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(54) **RECLOSABLE SLEEVE ASSEMBLY AND METHODS FOR ISOLATING HYDROCARBON PRODUCTION**

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CPC ***E21B 34/14*** (2013.01); *E21B 2034/007* (2013.01)

(58) **Field of Classification Search**
CPC E21B 34/14; E21B 34/102
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,429,747 A *	2/1984	Williamson, Jr.	E21B 34/103 166/321
5,343,949 A *	9/1994	Ross	E21B 17/07 166/278
5,368,098 A *	11/1994	Blizzard, Jr.	E21B 33/127 166/100
5,597,042 A	1/1997	Tubel et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

CA	WO 2012024773 A1 *	3/2012	E21B 21/103
WO	9747850 A1	12/1997	

OTHER PUBLICATIONS

International Search Report and Written Opinion for PCT/US2012/052735 dated Mar. 27, 2013.

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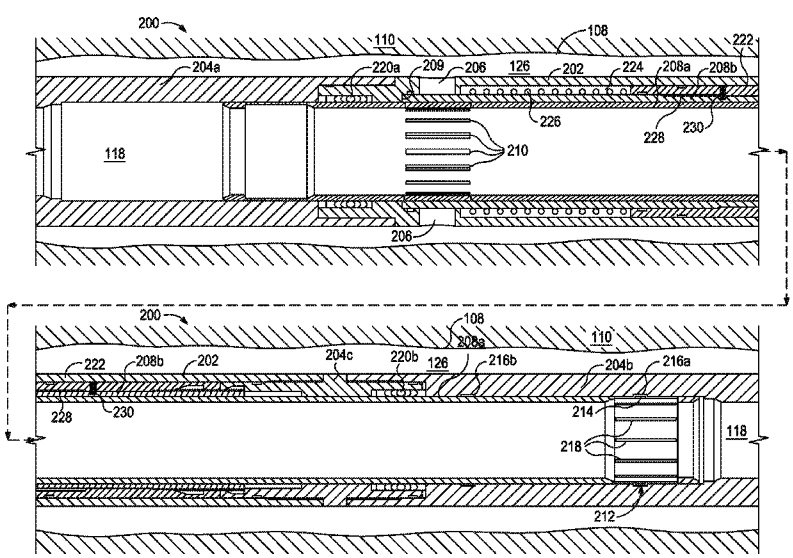
(57) **ABSTRACT**

Disclosed is reclosable sleeve assembly including a housing defining one or more flow ports that provide fluid communication between a wellbore annulus and an interior of the housing, an outer sleeve arranged within the housing and movable between a closed position, where the outer sleeve occludes the one or more flow ports, and an open position, where the one or more flow ports are exposed, and an inner sleeve concentrically arranged within the outer sleeve and defining a plurality of flow slots, the inner sleeve being movable between an open position and a closed position where, when in the open position, the plurality of flow slots are axially aligned with the one or more flow ports.

20 Claims, 4 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,609,178	A	3/1997	Hennig et al.	
5,890,537	A	4/1999	Lavaure et al.	
6,293,342	B1 *	9/2001	McGarian	E21B 21/10 166/317
6,397,949	B1	6/2002	Walker et al.	
6,422,317	B1 *	7/2002	Williamson, Jr.	E21B 34/10 166/320
6,571,875	B2	6/2003	Bissonnette et al.	
6,725,937	B1 *	4/2004	McHardy	E21B 21/103 166/334.4
2004/0244976	A1	12/2004	Turner et al.	
2008/0001111	A1 *	1/2008	Ross	E21B 23/04 251/230
2009/0095486	A1 *	4/2009	Williamson, Jr.	E21B 21/103 166/373
2010/0000727	A1	1/2010	Webb et al.	
2010/0224371	A1 *	9/2010	Swan	E21B 21/103 166/373
2011/0100643	A1 *	5/2011	Themig	E21B 34/102 166/373
2011/0108272	A1 *	5/2011	Watson	E21B 34/103 166/271
2011/0278017	A1 *	11/2011	Themig	E21B 34/14 166/373
2012/0012322	A1	1/2012	Korkmaz et al.	
2012/0279723	A1 *	11/2012	Hofman	E21B 34/063 166/373
2013/0056206	A1 *	3/2013	Jackson	E21B 34/102 166/281
2013/0168098	A1 *	7/2013	Campbell	E21B 34/14 166/308.1
2013/0319767	A1 *	12/2013	Wilson	E21B 21/10 175/24
2014/0076578	A1 *	3/2014	Hofman	E21B 34/10 166/373
2014/0083708	A1 *	3/2014	Beck	E21B 43/26 166/308.1
2015/0233210	A1 *	8/2015	Beck	E21B 34/14 166/373

* cited by examiner

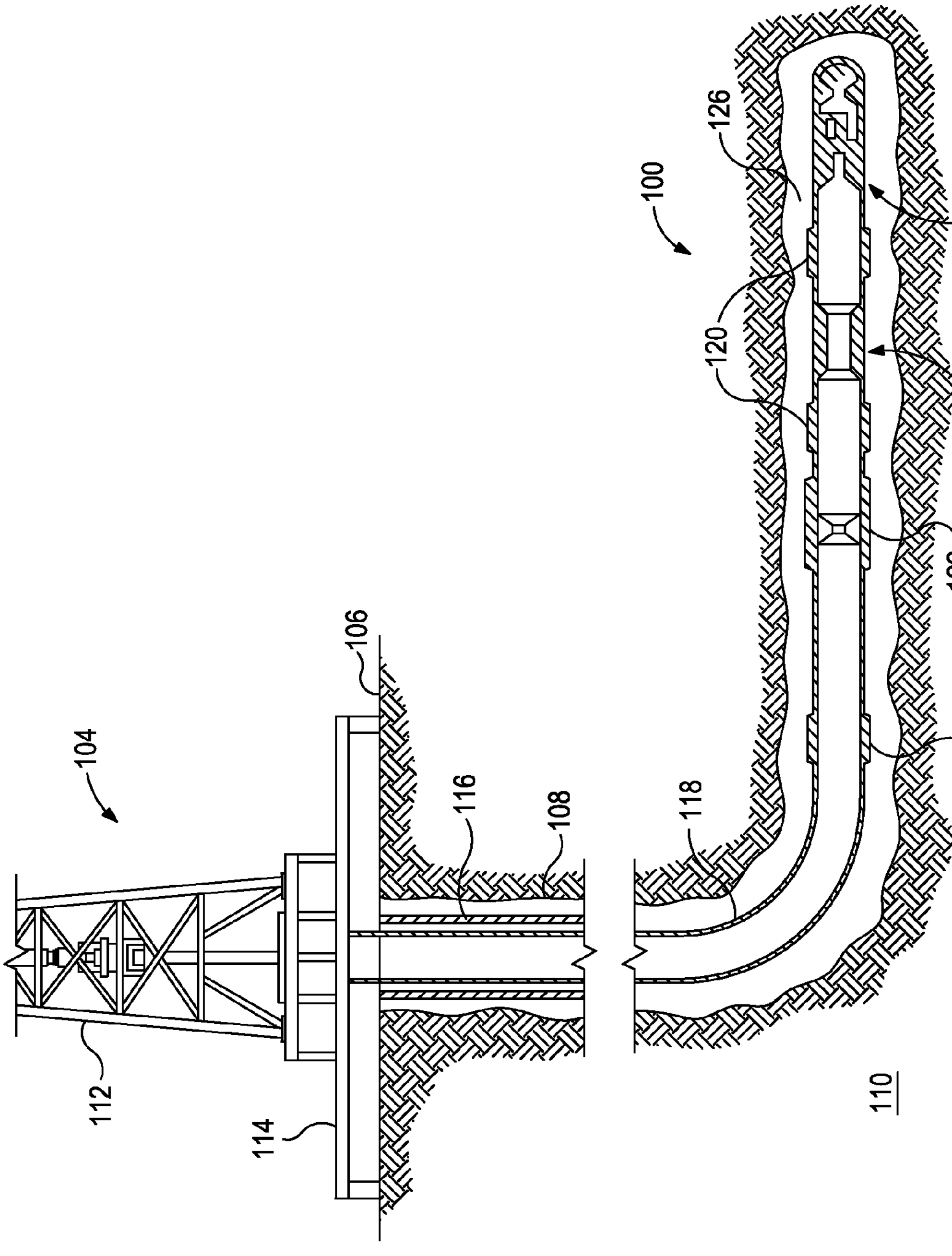


FIG. 1

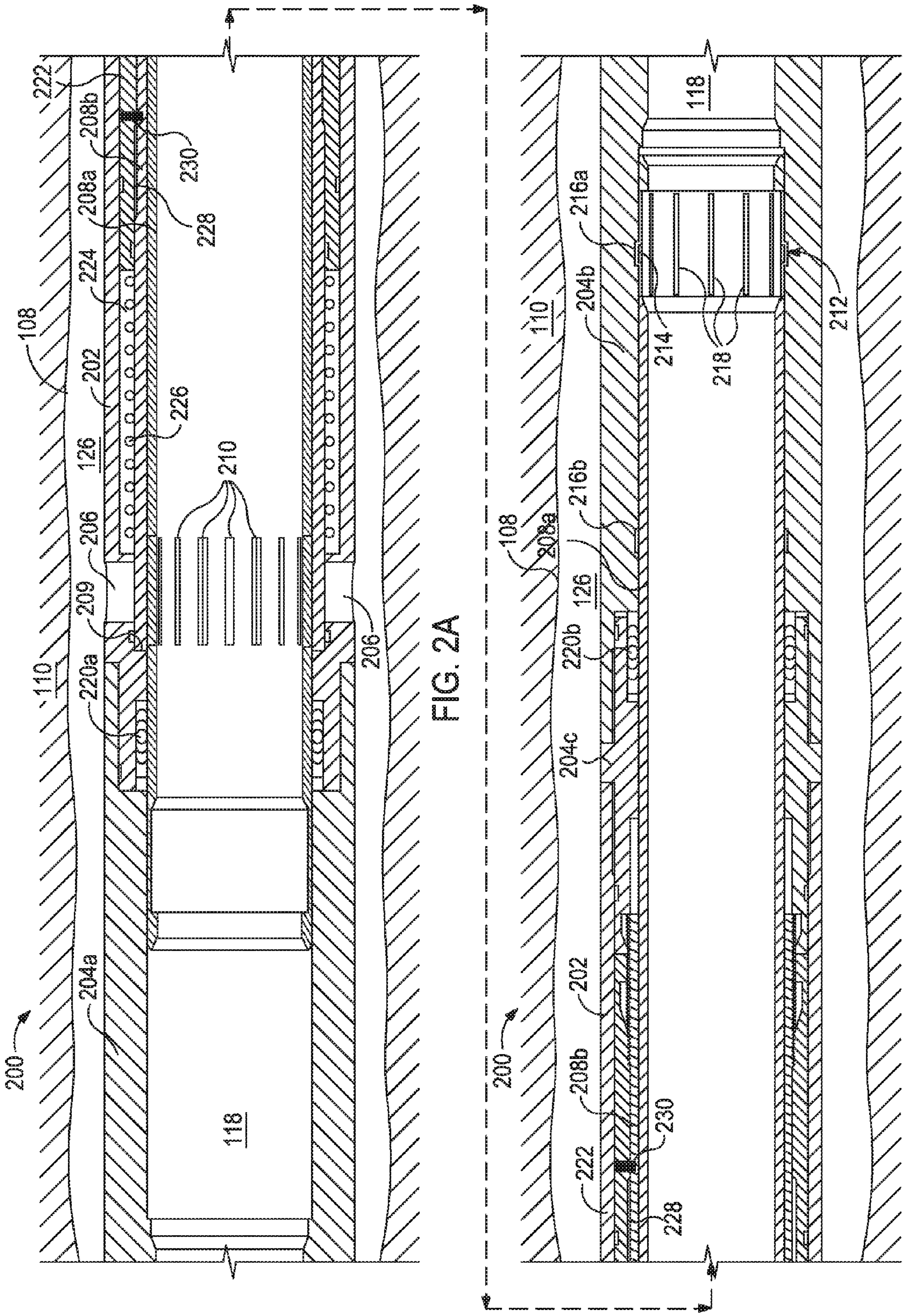
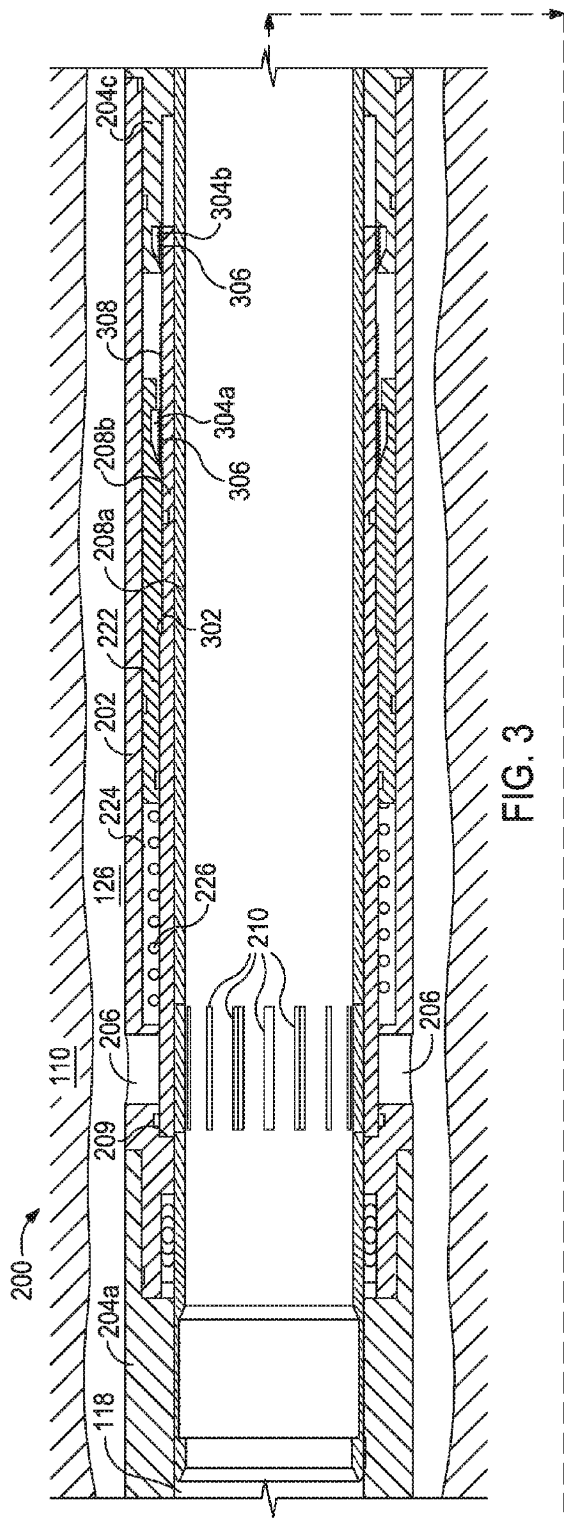

222
208b
230
208a
228
224
108
202
226
126
210
206
209
110
220a
206
204a
200
118
118
216a
110
204b
212
214
218
216b
108
208a
126
220b
204c
202
200
208b
230
222
228

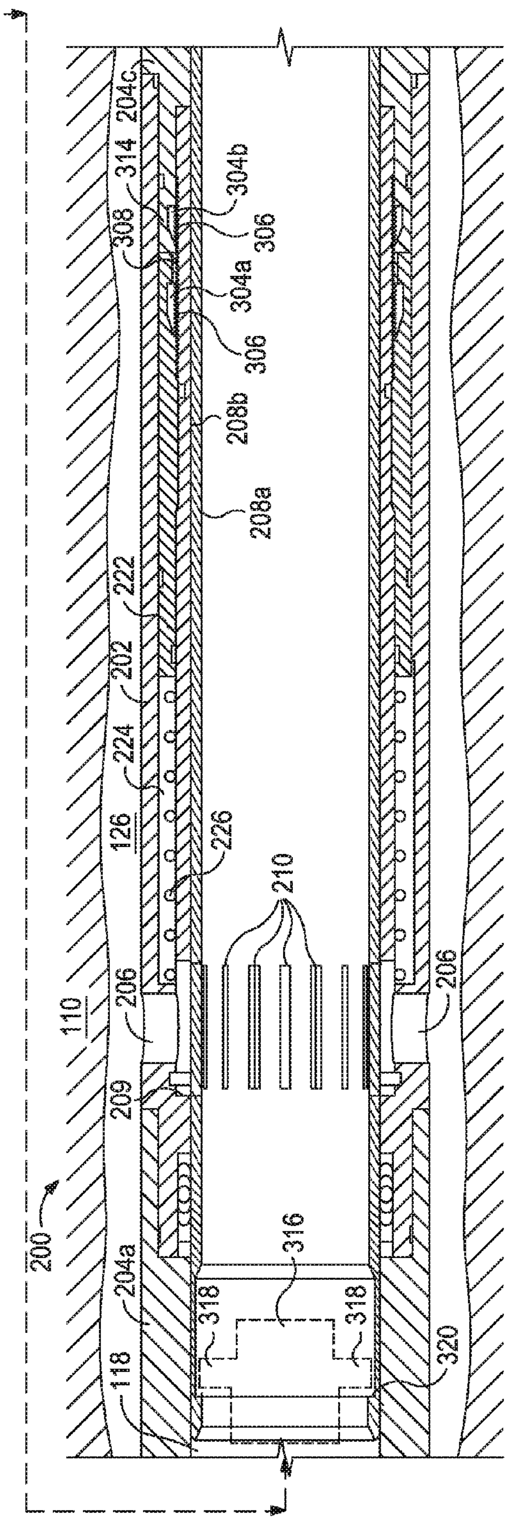
FIG. 2A

FIG. 2B



200
204c
304b
306
308
304a
208b
306
208a
222
302
202
224
126
226
210
206
110
209
206
204a
118

FIG. 3



204c
314
308
304b
306
304a
306
208b
208a
222
202
224
126
226
210
206
110
206
209
200
204a
316
318
318
320
118

FIG. 4

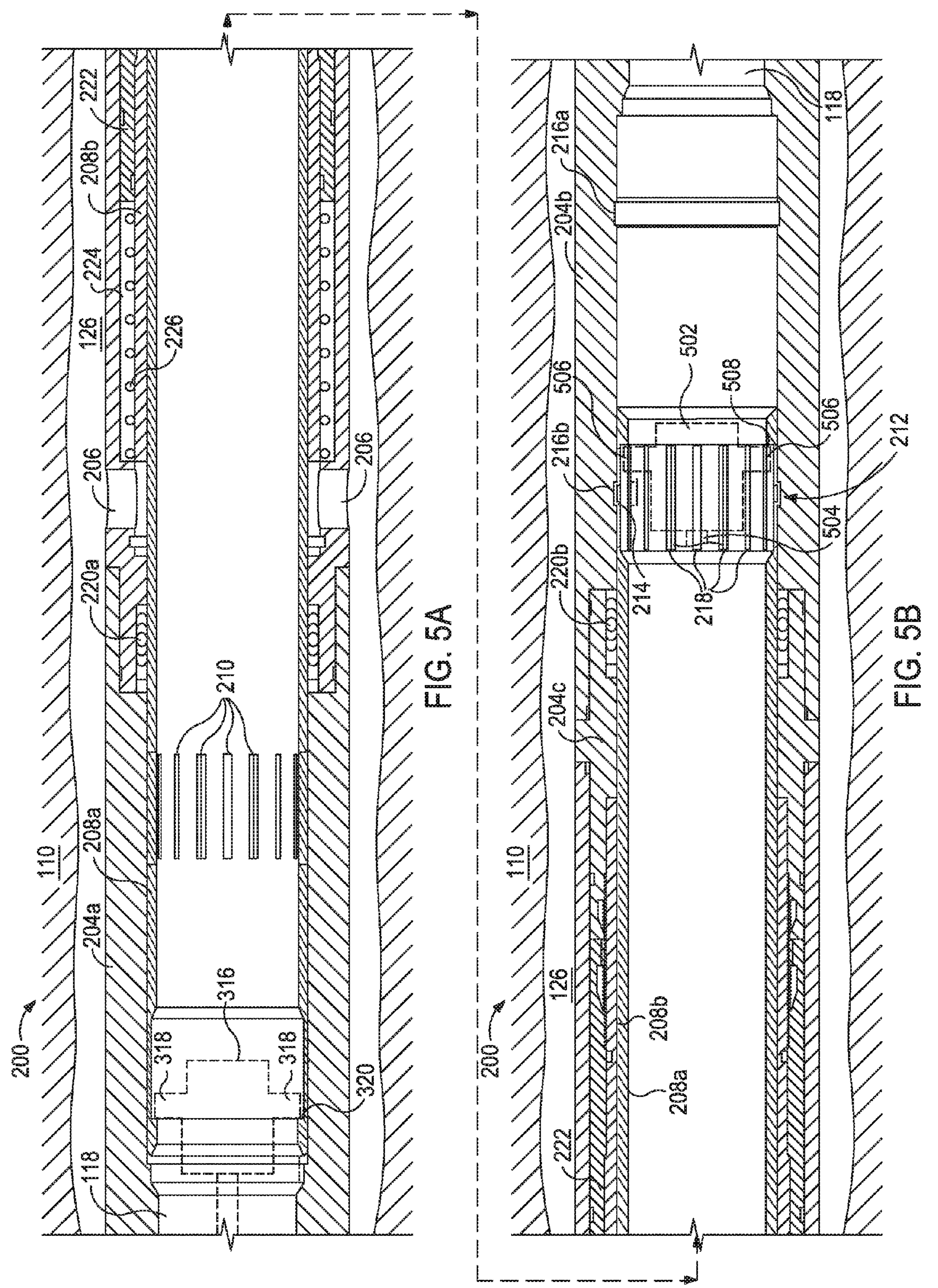

200
110
126
118
204a
208a
208b
222
224
226
206
220a
210
316
318
320
216a
204b
502
508
506
216b
212
504
214
218
220b
204c

FIG. 5A

FIG. 5B

RECLOSABLE SLEEVE ASSEMBLY AND METHODS FOR ISOLATING HYDROCARBON PRODUCTION

BACKGROUND

The present invention relates to equipment utilized in subterranean well operations and, more particularly, to a reclosable sleeve assembly and methods for isolating hydrocarbon production within a well.

Hydrocarbon-producing wells are often stimulated by one or more hydraulic fracturing operations which generally include injecting a fracturing fluid into a subterranean formation penetrated by a wellbore at a hydraulic pressure sufficient to create or enhance at least one fracture therein. One of the purposes of the fracturing process is to increase formation conductivity so that the greatest possible quantity of hydrocarbons from the formation can be extracted/produced into the penetrating wellbore.

In some wells, it may be desirable to selectively create multiple fractures along a wellbore at predetermined distances apart from each other, thereby creating multiple "pay zones" from which hydrocarbons can be intelligently produced. A series of actuatable sleeve assemblies may be arranged within the downhole completion assembly in order to separate the pay zones for intelligent production. These sleeve assemblies have devices movably arranged therein generally known as sliding sleeves or sliding side doors due to the ability of the devices to shift an inner sleeve from a first position to a second position. Shifting these inner sleeves allow the operator at the surface to initiate hydrocarbon production, cease hydrocarbon production, or generally regulate hydrocarbon production through the sleeve assembly at that particular location.

Actuating a sleeve downward within the sleeve assembly serves to reveal one or more flow ports that, once exposed, allow the influx of fluids into the production tubing. In conventional actuated sleeve assemblies, the sleeve is not designed to retract into the closed position in order to close the flow ports and thereby cease hydrocarbon production at that location. Instead, a tool, such as a side door choke, is typically run into the sleeve assembly to occlude the flow ports and provide a permanent installation within the production tubing. While effective in sealing the flow ports and ceasing hydrocarbon production at that location, the side door choke adversely reduces the inner diameter of the production tubing at that location which, in turn, reduces the potential flow rate through the production tubing. A reduced inner diameter of the production tubing also adversely affects the size of the downhole tools that can be extended past the sleeve assembly, which are thereafter required to be of smaller diameters. Thus, there is a need for a reclosable sleeve assembly that does not disadvantageously reduce the inner diameter of the production tubing but nonetheless is effective in ceasing hydrocarbon production through the one or more flow ports.

SUMMARY OF THE INVENTION

The present invention relates to equipment utilized in subterranean well operations and, more particularly, to a reclosable sleeve assembly and methods for isolating hydrocarbon production within a well.

In some aspects of the disclosure, a sleeve assembly is disclosed. The sleeve assembly may include a housing having an uphole end and a downhole end and defining one or more flow ports that provide fluid communication

between a wellbore annulus and an interior of the housing, the housing being coupled to a top sub at the uphole end and to a bottom sub at the downhole end, an outer sleeve arranged within the housing and movable between a closed position, where the outer sleeve occludes the one or more flow ports, and an open position, where the one or more flow ports are exposed, and an inner sleeve concentrically arranged within the outer sleeve and defining a plurality of flow slots, the inner sleeve being movable between an open position and a closed position where, when in the open position, the plurality of flow slots are axially aligned with the one or more flow ports.

In other aspects of the disclosure, a method of actuating a sleeve assembly installed in production tubing is disclosed. The method may include introducing a first shifting tool into the sleeve assembly, the sleeve assembly including a housing defining one or more flow ports, an outer sleeve arranged within the housing such that the one or more flow ports are exposed, and an inner sleeve concentrically arranged within the outer sleeve and defining a plurality of flow slots, wherein the plurality of flow slots are axially aligned with the one or more flow ports, thereby providing fluid communication between a wellbore annulus and an interior of the sleeve assembly, engaging the first shifting tool on a first radial shoulder defined on the inner sleeve, and axially moving the inner sleeve with the first shifting tool such that the plurality of flow slots are moved out of axial alignment with the one or more flow ports.

In yet other aspects of the disclosure, another sleeve assembly is disclosed. The sleeve assembly may include a housing defining one or more flow ports that provide fluid communication between a wellbore annulus and an interior of the housing, the housing being configured to be coupled at each end to production tubing, an outer sleeve arranged within the housing and movable between a closed position, where the outer sleeve occludes the one or more flow ports, and an open position, where the one or more flow ports are exposed, an inner sleeve concentrically arranged within the outer sleeve and defining a plurality of flow slots, the inner sleeve being movable between an open position and a closed position where, when in the open position, the plurality of flow slots are axially aligned with the one or more flow ports, a piston movably arranged within a piston bore defined in the housing, a spring arranged within the piston bore and configured to bias an uphole end of the piston, and an upper locking device arranged within a first cavity defined in the piston and movable therewith, the upper locking device being engageable with an outer radial surface of the outer sleeve such that as the spring biases against and axially moves the piston within the piston bore, the upper locking device engages and simultaneously moves the outer sleeve into its open position.

The features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the preferred embodiments that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The following figures are included to illustrate certain aspects of the present invention, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, as will occur to those skilled in the art and having the benefit of this disclosure.

FIG. **1** illustrates a well system employing one or more exemplary sleeve assemblies, according to one or more embodiments.

FIGS. **2**A and **2**B illustrate a partial cross-sectional view of an exemplary sleeve assembly, according to one or more embodiments.

FIG. **3** illustrates a partial cross-sectional view of the sleeve assembly of FIGS. **2**A and **2**B as a piston is forced to axially translate within a piston bore, according to one or more embodiments.

FIG. **4** illustrates a partial cross-sectional view of the sleeve assembly of FIGS. **2**A and **2**B as an outer sleeve is moved into its open position, according to one or more embodiments.

FIGS. **5**A and **5**B illustrate partial cross-sectional views of the sleeve assembly of FIGS. **2**A and **2**B as an inner sleeve is moved from its open position into its closed position, according to one or more embodiments.

DETAILED DESCRIPTION

The present invention relates to equipment utilized in subterranean well operations and, more particularly, to a reclosable sleeve assembly and methods for isolating hydrocarbon production within a well.

One advantage provided by the disclosed exemplary sleeve assembly is that, opposed to the bulky side door choke typically used to occlude the flow ports, the exemplary sleeve assembly includes an inner sleeve that is able to cover its flow ports without adversely reducing the inner diameter of the production tubing. As a result, the flow rate through the production tubing is largely unaffected and downhole tools that must traverse the sleeve assembly are therefore not required to exhibit a reduced diameter. An additional advantage of the exemplary sleeve assembly is the ability to close and reopen the sleeve assembly. For instance, in some applications, for various reasons it may be advantageous to close the sleeve assembly and thereby cease production at that location for a predetermined period of time and then reopen the sleeve assembly at a later time in order to recommence production.

Referring to FIG. **1**, illustrated is a well system **100** that may employ one or more exemplary sleeve assemblies **102** as disclosed herein, according to one or more embodiments. As depicted, the system **100** may include a drilling or servicing rig **104** that is positioned on the Earth's surface **106** and extends over and around a wellbore **108** that penetrates a subterranean formation **110** for the purpose of recovering hydrocarbons. The wellbore **108** may be drilled into the subterranean formation **110** using any suitable drilling technique known to those skilled in the art. In an embodiment, the drilling or servicing rig **104** includes a derrick **112** with a rig floor **114**. A casing string **116** may extend from the surface **106** and be cemented into an upper portion of the wellbore **108**. In some embodiments, lower portions of the wellbore **108** may be cemented or uncemented, without departing from the scope of the disclosure. While the rig **104** is depicted in FIG. **1** as a land-based facility, it may equally be located at any geographical location. Accordingly, the drilling or servicing rig **104** may be, for example, an offshore rig or drilling platform, without departing from the scope of the disclosure.

The wellbore **108** may extend substantially vertically away from the surface **106** over a vertical wellbore portion, or may deviate at any angle from the surface **106** over a deviated or horizontal wellbore portion. In other well systems **100**, portions or substantially all of the wellbore **108** may be vertical, deviated, horizontal, and/or curved. It is noted that although FIG. **1** depicts horizontal and vertical portions of the wellbore **108**, the principles of the systems and methods disclosed herein are applicable to any type of wellbore **108** configuration. Accordingly, the horizontal or vertical nature of any figure is not to be construed as limiting the wellbore **108**, or the use of a sleeve assembly **102** therein, to any particular configuration.

Production tubing **118** may extend from the rig floor **114** and into the wellbore **108** and casing string **116**. The production tubing **118** provides a conduit for formation fluids to travel from the formation **110** to the surface **106**. As illustrated, in one or more embodiments, the exemplary sleeve assembly **102** may be incorporated within the production tubing **118** at some part thereof. While only one sleeve assembly **102** is shown in FIG. **1**, it will be appreciated that more than one sleeve assembly **102** may be employed in any given well system **100**, without departing from the scope of the disclosure. In some embodiments, the well system **100** may further include one or more packers **120** configured to provide fluid seals between the production tubing **118** and the wellbore **108**, thereby defining various production intervals or pay zones. The well system **100** may also include one or more manipulatable servicing tools **122** and a float shoe **124**. A wellbore annulus **126** is defined between the production tubing **118** and the wellbore **108**, and in operation formation fluids, or other fluids disposed in the formation **110**, escape into the wellbore annulus **126** and are extracted therefrom via the one or more sleeve assemblies **102**, as will be described in more detail below.

The drilling or servicing rig **104** may be conventional and may comprise a motor driven winch and other associated equipment for lowering the production tubing **118** into the wellbore **108**, thereby positioning the sleeve assembly **102** and other wellbore servicing equipment at the desired depth. While the well system **100** depicted in FIG. **1** refers to a stationary drilling or servicing rig **104** for lowering and setting the production tubing **118** within a land-based wellbore **108**, one of ordinary skill in the art will readily appreciate that mobile workover rigs, offshore rigs and platforms, wellbore servicing units (e.g., coiled tubing units), and the like may be used to lower the production tubing **118**, and accompanying sleeve assembly **102**, into the wellbore **108**. Accordingly, it should be understood that the various disclosed embodiments of the sleeve assembly **102** may equally be used in other operational environments, such as within an offshore wellbore operational environment.

Moreover, use of directional terms such as above, below, upper, lower, upward, downward, uphole, downhole, and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward or uphole direction being toward the left of the corresponding figure and the downward or downhole direction being toward the right of the corresponding figure, the uphole direction being toward the surface of the well and the downhole direction being toward the toe or bottom of the well.

Referring now to FIGS. **2**A and **2**B, with continued reference to FIG. **1**, illustrated is a partial cross-sectional view of an exemplary sleeve assembly **200**, according to one or more embodiments. Specifically, FIG. **2**A illustrates an upper portion of the sleeve assembly **200** and FIG. **2**B illustrates a connected lower portion thereof, with some of the features or components of the sleeve assembly **200** overlapping in each figure. The sleeve assembly **200** may be similar to the sleeve assembly **102** of FIG. **1**, and therefore may be deployed in a wellbore **108** drilled into the subterranean formation **110** for the extraction of hydrocarbons from the wellbore annulus **126** defined between the wellbore **108** and the sleeve assembly **200**. As illustrated, the sleeve assembly **200** is depicted as being arranged in an open hole section of the wellbore **108**, but those skilled in the art will readily appreciate that the sleeve assembly **200** may equally be deployed in a cased section of the wellbore **108**, without departing from the scope of the disclosure.

The sleeve assembly **200** may include a housing **202** coupled or otherwise attached to a top sub **204***a* at an uphole end and coupled or otherwise attached to a bottom sub **204***b* at a downhole end. In at least one embodiment, the sleeve assembly **200** may also include a mid sub **204***c* that generally interposes the bottom sub **204***b* and the housing **202**. In some embodiments, the mid sub **204***c* may be considered part of the bottom sub **204***b*. Accordingly, in at least one embodiment, the bottom sub **204***b* is coupled to the downhole end of the housing **202** via interconnection with the mid sub **204***c*. The top and bottom subs **204***a,b* may form part of or otherwise be considered an integral portion of the production tubing **118**, and therefore may help facilitate the production of hydrocarbons from the formation **110** to the surface **106** (FIG. **1**).

The housing **202** may define one or more flow ports **206** (two shown) which provide fluid communication between the wellbore annulus **126** and the interior of the housing **202** when the sleeve assembly **200** is in an open configuration, as will be discussed in greater detail below. The sleeve assembly **200** may further include an inner sleeve **208***a* and an outer sleeve **208***b*. The inner sleeve **208***a* may be movably arranged or otherwise extend within each of the housing **202** and the top and bottom subs **204***a,b*. At or near an uphole end, the inner sleeve **208***a* may define a plurality of flow slots **210** about its circumference. The flow slots **210** may be equidistantly or randomly spaced from each other about the circumference of the inner sleeve **208***a*. While depicted in FIG. **2**A as elongate perforations in the inner sleeve **208***a*, it will be appreciated by those skilled in the art that the flow slots **210** can be defined in any geometric shape, without departing from the scope of the disclosure. The inner sleeve **208***a* may be movable between an open position and a closed position where, when in the open position, the flow slots **210** may be axially aligned, at least generally, with the flow ports **206** defined in the housing **202**. Accordingly, as depicted in FIGS. **2**A and **2**B, the inner sleeve **208***a* is shown in its open position.

At or near a downhole end, the inner sleeve **208***a* may provide or otherwise define a locking collet **212** configured to lock or otherwise secure the inner sleeve **208***a* in either its open or closed positions. In some embodiments, the locking collet **212** may define one or more locking keys **214** that extend radially from the locking collet **212**. The locking keys **214** may be configured to locate and extend into corresponding grooves defined on the inner radial surface of the bottom sub **204***b*, thereby securing the inner sleeve **208***a* against axial movement in either its open or closed positions. Specifically, the bottom sub **204***b* may define a first or lower groove **216***a* and a second or upper groove **216***b*. The lower groove **216***a* may be configured to receive the one or more locking keys **214** in order to lock the inner sleeve **208***a* in its open position (as depicted in FIGS. **2**A and **2**B). The upper groove **216***b*, however, may be axially offset from the lower groove **216***a* and configured to receive the one or more locking keys **214** in order to lock the inner sleeve **208***a* in its closed position (as depicted in FIGS. **5**A and **5**B).

While the upper groove **216***b* is shown as being axially offset from the lower groove **216***a* in the uphole direction, embodiments are also contemplated herein where the relative position of the grooves **216***a,b* and their respective functions are reversed. Moreover, additional embodiments are contemplated where the upper and lower grooves **216***a,b* are defined on the top sub **204***a* instead of the bottom sub **204***b*, and the locking collet **212** is otherwise configured to engage or otherwise interact with the grooves **216***a,b* as defined on the top sub **204***a*. For example, in at least one embodiment, the inner sleeve **208***a* may be configured to translate axially in the downhole direction and engage the upper groove **216***b* in order to secure the inner sleeve **208***a* in the closed position. Those skilled in the art will readily recognize several variations of the embodiments disclosed herein that will provide equally similar results.

In at least one embodiment, the locking collet **212** may define one or more longitudinal perforations **218** therein. The longitudinal perforations **218** may be configured to allow the locking collet **212** to flex such that the locking keys **214** are able to move or bend in and out of the corresponding lower and upper grooves **218***a,b* in response to an appropriate amount of axial force applied to the inner sleeve **208***a*.

In some embodiments, the sleeve assembly **200** may also include one or more seals **220***a* and **220***b* configured to prevent unwanted fluid communication between the inner sleeve **208***a* and portions of the housing **202** or mid sub **204***c*. Specifically, a first seal **220***a* may be arranged between the inner sleeve **208***a* and the housing **202** at or near an uphole end of the sleeve assembly **200** and a second seal **220***b* may be arranged between the inner sleeve **208***a* and the mid sub **204***c* (or alternatively the bottom sub **204***b*, in other embodiments) at or near a downhole end of the sleeve assembly **200**. The seals **220***a,b* may be useful in preventing unwanted fluid migration when the inner sleeve **208***a* is in either its open or closed positions, or during the transition between the open and closed positions. In some embodiments, the seals **220***a,b* may be v-packing seals (e.g., hydraulic seals). In other embodiments, the seals **220***a,b* may be any other type of seal known to those skilled in the art as suitable in the prevention of fluid migration in downhole environments.

The outer sleeve **208***b* may be radially offset from the inner sleeve **208***a* in a generally concentric or nested relationship, such that the inner sleeve **208***a* may translate axially within the outer sleeve **208***b*. The outer sleeve **208***b* may be otherwise movably arranged within the housing **202** and axially translatable between an open position and a closed position. In embodiments where the sleeve assembly **200** includes the mid sub **204***c*, the outer sleeve **208***b* may also be movably arranged within at least a portion of the mid sub **204***c*. In its closed position, as depicted in FIGS. **2**A and **2**B, the outer sleeve **208***b* may be configured to substantially occlude or otherwise cover the one or more flow ports **206** defined in the housing **202**, thereby preventing fluid communication between the wellbore annulus **126** and the interior of the housing **202**. Moreover, in its closed position, the uphole end of the outer sleeve **208***b* may be configured to engage or otherwise bias against a nipple shoulder **209** defined in the interior of the housing **202**. The nipple shoulder **209** may prevent the outer sleeve **208***b* from axially translating uphole (i.e., to the left).

The sleeve assembly **200** may further include a piston **222** movably arranged within a piston bore **224** defined in the housing **202**. In some embodiments, the piston bore **224** may be cooperatively defined by both the housing **202** and the outer sleeve **208***b*. The piston **222** may be configured to axially translate within the piston bore **224** and a spring **226** may be arranged within the piston bore **224** and configured to engage the piston **222** at its uphole end and thereby bias the piston **222** to the right.

A piston chamber **228** may be defined between the piston **222** and the outer sleeve **208***b*. In some embodiments, the piston chamber **228** may be cooperatively defined by both the piston **222** and the outer sleeve **208***b*. In at least one embodiment, the piston **222** may be coupled or otherwise attached to the outer sleeve **208***b* using one or more shear pins **230** (one shown). The shear pins **230** may extend at least partially through each of the piston **222** and the outer sleeve **208***b*. In order to move the outer sleeve **208***b* from its closed position to its open position (as depicted in FIGS. **4**, **5**A and **5**B), the shear pins **230** may be sheared with a predetermined amount of force applied to the piston **222**.

In at least one embodiment, the force required to shear the shear pins **230** may be obtained by pressurizing the production tubing **118**. For example, as the pressure within the production tubing **118** increases, it eventually surpasses the pressure of the wellbore annulus **126** and the pressure within the piston chamber **228**, thereby generating a pressure differential across the piston **222**. Further increasing the pressure within the production tubing **118** will force the piston **222** to move left (i.e., upward) with respect to the outer sleeve **208***b* (which is biased against the nipple shoulder **209**), thereby shearing the shear pins **230** and simultaneously axially collapsing the piston chamber **228**.

Referring now to FIG. **3**, with continued reference to FIGS. **2**A and **2**B, illustrated is a partial cross-sectional view of the sleeve assembly **200** as the piston **222** is forced to axially translate within the piston bore **224**, according to one or more embodiments. Specifically, FIG. **3** illustrates the piston **222** as it has been forced to move axially from a first position within the piston bore **224**, as shown in FIG. **2**A, to the left (i.e., upward) and to a second position, as shown in FIG. **3**. As the piston **222** moves axially to the left (i.e., upward) within the piston bore **224**, the piston chamber **228** (FIG. **2**A) collapses until the piston engages a shoulder **302** defined on the outer sleeve **208***b*. Moreover, as the piston **222** moves axially to the left (i.e., upward) within the piston bore **224**, the piston **222** also engages the spring **226** and overcomes its spring force and the pressure of the annulus **126**, thereby axially compressing the spring **226** within the piston bore **224** in the same direction.

The sleeve assembly **200** may further include a first or upper locking device **304***a* and a second or lower locking device **304***b*. The upper locking device **304***a* may be arranged within the piston bore **224** and otherwise configured to interact with the piston **222** and the outer radial surface of the outer sleeve **208***b*. The lower locking device **304***b* may also be arranged within the piston bore **224**, but otherwise configured to interact with the mid sub **204***c* and the outer radial surface of the outer sleeve **208***b*. In some embodiments, the upper locking device **304***a* may be arranged or otherwise captured within a cavity defined in the piston **222** and the lower locking device **304***b* may be arranged or otherwise captured within a cavity defined within the mid sub **204***c* (e.g., considered part of the bottom sub **204***b*).

In at least one embodiment, the upper and lower locking devices **304***a,b* may be beveled c-rings configured to extend about at least a portion of the circumference of the outer sleeve **208***b*. In some embodiments, each of the locking devices **304***a,b* may define a plurality of teeth **306** on their underside (i.e., their respective inner radial surfaces). The teeth **306** may be configured to interact with corresponding teeth **308** defined on the outer radial surface of the outer sleeve **208***b*. For example, as the piston **222** moves axially to the left (i.e., upward) within the piston bore **224**, the upper locking device **304***a* moves concurrently therewith since it is captured within the cavity defined in the piston **222**. As the upper locking device **304***a* moves axially to the left, its teeth **306** may be configured to move or otherwise bounce over the teeth **308** of the outer sleeve **208***b* or otherwise not cause a binding engagement therewith. On the other hand, if moving in the opposite direction (i.e., axially to the right or downward within the piston bore **224**), the teeth **306** of the upper locking device **304***a* may further be configured to engage or otherwise bind against the teeth **308** of the outer sleeve **208***b*.

Referring now to FIG. **4**, with continued reference to FIGS. **2**A-B and **3**, illustrated is a partial cross-sectional view of the sleeve assembly **200** as the outer sleeve **208***b* is moved into its open position, according to one or more embodiments. Specifically, in at least one embodiment, the outer sleeve **208***b* may be moved to the open position by decreasing the fluid pressure within the production tubing **118**. Decreasing the pressure in the production tubing **118** removes the pressure differential previously generated across the piston **222**, thereby allowing the spring **226** to expand and axially force the piston **222** back to the right (i.e., downward) within the piston bore **224**. The piston **222** is also forced to the right by the fluid pressure derived from the annulus **126**. The spring **226** may force the piston **222** axially to the right within the piston bore **224** until the downhole end of the piston **222** engages a pin nose **314** defined on the mid sub **204***c* and thereby stops its axial movement.

As the piston **222** moves axially to the right (i.e., downward), as briefly stated above, the teeth **306** of the upper locking device **304***a* may be configured to engage or otherwise bind against the teeth **308** of the outer sleeve **208***b*, thereby forcing the outer sleeve **208***b* also to translate axially to the right (i.e., downward) and into its open position. In the open position, the outer sleeve **208***b* may be configured to uncover the flow ports **206** defined in the housing **202**, thereby exposing the flow ports **206** to the flow slots **210** defined in the inner sleeve **208***a* and allowing fluid communication between the wellbore annulus **126** and the production tubing **118**.

In one or more embodiments, the lower locking device **304***b* may be configured to lock the outer sleeve **208***b* in the open position. For instance, as the outer sleeve **208***b* moves axially to the right, the teeth **306** of the lower locking device **304***b* may be configured to move or otherwise bounce over the teeth **308** of the outer sleeve **208***b* or otherwise not cause a binding engagement therewith. The teeth **306** of the lower locking device **304***b*, however, may further be configured to engage or otherwise bind against the teeth **308** of the outer sleeve **208***b* in the event the outer sleeve is forced in the opposite direction (i.e., axially to the left within the piston bore **224**). As a result, the lower locking device **304***b* secures the outer sleeve **208***b* in the open position such that it will not inadvertently close again.

The sleeve assembly **200** is depicted in FIG. **4** in its open configuration. In the open configuration, production operations can be undertaken in order to extract the hydrocarbons present in the surrounding subterranean formation **110**. As briefly mentioned above, however, at least one of the advantages of the exemplary sleeve assembly **200** is the incorporation of the inner sleeve **208***a* which may be useful in reclosing the sleeve assembly **200** if desired. In some applications, an operator may want to reclose the sleeve assembly **200** in order to cease production from that particular location, or to allow pressure testing to be undertaken in the production tubing **118**. In other applications, the operator may want to reclose the sleeve assembly **200** in order to isolate certain sections of the production tubing **118** where it would otherwise be disadvantageous to do so while having fluid communication through open flow ports **206** in the sleeve assembly **200**.

To reclose the sleeve assembly **200**, or otherwise place the sleeve assembly **200** in a closed configuration, the inner sleeve **208***a* may be configured to be moved from its open position, as shown in FIGS. **2**A-B, **3**, and **4**, and into its closed position, as shown in FIGS. **5**A and **5**B. In some embodiments, this may be accomplished by introducing a shifting tool **316** (shown in phantom in FIG. **4**) into the production tubing **118** and run to the sleeve assembly **200**. In some embodiments, the shifting tool **316** is run in hole via wireline (not shown), or any other suitable conveyance. In at least one embodiment, the shifting tool **316** may have one or more radial keys or arms **318** configured to extend radially from the shifting tool **316** and locate or otherwise engage a radial shoulder **320** defined on the inner sleeve **208***a*. In some embodiments, the radial arms **318** may be spring loaded. In other embodiments, however, the radial arms **318** may be mechanically, electromechanically, or hydraulically actuated. While the shifting tool **316** has been described herein as having a particular configuration, those skilled in the art will readily recognize that many variations of the shifting tool **316** may be used to engage and shift the inner sleeve **208***a*, without departing from the scope of the disclosure.

Once the shifting tool **316** is properly engaged with the radial shoulder **320** of the inner sleeve **208***a*, the shifting tool **316** may then be "jarred" upwards, i.e., towards the left in FIG. **4** or otherwise towards the surface **106** (FIG. **1**). As known by those skilled in the art, jarring upwards refers to an upward impulse of force that is applied to an element, such as in this case the shifting tool **316**. Jarring upwards on the shifting tool **316** as engaged with the radial shoulder **320** may force the inner sleeve **208***a* to also move axially to the left within the production tubing **118**, thereby shifting the inner sleeve **208***a* from its open position into its closed position.

Referring now to FIGS. **5**A and **5**B, with continued reference to FIGS. **2**A-B, **3**, and **4**, illustrated are partial cross-sectional views of the sleeve assembly **200** as the inner sleeve **208***a* is moved from its open position into its closed position, according to one or more embodiments. Specifically, FIG. **5**A illustrates the upper portion of the sleeve assembly **200** and FIG. **2**B illustrates a connected lower portion thereof, with some of the features of the sleeve assembly **200** overlapping in each figure.

In order to axially move the inner sleeve **208***a* to the left within the production tubing **118**, and therefore into its closed position, the jarring of the shifting tool **316** may be configured to overcome the locking engagement between the locking collet **212** and the lower groove **216***a*. In particular, the shifting tool **316** may be jarred sufficiently such that the locking keys **214** flex inwards and out of engagement with the lower groove **216***a*. Once out of engagement with the lower groove **216***a*, the locking keys **214** may be able to slide along the inner radial surface of the bottom sub **204***b* as the inner sleeve **208***a* moves axially to the left and towards its closed position. Upon locating or otherwise engaging the upper groove **216***b*, the locking keys **214** may be configured to once again flex outwards and into engagement with the upper groove **216***b*, thereby securing the inner sleeve **208***a* in the closed position.

With the inner sleeve **208***a* in its closed position, the flow slots **210** are no longer exposed to the flow ports **206**. Instead, the flow ports **206** are generally occluded by the wall of the inner sleeve **208***a*, thereby preventing fluid communication between the wellbore annulus **126** and the production tubing **118**, and effectively ceasing fluid production at the location of the sleeve assembly **200**. Accordingly, FIGS. **5**A and **5**B depict the sleeve assembly **200** in a closed configuration.

One of the advantages of the exemplary sleeve assembly **200** is that the locking engagement between the upper groove **216***b* and the locking keys **214** may prevent the inner sleeve **208***a* from inadvertently moving back into its open position. In some applications, however, an operator may want to recommence production at the sleeve assembly **200** at a later time, thereby requiring the inner sleeve **208***a* to move back into its open position and the sleeve assembly **200** back into its open configuration. To accomplish this, in some embodiments, a shifting tool **502** (shown in phantom in FIG. **5**B) may be introduced into the production tubing **118** and run to the sleeve assembly **200** via wireline **504** or other suitable conveyance means. In some embodiments, the shifting tool **502** may be similar to or the same as the shifting tool **316** shown in FIGS. **4** and **5**A. In other embodiments, however, the shifting tool **502** may be any suitable shifting tool known to those skilled in the art.

In at least one embodiment, the shifting tool **502** may have one or more radial keys or arms **506** configured to extend radially from the shifting tool **502** and locate or otherwise engage a radial shoulder **508** defined on the inner sleeve **208***a*. In one embodiment, the radial shoulder **508** may be defined on the inner radial surface of the locking collet **212** of the inner sleeve **208***a*. Once the shifting tool **502** is properly engaged with the radial shoulder **508**, the shifting tool **502** may then be jarred downwards, i.e., towards the right in FIG. **5**B or otherwise towards the toe of the well. As known by those skilled in the art, jarring downwards refers to a downward impulse of force that is applied to an element, such as in this case the shifting tool **502**. Jarring downwards on the shifting tool **502** as engaged with the radial shoulder **508** may force the inner sleeve **208***a* to move axially to the right within the production tubing **118**, and thereby back towards its open position.

In order to axially move the inner sleeve **208***a* to the right within the production tubing **118**, however, the jarring of the shifting tool **502** must overcome the locking engagement between the locking collet **212** and the upper groove **216***b*. In particular, the shifting tool **502** may be jarred sufficiently such that the locking keys **214** flex inwards and out of engagement with the upper groove **216***b*. Once out of engagement with the upper groove **216***b*, the locking keys **214** may be able to slide along the inner radial surface of the bottom sub **204***b* as the inner sleeve **208***a* moves axially to the right and back towards its open position. Upon locating or otherwise engaging the lower groove **216***a*, the locking keys **214** may be configured to once again flex outwards and into engagement with the lower groove **216***a*, thereby securing the inner sleeve **208***a* in the closed position.

Accordingly, it will be appreciated by those skilled in the art that the sleeve assembly **200** may be opened and closed multiple times. This provides a distinct and valuable advantage over prior art sleeve assemblies which oftentimes provide a permanent fixation in either the open or closed configurations.

Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope and spirit of the present invention. The invention illustratively disclosed herein suitably may be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

The invention claimed is:

1. A sleeve assembly, comprising:

a housing having an uphole end and a downhole end and defining one or more flow ports that provide fluid communication between a wellbore annulus and an interior of the housing, the housing being coupled to a top sub at the uphole end and to a bottom sub at the downhole end;

an outer sleeve arranged within the housing and movable between a closed position, where the outer sleeve occludes the one or more flow ports, and an open position, where the one or more flow ports are exposed;

an inner sleeve concentrically arranged within the outer sleeve and defining a plurality of flow slots, the inner sleeve being movable between an open position and a closed position where, when in the open position, the plurality of flow slots are axially aligned with the one or more flow ports;

a piston movably arranged within a piston bore defined in the housing; and

an upper locking device arranged within a first cavity defined in the piston and, movable therewith, the upper locking device being engageable with an outer radial surface of the outer sleeve.

2. The sleeve assembly of claim **1**, further comprising:

a spring arranged within the piston bore and configured to bias an uphole end of the piston, wherein

as the spring biases against and axially moves the piston within the piston bore, the upper locking device engages and simultaneously moves the outer sleeve into the open position of the outer sleeve.

3. The sleeve assembly of claim **2**, further comprising:

a plurality of teeth defined on an inner radial surface of the upper locking device; and

a plurality of corresponding teeth defined on the outer radial surface of the outer sleeve,

wherein, when the spring biases against and axially moves the piston, the plurality of teeth of the upper locking device bind against the plurality of corresponding teeth of the outer sleeve, thereby moving the outer sleeve into the open position of the outer sleeve.

4. The sleeve assembly of claim **2**, further comprising a lower locking device arranged within a second cavity defined in the bottom sub, the lower locking device being configured to secure the outer sleeve in the open position of the outer sleeve.

5. The sleeve assembly of claim **4**, further comprising

a plurality of teeth defined on an inner radial surface of the lower locking device; and

a plurality of corresponding teeth defined on the outer radial surface of the outer sleeve, wherein, when the outer sleeve is in the open position, the plurality of teeth of the lower locking device bind against the plurality of corresponding teeth of the outer sleeve, thereby securing the outer sleeve into the open position.

6. The sleeve assembly of claim **3**, further comprising a locking collet provided on the inner sleeve and being configured to secure the inner sleeve in either the open or closed positions.

7. The sleeve assembly of claim **6**, further comprising:

one or more locking keys extending radially from the locking collet;

a first groove defined on an inner radial surface of the bottom sub; the one or more locking keys being configured to engage the first groove in order to lock the inner sleeve in the open position; and

a second groove defined on the inner radial surface of the bottom sub, the one or more locking keys being configured to engage the second groove in order to lock the inner sleeve in the closed position.

8. The sleeve assembly of claim **7**, further comprising one or more longitudinal perforations defined in the locking collet, the longitudinal perforations being configured to allow the locking collet to flex such that the one or more locking keys is able to move in and out of the first and second grooves.

9. The sleeve assembly of claim **3**, further comprising a shifting tool engageable with a radial shoulder defined on the inner sleeve, the shifting tool being configured to move the inner sleeve between the open and closed positions of the inner sleeve.

10. A method of actuating a sleeve assembly installed in production tubing, the method comprising:

introducing a first shifting tool into the sleeve assembly, the sleeve assembly including a housing defining one or more flow ports, an outer sleeve arranged within the housing such that the one or more flow ports are exposed, a piston movably arranged within the housing, and an inner sleeve concentrically arranged within the outer sleeve and defining a plurality of flow slots, wherein the plurality of flow slots are axially-aligned with the one or more flow ports, thereby providing fluid communication between a wellbore annulus and an interior of the sleeve assembly,

engaging an outer radial surface of the outer sleeve and moving the outer sleeve with an upper locking device arranged within a first cavity defined in the piston and movable therewith, the upper locking device moving the outer sleeve so as to expose the one or more flow ports and provide the fluid communication between the wellbore annulus and the interior of the sleeve assembly;

engaging the first shifting tool on a first radial shoulder defined on the inner sleeve; and

axially moving the inner sleeve with the first shifting tool such that the plurality of flow slots are moved out of axial alignment with the one or more flow ports.

11. The method of claim **10**, wherein the inner sleeve further includes a locking collet having one or more locking keys extending radially therefrom, and axially moving the inner sleeve further comprises forcing the one or more locking keys out of engagement with a first groove defined on an inner radial surface of the production tubing.

12. The method of claim **11**, further comprising:

engaging the one or more locking keys in a second groove defined on the inner radial surface of the production tubing, the second groove being axially offset from the first groove; and

locking the inner sleeve in an axial position with the plurality of flow slots moved out of axial alignment with the one or more flow ports.

13. The method of claim **12**, further comprising:

introducing a second shifting tool into the sleeve assembly;

engaging the second shifting tool on a second radial shoulder defined on the inner sleeve; and

axially moving the inner sleeve with the second shifting tool such that the plurality of flow slots are moved back into axial alignment with the one or more flow ports.

14. The method of claim **13**, wherein axially moving the inner sleeve with the second shifting tool further comprises:

forcing the one or more locking keys out of engagement with the second groove;

engaging the one or more locking keys once more in the second groove; and

locking the inner sleeve in the axial position with the plurality of flow slots axially aligned with the one or more flow ports.

15. The method of claim **11**, preceded by the following steps:

increasing a pressure within the sleeve assembly;

generating a pressure differential across the piston;

forcing the piston to move axially within the piston bore from a first position to a second position, thereby axially compressing a spring arranged within the piston bore;

reducing the pressure within the sleeve assembly; and

forcing the piston with the spring back to the first position.

16. The method of claim **15**, wherein generating the pressure differential across the piston further comprises collapsing a piston chamber defined between the piston and the outer sleeve.

17. The method of claim **16**, wherein forcing the piston to move axially within the piston bore from the first position further comprises shearing one or more shear pins used to couple the piston to the outer sleeve.

18. A sleeve assembly, comprising:

a housing defining one or more flow ports that provide fluid communication between a wellbore annulus and an interior of the housing, the housing being configured to be coupled at each end to production tubing;

an outer sleeve arranged within the housing and movable between a closed position, where the outer sleeve occludes the one or more flow ports, and an open position, where the one or more flow ports are exposed;

an inner sleeve concentrically arranged within the outer sleeve and defining a plurality of flow slots, the inner sleeve being movable between an open position and a closed position where, when in the open position, the plurality of flow slots are axially aligned with the one or more flow ports;

a piston movably arranged within a piston bore defined in the housing;

a spring arranged within the piston bore and configured to bias an uphole end of the piston; and

an upper locking device arranged within a first cavity defined in the piston and movable therewith, the upper locking device being engageable with an outer radial surface of the outer sleeve such that as the spring biases against and axially moves the piston within the piston bore, the upper locking device engages and simultaneously moves the outer sleeve into the open position of the inner sleeve.

19. The sleeve assembly of claim **18**, further comprising a locking collet provided on the inner sleeve and being configured to secure the inner sleeve in either the open or closed positions.

20. The sleeve assembly of claim **19**, further comprising:

one or more locking keys extending radially from the locking collet;

a first groove defined on an inner radial surface of the production tubing, the one or more locking keys being configured to engage the first groove in order to lock the inner sleeve in the open position; and

a second groove defined on the inner radial surface of the production tubing and axially offset from the first groove, the one or more locking keys being configured to engage the second groove in order to lock the inner sleeve in the closed position.

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