.g., such as the pressure sensor **320**), RFID sensors, or both types of sensors to allow flexibility as to the mode of actuation.

[0067] In some embodiments, the sealing device **300** may be tension-set according to the method substantially described above with respect to FIGS. **15** and **16**, except that between the step of advancing the sealing device **300** and inner pipe segment **101** through the outer pipe segment **111** to an axial position at which the latch mechanism **336** is located below and spaced apart from the groove **109**, and the step of performing a cement job, an activation device is dropped into the interior channel **129** of the inner pipe **101** or a pressure signal is sent to the actuation module **340** via downlinking.

[0068] The above-discussed embodiments and other embodiments are within the scope of the following claims.

EXAMPLES

[0069] In an example aspect, a sealing device includes a first ring that is fixedly attached to a pipe segment, a second ring that is movably secured to the pipe segment and spaced axially apart from the first ring in an initial configuration of the sealing device, and a third ring that axially overlaps a first wall portion of the first ring and a second wall portion of the second ring, wherein the third ring is expandable radially to accommodate a third wall portion of the first ring and a fourth wall portion of the second ring within an interior region of the third ring.

[0070] Embodiments may provide one or more of the following features.

[0071] In an example aspect combinable with any other example aspect, the third ring is made of one or more metals.

[0072] In an example aspect combinable with any other example aspect, the third ring is made entirely of metals.

[0073] In an example aspect combinable with any other example aspect, the third ring is slidable axially with respect to the first ring.

[0074] In an example aspect combinable with any other example aspect, the second ring is slidable axially with respect to the first ring in an operational configuration of the sealing device.

[0075] In an example aspect combinable with any other example aspect, the second ring is slidable axially with respect to the third ring in an operational configuration of the sealing device.

[0076] In an example aspect combinable with any other example aspect, the third ring includes multiple circumferential ribs.

[0077] In an example aspect combinable with any other example aspect, the second ring includes multiple circumferential ribs that engage the third ring and progressively increase in height along a central axis of the sealing device.

[0078] In an example aspect combinable with any other example aspect, the second ring includes a latch that is configured to engage a surrounding pipe segment.

[0079] In an example aspect combinable with any other example aspect, the latch is spring-loaded.

[0080] In an example aspect combinable with any other example aspect, the third ring overlaps the second ring by a first length in the initial configuration of the sealing device, and the third ring overlaps the second ring by a second length that is larger than the first length in a final configuration of the sealing device.

[0081] In an example aspect combinable with any other example aspect, the first, second, and third rings define a gap within the sealing device.
[0082] In an example aspect combinable with any other example aspect, the movable ring is configured to move a total axial distance of about 0.3 m to about 5 m with respect to the pipe segment during a setting operation.
[0083] In an example aspect combinable with any other example aspect, the sealing device is configured to be weight-set within a well.
[0084] In an example aspect combinable with any other example aspect, the sealing device is configured to be tension-set within a well.
[0085] In an example aspect combinable with any other example aspect, the second ring includes an automated latch mechanism that is configured to engage a surrounding pipe segment.
[0086] In an example aspect combinable with any other example aspect, the automated latch mechanism is configured to be controlled from a subterranean surface above a well in which the sealing device is installed.
[0087] In an example aspect combinable with any other example aspect, the automated latch mechanism is configured to receive and process downlink commands.
[0088] In an example aspect combinable with any other example aspect, the automated latch mechanism includes a hydraulic actuation system.
[0089] In another example aspect, a method of sealing an annular region includes moving a first pipe segment within a second pipe segment to a first downhole position, the first and second pipe segments defining the annular region therebetween. The first pipe segment carries a sealing device that includes a first ring that is fixedly attached to the first pipe segment, a second ring that is movably secured to the first pipe segment, and a third ring that axially overlaps a first wall portion of the first ring and a second wall portion of the second ring. In some embodiments, the method further includes causing cement to move along the annular region, moving the first pipe segment within the second pipe segment to a second downhole position at which a latch of the second ring is retained within a groove of the second pipe segment, and expanding the third ring radially outward to contact the second pipe segment and seal the annular region.

Claims

1. A sealing device comprising: a first ring that is fixedly attached to a pipe segment; a second ring that is movably secured to the pipe segment and spaced axially apart from the first ring in an initial configuration of the sealing device; and a third ring that axially overlaps a first wall portion of the first ring and a second wall portion of the second ring, wherein the third ring is expandable radially to accommodate a third wall portion of the first ring and a fourth wall portion of the second ring within an interior region of the third ring.
2. The sealing device of claim 1, wherein the third ring is made of one or more metals.
3. The sealing device of claim 1, wherein the third ring is made entirely of metals.
4. The sealing device of claim 1, wherein the third ring is slidable axially with respect to the first ring.
5. The sealing device of claim 1, wherein the second ring is slidable axially with respect to the first ring in an operational configuration of the sealing device.
6. The sealing device of claim 1, wherein the second ring is slidable axially with respect to the third ring in an operational configuration of the sealing device.
7. The sealing device of claim 1, wherein the third ring comprises multiple circumferential ribs.
8. The sealing device of claim 1, wherein the second ring comprises multiple circumferential ribs that engage the third ring and progressively increase in height along a central axis of the sealing device.
9. The sealing device of claim 1, wherein the second ring comprises a latch that is configured to

engage a surrounding pipe segment.

10. The sealing device of claim 9, wherein the latch is spring-loaded.

11. The sealing device of claim 1, wherein the third ring overlaps the second ring by a first length in the initial configuration of the sealing device, and wherein the third ring overlaps the second ring by a second length that is larger than the first length in a final configuration of the sealing device.

12. The sealing device of claim 1, wherein the first, second, and third rings define a gap within the sealing device.

13. The sealing device of claim 1, wherein the movable ring is configured to move a total axial distance of about 0.3 m to about 5 m with respect to the pipe segment during a setting operation.

14. The sealing device of claim 1, wherein the sealing device is configured to be weight-set within a well.

15. The sealing device of claim 1, wherein the sealing device is configured to be tension-set within a well.

16. The sealing device of claim 1, wherein the second ring comprises an automated latch mechanism that is configured to engage a surrounding pipe segment.

17. The sealing device of claim 16, wherein the automated latch mechanism is configured to be controlled from a subterranean surface above a well in which the sealing device is installed.

18. The sealing device of claim 16, wherein the automated latch mechanism is configured to receive and process downlink commands.

19. The sealing device of claim 16, wherein the automated latch mechanism comprises a hydraulic actuation system.

20. A method of a sealing an annular region, the method comprising: moving a first pipe segment within a second pipe segment to a first downhole position, the first and second pipe segments defining the annular region therebetween, and the first pipe segment carrying a sealing device that comprises: a first ring that is fixedly attached to the first pipe segment, a second ring that is movably secured to the first pipe segment, and a third ring that axially overlaps a first wall portion of the first ring and a second wall portion of the second ring; causing cement to move along the annular region; moving the first pipe segment within the second pipe segment to a second downhole position at which a latch of the second ring is retained within a groove of the second pipe segment; and expanding the third ring radially outward to contact the second pipe segment and seal the annular region.