SYSTEMS AND METHODS FOR RESTRICTING FLUID FLOW IN A WELLBORE WITH AN AUTONOMOUS SEALING DEVICE AND MOTION-ARRESTING STRUCTURES

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ABSTRACT

Systems and methods for restricting fluid flow in a casing conduit, including a wellbore that extends within a subterranean formation, a casing string that extends within the wellbore and defines a portion of the casing conduit, a plurality of motion-arresting structures that project from an inner surface of the casing string to define a plurality of reduced-area regions of the casing conduit, and an autonomous sealing device that defines a contracted configuration and an expanded configuration. The methods include conveying the autonomous sealing device through the casing conduit, determining that the autonomous sealing device is located within a target portion of the casing conduit, expanding the autonomous sealing device to the expanded configuration, retaining the autonomous sealing device on a selected motion-arresting structure, and restricting fluid flow within the casing conduit with the autonomous sealing device.
Locate autonomous sealing device within casing conduit

Supply stimulant fluid to casing conduit

Convey autonomous sealing device

Detect variable associated with autonomous sealing device

Determine that autonomous sealing device is located within target portion of casing conduit

Expand autonomous sealing device

Retain autonomous sealing device

Restrict fluid flow

Stimulate subterranean formation

Translate sliding sleeve

Perforate casing string

Repeat method

Remove autonomous sealing device from casing conduit

Produce reservoir fluid

FIG. 10
SYSTEMS AND METHODS FOR
RESTRICTING FLUID FLOW IN A
WELLBORE WITH AN AUTONOMOUS
SEALING DEVICE AND
MOTION-ARRESTING STRUCTURES

CROSS REFERENCE TO RELATED
APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional No. 61/871,675, filed Aug. 29, 2013, the entirety of which is incorporated herein by reference for all purposes.

FIELD OF THE DISCLOSURE

[0002] The present disclosure is directed generally to systems and methods for restricting fluid flow within a casing conduit, and more particularly to systems and methods that utilize an autonomous sealing device and a plurality of motion-arresting structures to restrict fluid flow within the casing conduit.

BACKGROUND OF THE DISCLOSURE

[0003] A well may be utilized to produce one or more reservoir fluids, such as liquid and/or gaseous hydrocarbons, from a subterranean formation. The well may include a wellbore, which extends between a surface region and the subterranean formation, and a casing string that extends within the wellbore and defines a casing conduit.

[0004] During construction and/or operation of the well, it may be desirable to restrict fluid flow between an upper portion of the casing conduit and a downhole portion of the casing conduit, such as to stimulate the subterranean formation. Illustrative examples of stimulation processes include fracturing the formation and acidizing, or acid treating, the formation. Often, the stimulating process may be repeated a plurality of times along a length of the production casing to stimulate a plurality of zones of the subterranean formation.

As an illustrative, non-exclusive example, the stimulating may include providing a stimulant fluid to the casing conduit, with the stimulant fluid flowing from the casing conduit into the subterranean formation to thereby stimulate the subterranean formation, and with the fluid flow restriction being utilized to focus the stimulant fluid flow into a desired portion, region, and/or zone of the subterranean formation.

[0005] A number of processes have been utilized to stimulate subterranean formations. While these processes may be effective under certain conditions, they may be ineffective under others. As an illustrative, non-exclusive example, a well may include a wellbore with a long horizontal section. This extended horizontal section may extend within the subterranean formation, and it may be desirable to stimulate a plurality of zones in the subterranean formation that may be distributed along the length of the horizontal section.

[0006] Traditional stimulant processes may include establishing fluid communication between the casing conduit and a given zone of the subterranean formation, providing the stimulant fluid to the given zone of the subterranean formation to stimulate the given zone of the subterranean formation, and then fluidly isolating at least a portion of the casing conduit from the subterranean formation. This process may be repeated a plurality of times along a length of the horizontal section to stimulate the plurality of zones of the subterranean formation.

[0007] Generally, the traditional stimulating processes fluidly isolate the portion of the casing conduit from downhole portions of the casing conduit using isolation plugs or using traditional isolation balls and seats. It follows that this isolation from the downhole portions also isolates the portion of the casing conduit from corresponding regions of the subterranean formation that are in fluid communication with the downhole portions. Isolation plugs may include and/or be expandable plugs that may be located within the casing conduit and subsequently expanded to fill a portion of the casing conduit, thereby blocking fluid flow therethrough. Traditional isolation balls may include and/or be elastomeric balls that are sized to fit within the casing conduit and to seal with a respective seat that is sized to receive the isolation ball to block the flow of fluid therethrough.

[0008] However, as the length of the well is increased, setting the required number of isolation plugs becomes increasingly difficult and/or expensive and may inhibit economic and/or efficient stimulation of the subterranean formation. Moreover, the isolation plugs must be removed from the casing conduit, typically by time-consuming and/or expensive processes that include drilling the isolation plugs from the casing conduit, prior to production of the reservoir fluid from the subterranean formation.

[0009] Similarly, traditional isolation balls and seats rely on progressively smaller balls and seats to stimulate a desired number of zones of the subterranean formation. Thus, there is a practical limit to the number of zones that may be stimulated with isolation balls and seats while still permitting sufficient fluid flow rates within the casing conduit. In addition, the progressively smaller balls may effectively limit access to portions of the casing conduit that are downhole therefrom, as many downhole assemblies simply may be too large to fit, or flow, through the seats. Furthermore, these seats often must be removed from the casing conduit prior to production of the reservoir fluid from the subterranean formation, and doing so increases the overall cost of the stimulation, and subsequent production, process. Thus, there exists a need for improved systems and methods for restricting fluid flow in a casing conduit.

SUMMARY OF THE DISCLOSURE

[0010] Systems and methods for restricting fluid flow in a casing conduit are disclosed herein. The systems include a wellbore that extends within a subterranean formation, a casing string that extends within the wellbore and defines a portion of the casing conduit, a plurality of motion-arresting structures that project from an inner surface of the casing string to define a plurality of reduced-area regions of the casing conduit, and an autonomous sealing device that defines a contracted configuration and an expanded configuration. The autonomous sealing device is sized to flow past, or through, the plurality of reduced-area regions when in the contracted configuration, to be retained on a selected motion-arresting structure upon transitioning to the expanded configuration, and to restrict fluid flow within the casing conduit upon being retained on the selected motion-arresting structure.

[0011] In some embodiments, the autonomous sealing device is configured to form a fluid seal with the selected motion-arresting structure. In some embodiments, the selected motion-arresting structure is defined by the selected transitioning of the motion-arresting structure to the expanded configuration. In some embodiments, the selected
motion-arresting structure defines a sealing surface that is sized to form the fluid seal. In some embodiments, the autonomous sealing device is configured to form a fluid seal with an inner surface of the casing string. In some embodiments, the autonomous sealing device includes an expansion mechanism that is configured to transition the autonomous sealing device to the expanded configuration. In some embodiments, the autonomous sealing device is further configured to transition from the expanded configuration to a retracted configuration. In some embodiments, the autonomous sealing device is configured to release a supplemental material into the casing conduit. In some embodiments, the autonomous sealing device is operatively attached to a perforation device.

[0012] In some embodiments, the autonomous sealing device further includes an autonomous controller. In some embodiments, the autonomous controller is programmed to determine a location of the autonomous sealing device within the casing conduit and to transition the autonomous sealing device to the expanded configuration based on the determined location.

[0013] In some embodiments, the plurality of motion-arresting structures includes a plurality of isolation rings. In some embodiments, the plurality of motion-arresting structures includes a plurality of stops. In some embodiments, the plurality of motion-arresting structures includes a plurality of sliding sleeves. In some embodiments, the well further includes a hydraulically actuated sleeve.

[0014] The methods include conveying the autonomous sealing device through the casing conduit, determining that the autonomous sealing device is located within a target portion of the casing conduit, expanding the autonomous sealing device to the expanded configuration, retaining the autonomous sealing device on a selected motion-arresting structure, and restricting fluid flow within the casing conduit with the autonomous sealing device.

[0015] In some embodiments, the methods further include supplying a stimulant fluid to the casing conduit, and the conveying includes conveying the autonomous sealing device within the stimulant fluid. In some embodiments, the methods further include detecting a variable associated with the autonomous sealing device. In some embodiments, the determining is based upon the variable associated with the autonomous sealing device.

[0016] In some embodiments, the restricting includes forming a fluid seal between the selected motion-arresting structure and the autonomous sealing device. In some embodiments, the restricting includes forming a fluid seal with the inner surface of the casing string. In some embodiments, the methods further include removing the autonomous sealing device from the casing conduit. In some embodiments, the removing includes transitioning the autonomous sealing device from the expanded configuration to a retracted configuration.

[0017] In some embodiments, the methods further include stimulating the subterranean formation. In some embodiments, the stimulating includes supplying a stimulant fluid to the subterranean formation. In some embodiments, the stimulant fluid is supplied via a sleeve port, via an injection port, and/or via a perforation. In some embodiments, the methods further include repeating the methods to restrict fluid flow within a plurality of portions of the casing conduit. In some embodiments, the methods further include producing a reservoir fluid from the subterranean formation.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0018] FIG. 1 is a schematic representation of illustrative, non-exclusive examples of a hydrocarbon well that may be utilized with and/or may include the systems and methods according to the present disclosure.

[0019] FIG. 2 is a schematic cross-sectional view of illustrative, non-exclusive examples of a casing string that includes a motion-arresting structure and may be utilized with an autonomous sealing device according to the present disclosure.

[0020] FIG. 3 is a schematic cross-sectional view of illustrative, non-exclusive examples of another motion-arresting structure that may be utilized with an autonomous sealing device according to the present disclosure.

[0021] FIG. 4 is a schematic representation of illustrative, non-exclusive examples of a process flow that may be utilized with a flow-arresting structure and an autonomous sealing device according to the present disclosure.

[0022] FIG. 5 is another schematic representation of illustrative, non-exclusive examples of a process flow that may be utilized with a flow-arresting structure and an autonomous sealing device according to the present disclosure.

[0023] FIG. 6 is another schematic representation of illustrative, non-exclusive examples of a process flow that may be utilized with a flow-arresting structure and an autonomous sealing device according to the present disclosure.

[0024] FIG. 7 is another schematic representation of illustrative, non-exclusive examples of a process flow that may be utilized with a flow-arresting structure and an autonomous sealing device according to the present disclosure.

[0025] FIG. 8 is another schematic representation of illustrative, non-exclusive examples of a process flow that may be utilized with a flow-arresting structure and an autonomous sealing device according to the present disclosure.

[0026] FIG. 9 is another schematic representation of illustrative, non-exclusive examples of a process flow that may be utilized with a flow-arresting structure and an autonomous sealing device according to the present disclosure.

[0027] FIG. 10 is a flowchart depicting methods according to the present disclosure of restricting fluid flow between an upper portion of a casing conduit and a downhole portion of the casing conduit.

**DETAILED DESCRIPTION AND BEST MODE**

**OF THE DISCLOSURE**

[0028] FIGS. 1-9 provide illustrative, non-exclusive examples of hydrocarbon wells 30 according to the present disclosure and/or of components of hydrocarbon wells 30, such as motion-arresting structures 100 and/or autonomous sealing devices 150. Elements that serve a similar, or at least substantially similar, purpose are labeled with like numbers in each of FIGS. 1-9, and these elements may not be discussed in detail herein with reference to each of FIGS. 1-9. Similarly, all elements may not be labeled in each of FIGS. 1-9, but reference numerals associated therewith may be utilized herein for consistency. Elements, components, and/or features that are discussed herein with reference to one or more of FIGS. 1-9 may be included in and/or utilized with any of FIGS. 1-9 without departing from the scope of the present disclosure.

[0029] In general, elements that are likely to be included in a given (i.e., a particular) embodiment are illustrated in solid lines, while elements that are optional to a given embodiment
are illustrated in dashed lines. However, elements that are shown in solid lines are not essential to all embodiments, and an element shown in solid lines may be omitted from a particular embodiment without departing from the scope of the present disclosure.

**0030** FIG. 1 is a schematic representation of illustrative, non-exclusive examples of a hydrocarbon well 30 that may be utilized with and/or include the systems and methods according to the present disclosure and with and/or within which the methods according to the present disclosure may be utilized and/or implemented. Hydrocarbon well 30 includes a wellbore 32 that extends from a surface region 10 and/or within a subterranean formation 22 that is present within a subsurface region 20. A casing string 40 extends within wellbore 32 and has an inner surface 42 that defines a portion of a casing conduit 44. Casing string 40 may include a plurality of sections 43 of casing that may be operatively attached to one another with respective casing collars 41 to form the casing string. FIG. 1 illustrates hydrocarbon well 30 as including a single, continuous, and/or unbranched wellbore 32. However, the wellbore shown in FIG. 1 is intended to schematically depict wellbore 30, and therefore to include, but not be limited to, such a single, continuous, and/or unbranched wellbore. Accordingly, it also is within the scope of the present disclosure and the schematic depiction of FIG. 1 that hydrocarbon well 30 may include a plurality of branches and/or laterals. Each of these branches and/or laterals, when present, may include a respective casing string 40; and the systems and methods according to the present disclosure may be located in and/or utilized with any and/or all branches and/or laterals of hydrocarbon well 30.

**0031** Hydrocarbon well 30, which also may be referred to herein as a well 30, further includes a plurality of motion-arresting structures 100 that are spaced apart from one another along a (longitudinal) length of casing string 40. Motion-arresting structures 100 project from inner surface 42 to define a plurality of reduced-area regions 102 of casing conduit 44. Hydrocarbon well 30 further includes one or more autonomous sealing devices 150 and also may include a perforation device 170 and/or one or more hydraulically actuated sleeves 74.

**0032** During the construction, formation, and/or operation of hydrocarbon well 30, one or more autonomous sealing devices 150 may be located within casing conduit 44 and a stimulant fluid 62 may be provided to the casing conduit. This may flow the autonomous sealing device within the casing conduit in a downhole direction 38 and/or toward subterranean formation 22. Upon reaching a desired, or target, location within the casing conduit, the autonomous sealing device may transition from a contracted configuration 152 to an expanded configuration 154 and be retained on a selected motion-arresting structure 100, thereby fluidly isolating an upheole portion 46 of casing conduit 44 from a downhole portion 48 of the casing conduit. This fluid isolation may facilitate performing one or more completion and/or stimulation operations within hydrocarbon well 30.

**0033** Autonomous sealing device 150 may include any suitable structure that may define contracted configuration 152 and expanded configuration 154. When in contracted configuration 152, the autonomous sealing device is adapted, configured, constructed, designed, and/or sized to pass through the plurality of reduced-area regions 102 within casing conduit 44. However, upon transitioning to expanded configuration 154, the autonomous sealing device is adapted, configured, constructed, and/or sized not to pass through reduced-area regions 102, to be retained on a selected motion-arresting structure 100, and/or to restrict fluid flow between a portion of casing conduit 44 that is upheole from (or located in an upheole direction 36 from) the selected motion-arresting structure (i.e., upheole portion 46 of the casing conduit) and a portion of the casing conduit that is downhole from (or located in downhole direction 38 from) the selected motion-arresting structure (i.e., downhole portion 48 of the casing conduit).

**0034** As discussed in more detail herein, autonomous sealing device 150 may be adapted, configured, constructed, and/or programmed for autonomous, or independent, operation within casing conduit 44. As such, the autonomous sealing device may not be attached to a tether, a working line, a wireline, and/or tubing. Illustrative, non-exclusive examples of autonomous devices that may be utilized within a wellbore are disclosed in U.S. Patent Application Publication Nos. 2013/0062055; U.S. Patent Application Publication Nos. 2013/0255939; and U.S. Patent Application Publication Nos. 2013/0248174, the complete disclosures of which are hereby incorporated by reference.

**0035** As used herein, the phrases “expanded configuration” and “contracted configuration” are relative phrases that do not, necessarily, refer to discrete and/or single configurations for autonomous sealing device 150. Instead, these phrases refer to configurations in which autonomous sealing device 150 is sized to pass through reduced-area regions 102 (i.e., contracted configuration 152) and configurations in which autonomous sealing device 150 is sized to be retained on motion-arresting structures 100 and/or not to pass through reduced-area regions 102 (i.e., expanded configuration 154). As such, contracted configuration 152 and expanded configuration 154 optionally may refer to a range of configurations that is bounded by a fully contracted configuration and a fully expanded configuration, respectively.

**0036** With this in mind, it is within the scope of the present disclosure that contracted configuration 152 and/or expanded configuration 154 may be defined in any suitable manner and/or may define any suitable configuration, or relative configuration, for autonomous sealing device 150 such that the autonomous sealing device may pass through reduced-area regions 102 while in the contracted configuration but is retained on motion-arresting structures 100 (i.e., may/can not pass through reduced-area regions 102) when in the expanded configuration. As an illustrative, non-exclusive example, contracted configuration 152 may define a contracted volume and expanded configuration 154 may define an expanded volume that is greater than the contracted volume. As another illustrative, non-exclusive example, contracted configuration 152 may define a contracted characteristic dimension (or diameter and/or cross-sectional area transverse to the longitudinal axis of the corresponding portion of the casing conduit within which the motion-arresting structure is located) and expanded configuration 154 may define an expanded characteristic dimension (or diameter and/or cross-sectional area transverse to the longitudinal axis of the corresponding portion of the casing conduit within which the motion-arresting structure is located) that is greater than the contracted characteristic dimension. As additional illustrative, non-exclusive examples, contracted configuration 152 and/or expanded configuration 154 may define respective cylindrical and/or spherical configurations, profiles, and/or surface profiles.
Autonomous sealing device 150 may include an expansion mechanism 158 that may be configured to transition (or provide a motive force for transitioning) the autonomous sealing device to expanded configuration 154 and/or from contracted configuration 152 to expanded configuration 154. Expansion mechanism 158 may include any suitable structure. As illustrative, non-exclusive examples, expansion mechanism 158 may include and/or be an explosive charge, a mechanical actuator, an electric actuator, a hydraulic actuator, a chemical reaction, and/or a material that swells upon contact with a wellbore fluid.

As a more specific but still illustrative, non-exclusive example, autonomous sealing device 150 and/or expansion mechanism 158 may include a reservoir chamber 190 and an expansion chamber 192. Under these conditions, expansion mechanism 158 may be configured to direct an expansion fluid from reservoir chamber 190 to expansion chamber 192 to swell the autonomous sealing device and/or to transition the autonomous sealing device to the expanded configuration. When autonomous sealing device 150 includes reservoir chamber 190 and expansion chamber 192, the autonomous sealing device further may include a check valve 194 that is configured to at least temporarily retain the expansion fluid within the expansion chamber subsequent to the autonomous sealing device transitioning to the expanded configuration.

Autonomous sealing device 150 further may be configured to transition from expanded configuration 154 to a retracted configuration 156, which also may be referred to herein as a spent configuration 156 and/or a post-expansion configuration 156. Upon transitioning to retracted configuration 156, the autonomous sealing device may be configured to permit fluid flow between upright portion 46 and downhole portion 48 and/or may be configured to pass through reduced-area regions 102. As an illustrative, non-exclusive example, retracted configuration 156 may define a retracted configuration volume that is less than the expanded configuration volume. As another illustrative, non-exclusive example, retracted configuration 156 may define a retracted configuration characteristic dimension, or diameter, that is less than the expanded characteristic dimension, or diameter.

It is within the scope of the present disclosure that autonomous sealing device 150 may transition from expanded configuration 154 to retracted configuration 156 in any suitable manner, at any suitable timing, and/or responsive to any suitable conditions or actuator. As illustrative, non-exclusive examples, the autonomous sealing device may shrink, retract, break apart, and/or dissolve to transition to, or toward, the retracted configuration. As a more specific but still illustrative, non-exclusive example, the autonomous sealing device may be a frangible autonomous sealing device that is formed, at least partially, from a frangible material, and the autonomous sealing device further may include a fragmentation change 196 that is configured to be actuated to break apart the frangible autonomous sealing device and thereby transition the frangible autonomous sealing device to the retracted configuration.

Autonomous sealing device 150 further may include a supplemental material 198, and the autonomous sealing device may be configured to release the supplemental material within casing conduit 44. This may include releasing the supplemental material subsequent to transitioning to the expanded configuration, upon transitioning to the contracted configuration, upon breaking apart within the casing conduit, and/or upon dissolving within the casing conduit. Illustrative, non-exclusive examples of supplemental material 198 include any suitable gel breaker, paraffin inhibitor, corrosion inhibitor, and/or tracer material. It also is within the scope of the present disclosure that the systems and/or methods may utilize supplemental material and/or mechanisms or devices for delivering and/or releasing supplemental material that are not attached to, are not included in, and/or do not form a portion of an autonomous sealing device 150.

Hydrocarbon well 30 and/or casing conduit 44 thereof may include and/or contain a plurality of autonomous sealing devices 150 that each may contain a respective volume of supplemental material 198. Under these conditions, each of the respective volumes of supplemental material 198 may include a respective (or unique) tracer material that may be readily distinguished from the tracer material that may be included in a remainder of the respective volumes of supplemental sealing material. In addition, the systems and methods disclosed herein may be configured to detect the presence of the respective tracer materials within a reservoir fluid 24 that is produced from hydrocarbon well 30, thereby providing information regarding which region(s) of subterranean formation 22 are producing the reservoir fluid and/or which autonomous sealing device(s) are restricting fluid flow between respective upright and downhole portions of the casing conduit.

Autonomous sealing device 150 may be configured to form a fluid seal with the selected motion-arresting structure 100 upon transitioning to expanded configuration 154 and to thereby restrict the fluid flow between upright portion 46 and downhole portion 48. As an illustrative, non-exclusive example, motion-arresting structures 100 may define a sealing surface 112 that may be designed, constructed, shaped, and/or sized to form the fluid seal with the autonomous sealing device. Under these conditions, and when autonomous sealing device 150 is in expanded configuration 154, an outer diameter of the autonomous sealing device may be less than an inner diameter of casing conduit 44. Additionally or alternatively, and when autonomous sealing device 150 is in expanded configuration 154, the outer diameter of the autonomous sealing device may be equal to the inner diameter of the casing conduit and/or the autonomous sealing device may be designed, constructed, shaped, and/or sized to form the fluid seal with inner surface 42 of casing string 40. This is discussed in more detail herein with reference to FIG. 2.

Autonomous sealing device 150 may be configured, constructed, and/or programmed to transition from contracted configuration 152 to expanded configuration 154, and/or to retracted configuration 156 based upon any suitable criteria and/or responsive to any suitable event. As an illustrative, non-exclusive example, the autonomous sealing device may transition (or be transitioned) to expanded configuration 154 responsive to being located within a target, and/or otherwise selected, portion of casing conduit 44 (such as a portion of casing conduit 44 that is upright from, directly upright from, and/or within a threshold distance of the selected motion-arresting structure 100). As another illustrative, non-exclusive example, the autonomous sealing device may transition (or be transitioned) to expanded configuration 154 responsive to flowing a target, or desired, distance along a (longitudinal) length of (and/or within) casing conduit 44. As yet another illustrative, no-exclusive example, autonomous sealing device 150 may transition (or be transitioned) to retracted configuration 156 subsequent to stimulation of a
target region of subterranean formation 22, responsive to (or upon) being located within casing conduit 44 for at least a threshold period of time, and/or responsive to (or upon) production of reservoir fluid 24 from subterranean formation 22.

[0045] It is within the scope of the present disclosure that autonomous sealing device 150 may transition among and/or between contracted configuration 152, expanded configuration 154, and/or retracted configuration 156 at any suitable transition rate. As an illustrative, non-exclusive example, autonomous sealing device 150 may be configured to partially transition to expanded configuration 154 prior to being retained on the selected motion-arresting structure 100 to complete the transition to the expanded configuration subsequent to being retained on the selected motion-arresting structure. As another illustrative, non-exclusive example, autonomous sealing device 150 also may be configured to completely transition to expanded configuration 154 prior to being retained on the selected motion-arresting structure.

[0046] The transitioning of autonomous sealing device 150 among the various configurations thereof may be controlled, regulated, and/or initiated in any suitable manner. As an illustrative, non-exclusive example, expansion mechanism 158 may be a passive structure that is configured to control the transitioning of the autonomous sealing device responsive to temperatures and/or pressures within casing conduit 44 and/or responsive to a residence time of the autonomous sealing device within the casing conduit.

[0047] As another illustrative, non-exclusive example, the transition may be actively controlled, such as via an autonomous controller 160 that is adapted, configured, and/or programmed to control the operation of the autonomous sealing device. As an illustrative, non-exclusive example, autonomous controller 160 may be programmed to determine a location of autonomous sealing device 150 within casing conduit 44 and/or may transition the autonomous sealing device to expanded configuration 154 based upon the determined location and/or when the determined location corresponds to a target location within the casing conduit. The location of the autonomous sealing device may be and/or may be determined based upon a distance that the autonomous sealing device has traveled within the casing conduit and/or a depth of the autonomous sealing device below a ground surface. Additionally or alternatively, the autonomous controller also may be programmed to time the transition to the expanded configuration such that the autonomous sealing device is retained on the selected motion-arresting structure while passing through motion-arresting structures that may be uphill from the selected motion-arresting structure.

[0048] Additionally or alternatively, autonomous controller 160 may be programmed to determine a variable associated with the autonomous sealing device and/or to transition the autonomous sealing device to the expanded configuration based upon the determined variable. Illustrative, non-exclusive examples of the variable associated with the autonomous sealing device include a velocity of the autonomous sealing device within the casing conduit, a speed of the autonomous sealing device within the casing conduit, an acceleration of the autonomous sealing device within the casing conduit, a deceleration of the autonomous sealing device within the casing conduit, a pressure proximal to the autonomous sealing device within the casing conduit, a location of the autonomous sealing device along the length of the casing string, and/or a number of casing collars 41 that the autonomous sealing device has traveled past while located within the casing conduit.

[0049] It is within the scope of the present disclosure that autonomous controller 160 may include one or more sensors and/or detectors. These sensors and/or detectors may be configured to determine, measure, and/or detect any suitable variable associated with autonomous sealing device 150, illustrative, non-exclusive examples of which are disclosed herein.

[0050] Motion-arresting structures 100 may include any suitable structure that defines reduced-area regions 102 and/or that is configured to retain autonomous sealing device 150 subsequent to the autonomous sealing device transitioning to expanded configuration 154. In addition, motion-arresting structures 100 also may be formed in any suitable manner. As an illustrative, non-exclusive example, the casing string may include and/or be a monolithic structure that includes one or more sections of casing 43 and motion-arresting structures 100. Under these conditions, motion-arresting structures 100 may be formed from casing string 40 (or section(s) of casing 43 thereof). This may include forming the motion-arresting structure with, or concurrently with, the casing string (such as by molding, rolling, and/or extruding the motion-arresting structures with the casing string) and/or deforming the casing string to form the motion-arresting structures (such as by indenting and/or dimpling the casing string).

[0051] As another illustrative, non-exclusive example, motion-arresting structures 100 may be formed separately from casing string 40 (and/or sections of casing 43 thereof) and/or may be operatively attached to the casing string. As an illustrative, non-exclusive example, casing collars 41 may include and/or define motion-arresting structures 100. Under these conditions, motion-arresting structures 100 also may be referred to herein as motion-arresting casing collar assemblies 101. As another illustrative, non-exclusive example, motion-arresting structures 100 may extend through holes in casing string 40 and thus into casing conduit 44. As yet another illustrative, non-exclusive example, motion-arresting structures 100 may be welded or otherwise secured to the inner surface of the casing conduit.

[0052] Hydrocarbon well 30 and/or casing string 40 thereof may include any suitable number of motion-arresting structures 100. As illustrative, non-exclusive examples, the hydrocarbon well may include at least 2, at least 4, at least 6, at least 10, at least 15, at least 20, at least 25, at least 30, at least 35, at least 40, at least 45, at least 50, at least 55, at least 60, at least 70, at least 80, at least 90, at least 100, at least 125, at least 150, at least 200, or at least 250 motion-arresting structures 100.

[0053] The plurality of motion-arresting structures 100 may be spaced apart along the length of casing string 40 at any suitable spacing, or relative spacing. As an illustrative, non-exclusive example, an average distance between a given motion-arresting structure and the adjacent motion-arresting structure (i.e., the next motion-arresting structure in an uphill or downhill direction) may be at least 10 meters, at least 15 meters, at least 20 meters, at least 30 meters, at least 40 meters, at least 50 meters, at least 60 meters, at least 70 meters, at least 80 meters, at least 90 meters, or at least 100 meters. Additionally or alternatively, the average distance between adjacent motion-arresting structures also may be less than 300 meters, less than 250 meters, less than 200 meters, less than 175 meters, less than 150 meters.
140 meters, less than 130 meters, less than 120 meters, less than 110 meters, less than 100 meters, less than 90 meters, less than 80 meters, less than 70 meters, less than 60 meters, less than 50 meters, less than 40 meters, or less than 30 meters.

[0054] Reduced-area regions 102 may define any suitable cross-sectional area (or transverse cross-sectional area) relative to the cross-sectional area (or transverse cross-sectional area) of casing conduit 44 (or the cross-sectional area that is defined by inner surface 42 of casing string 40). As illustrative, non-exclusive examples, the transverse cross-sectional area of reduced-area regions 102 may be at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, or at least 95% of the transverse cross-sectional area of the portion of the casing conduit that is defined by inner surface 42 of casing string 40.

As another illustrative, non-exclusive example, the transverse cross-sectional area of reduced-area regions 102 may be less than 99%, less than 98%, less than 97%, less than 96%, less than 95%, less than 94%, less than 93%, less than 92%, less than 91%, less than 90%, less than 89%, less than 88%, less than 87%, less than 86%, or less than 85% of the transverse cross-sectional area of the portion of the casing conduit that is defined by the inner surface of the casing string.

[0055] It is within the scope of the present disclosure that the plurality of reduced-area regions may define a respective plurality of similar, or even identical, transverse cross-sectional areas. However, it is also within the scope of the present disclosure that the plurality of reduced-area regions may define a respective plurality of similar transverse cross-sectional areas and/or that a transverse cross-sectional area of a first portion of the plurality of reduced area regions may be different from a transverse cross-sectional area of a second portion of the plurality of reduced area regions.

[0056] As an illustrative, non-exclusive example, a first reduced-area region may have a first transverse cross-sectional area that is less than a transverse cross-sectional area of the remaining reduced-area regions. In addition, a second reduced-area region may have a second transverse cross-sectional area that is greater than a transverse cross-sectional area of the remaining reduced-area regions. Under these conditions, a ratio of the first transverse cross-sectional area to the second transverse cross-sectional area may be at least a three-fold ratio. As illustrative, non-exclusive examples of the threshold area ratio include threshold area ratios of at least 0.55, at least 0.6, at least 0.65, at least 0.7, at least 0.75, at least 0.8, at least 0.85, at least 0.9, at least 0.95, at least 0.96, at least 0.97, at least 0.98, or at least 0.99.

[0057] Perforation device 170 may be operatively attached to, included in, and/or form a portion of autonomous sealing device 150 and may include any suitable structure that may be configured to create a perforation within casing string 40. As illustrative, non-exclusive example, perforation device 170 may include and/or be a perforation gun that includes one or more perforation charges. It also is within the scope of the present disclosure that the systems and/or methods disclosed herein may utilize one or more perforation devices 170 that are not attached to, are not included in, and/or do not form a portion of an autonomous sealing device 150.

[0058] Illustrative, non-exclusive examples of the operation of perforation device 170 within hydrocarbon well 30 are discussed in more detail herein. As illustrative, non-exclusive examples, perforation device 170 may be configured to create the perforation prior to, concurrent with, and/or subsequent to autonomous sealing device 150 being retained on the selected motion-arresting structure 100. Additionally or alternatively, the perforation device 170 may be configured to create the perforation responsive to the pressure proximal to the autonomous sealing device exceeding a threshold perforating pressure.

[0059] Casing string 40 may include and/or be any suitable structure that defines the portion of casing conduit 44. As an illustrative, non-exclusive example, and as discussed, the casing string may include a plurality of sections of casing 43 that are operatively attached to one another via a plurality of casing collars 41. Under these conditions, a distance between adjacent casing collars (or a length of sections of casing 43) may be at least 5 meters, at least 6 meters, at least 7 meters, at least 8 meters, at least 9 meters, at least 10 meters, at least 11 meters, at least 12 meters, or at least 13 meters. Additionally or alternatively, the distance between adjacent casing collars also may be less than 20 meters, less than 19 meters, less than 18 meters, less than 17 meters, less than 16 meters, less than 15 meters, less than 14 meters, or less than 13 meters. As another illustrative, non-exclusive example, the casing string may include and/or be a continuous, or at least substantially continuous, casing string, such as may be formed by a continuous, or at least substantially continuous, length of tubing.

[0060] It is within the scope of the present disclosure that casing string 40 may be formed from any suitable material. As illustrative, non-exclusive examples, the casing string may be a metallic casing string, a non-metallic casing string, and/or a polymeric casing string.

[0061] It is also within the scope of the present disclosure that casing string 40 may define any suitable (longitudinal) length. As illustrative, non-exclusive examples, the length of the casing string may be at least 1000 meters, at least 1500 meters, at least 2000 meters, at least 2500 meters, at least 3000 meters, at least 3500 meters, at least 4000 meters, at least 4500 meters, or at least 5000 meters. Additionally or alternatively, the length of the casing string also may be less than 10,000 meters, less than 9000 meters, less than 8000 meters, less than 7000 meters, less than 6000 meters, less than 5000 meters, less than 4500 meters, less than 4000 meters, less than 3500 meters, or less than 3000 meters.

[0062] The portion of the length of the casing string that includes motion-arresting structures 100 may include at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, or at least 90% of the (total) length of the casing string. Additionally or alternatively, the portion of the length also may be less than 100%, less than 95%, less than 90%, less than 85%, less than 80%, or less than 75% of the (total) length of the casing string.

[0063] Subterranean formation 22 may include any suitable structure that may include and/or contain reservoir fluid 24. As illustrative, non-exclusive examples, subterranean formation 22 may include and/or be a hydrocarbon formation, a hydrocarbon reservoir, and/or an oil shale formation. In addition, reservoir fluid 24 may include any suitable fluid, illustrative, non-exclusive examples of which include a liquid, such as oil, and/or a gas, such as natural gas.

[0064] FIG. 2 is a schematic cross-sectional view of illustrative, non-exclusive examples of a casing string 40 and/or of a casing collar 41 that includes a motion-arresting structure 100 and that may be utilized with an autonomous sealing device 150 according to the present disclosure. As illustrated in solid lines in FIG. 2, motion-arresting structure 100...
includes an isolation ring 110 that is configured to receive autonomous sealing device 150 and that defines a reduced-area region 102 of a casing conduit 44. Isolation ring 100 may define a sealing surface 112 that is configured to form a fluid seal with autonomous sealing device 150, as indicated at 185. Additionally or alternatively, the autonomous sealing device may be configured to form the fluid seal with an inner surface 42 of casing string 40, as indicated at 180.

[0065] Isolation ring 110 further may include a sealing device seat 114 that is sized to receive autonomous sealing device 150 when the autonomous sealing device is in expanded configuration 154 and/or to define at least a portion of sealing surface 112. Sealing device seat 114 may be shaped and/or contoured to complement a shape of autonomous sealing device 150 and thereby to enhance the fluid seal between the isolation ring and the autonomous sealing device.

[0066] Isolation ring 110 also may include and/or define a contoured surface 116. Contoured surface 116 may be configured to permit and/or facilitate flow of autonomous sealing device 150 past motion-arresting structure 100 when the autonomous sealing device is in a contracted and/or retracted configuration (as discussed herein). Additionally or alternatively, contoured surface 116 also may include, be, and/or function as sealing surface 112 and/or as sealing device seat 114.

[0067] As illustrated in dashed lines in FIG. 2, isolation ring 110 further may include and/or be a sliding sleeve 130 that is configured to transition between a closed configuration 137 and an open configuration 138. This may include transitioning responsive to retaining autonomous sealing device 150 and/or responsive to establishing at least a threshold pressure differential between an upper portion 46 of casing conduit 44 and a downhole portion 48 of the casing conduit. When in closed configuration 137, sliding sleeve 130 may be configured to restrict, block, and/or occlude a fluid flow through an injection port 132 that is associated therewith. However, and upon transitioning to open configuration 138, sliding sleeve 130 may permit the fluid flow through the injection port (i.e., from the casing string to the subterranean formation, or vice versa). As used herein, the fluid conduit from the casing string to the subterranean formation additionally or alternatively referred to as an injection conduit 132, an injection passage 132, and/or a casing port 132, a casing-to-wellbore passage 132.

[0069] FIG. 3 is a schematic cross-sectional view of an illustrative, non-exclusive example of another motion-arresting structure 100 that may be utilized with an autonomous sealing device 150 according to the present disclosure. Motion-arresting structure 100 of FIG. 3 includes a plurality of (discrete) stops 120, which also may be referred to herein as pins 120 and/or as projections 120, that project into a casing conduit 44 and/or from an inner surface 42 of a casing string 40 to define a reduced-area region 102. Stops 120 are sized to retain autonomous sealing device 150 thereon when the autonomous sealing device is in expanded configuration 154. However, stops 120 may not include sealing surface 112 of FIG. 2. Thus, autonomous motion-arresting structure 150 may be configured to form the fluid seal with inner surface 42, as indicated at 180.

[0070] FIGS. 4-9 are illustrative, non-exclusive examples of hydrocarbon wells 30 that include flow-arresting structures 100 and autonomous sealing devices 150 according to the present disclosure and/or of process flows that may be utilized with the flow-arresting structures and the autonomous sealing devices. The flow-arresting structures and/or the autonomous sealing devices of FIGS. 4-9 may include and/or be the flow-arresting structures and/or the autonomous sealing devices of FIGS. 1-3 and the process flows that are described herein with reference to FIGS. 4-9 may be utilized with hydrocarbon well 30 of FIG. 1 without departing from the scope of the present disclosure.

[0071] FIGS. 4-5 are schematic representations of illustrative, non-exclusive examples of a process flow that may be utilized with a hydrocarbon well 30 according to the present disclosure that includes a flow-arresting structure 100 that includes sliding sleeves 130. In FIG. 4, sliding sleeves 130 are in a closed configuration 137 and restrict fluid flow through injection conduits 132 that are associated therewith. As illustrated in dash-dot lines, autonomous sealing device 150 may flow with stimulant fluid 62 through a first motion-arresting structure 100 while in a contracted configuration 152. Subsequently, the autonomous sealing device may transition to an expanded configuration 154 and be retained on a second motion-arresting structure 100 (as illustrated in solid lines).

[0072] The autonomous sealing device forms a fluid seal with the second motion-arresting structure, thereby restricting fluid flow from an upper portion 46 of a casing conduit 44 to a downhole portion 48 of the casing conduit. This may permit pressurization of the upper portion of the casing conduit. Then, as illustrated in FIG. 5, sliding sleeve 130 of the second motion-arresting structure may transition to an open configuration 138 (as such responsive to the pressure within the upper portion of the casing conduit exceeding a threshold stimulating pressure), thereby permitting stimulant fluid 62 to flow through injection conduit 132 and into subterranean formation 22, such as to stimulate and/or fracture the subterranean formation.

[0073] FIGS. 4-5 illustrate hydrocarbon well 30 including two motion-arresting structures 100. However, it is within the scope of the present disclosure that any suitable number of motion-arresting structures may be present within hydrocarbon well 30. Thus, the above-described process may be repeated any suitable number of times to transition any suitable number of sliding sleeves 130 from the closed configuration to the open configuration and thereby to stimulate and/or fracture any suitable number of regions, zones, and/or portions of subterranean formation 22.

[0074] FIGS. 6-7 are schematic representations of illustrative, non-exclusive examples of another process flow that may be utilized with a hydrocarbon well 30 according to the present disclosure that includes an autonomous sealing device 150 that includes and/or is operatively attached to a perforation device 170. As illustrated in dash-dot lines in FIG. 6, autonomous sealing device 150 and perforation device 170 may flow with stimulant fluid 62 through a first motion-arresting structure 100 while autonomous sealing device 150 is in a contracted configuration 152. Subsequently, the autonomous sealing device may transition to an expanded configuration 154 and be retained on a second motion-arresting structure 100 (as illustrated in solid lines).

[0075] The autonomous sealing device forms a fluid seal with the second motion-arresting structure, thereby restricting fluid flow from an upper portion 46 of a casing conduit 44 to a downhole portion 48 of the casing conduit. This may permit pressurization of the upper portion of the casing conduit. Then, as illustrated in FIG. 7, perforation device 170 may create one or more perforations 172 within a casing string 40 that defines casing conduit 44 (such as responsive to
the pressure within the uphole portion of the casing conduit exceeding a threshold perforating pressure). This may permit stimulant fluid 62 to flow through perforations 172 into subterranean formation 22, such as to stimulate and/or fracture the subterranean formation.

[0076] FIGS. 6-7 illustrate hydrocarbon well 30 with only two motion-arresting structures 100. However, and as discussed herein with reference to FIGS. 4-5, hydrocarbon well 30 may include any suitable number of motion-arresting structures 100 and the above-described process may be repeated any suitable number of times to stimulate and/or fracture any suitable number of regions, zones, and/or portions of subterranean formation 22.

[0077] FIGS. 8-9 are schematic representations of illustrative, non-exclusive examples of another process flow that may be utilized with a hydrocarbon well 30 according to the present disclosure that includes a motion-arresting structure 100, an autonomous sealing device 150, and a hydraulically actuated sleeve 74. In FIG. 8, hydraulically actuated sleeve 74 is in a closed configuration 77 and restricts fluid flow through a sleeve port 76 that is associated therewith. As illustrated in dash-dot lines, autonomous sealing device 150 may flow with stimulant fluid 62 through a first motion-arresting structure 100 while in a contracted configuration 152. Subsequently, the autonomous sealing device may transition to an expanded configuration 154 and be retained on a second motion-arresting structure 100 (as illustrated in solid lines).

[0078] The autonomous sealing device forms a fluid seal with the second motion-arresting structure, thereby restricting fluid flow from an uphole portion 46 of a casing conduit 44 to a downhole portion 48 of the casing conduit. This may permit pressurizing of the uphole portion of the casing conduit. Then, and as illustrated in FIG. 9, hydraulically actuated sleeve 74 may transition to an open configuration 78 (such as responsive to the pressure within the uphole portion of the casing conduit exceeding a threshold stimulating pressure and/or a pressure differential between the uphole portion of the casing conduit and the subterranean formation exceeding a threshold pressure differential), thereby permitting stimulant fluid 62 to flow through sleeve port 76 and into subterranean formation 22, such as to stimulate and/or fracture the subterranean formation.

[0079] FIGS. 8-9 illustrate hydrocarbon well 30 as including only two motion-arresting structures 100 and a single hydraulically actuated sleeve 74. However, and as discussed herein with reference to FIGS. 4-7, hydrocarbon well 30 may include any suitable number of motion-arresting structures 100 and/or hydraulically actuated sleeves 74 and the above-described process may be repeated any suitable number of times to stimulate and/or fracture any suitable number of regions, zones, and/or portions of subterranean formation 22.

[0080] FIG. 10 is a flowchart depicting methods according to the present disclosure of restricting fluid flow between an uphole portion of a casing conduit and a downhole portion of the casing conduit. The casing conduit is partially defined by a casing string that extends within a wellbore that is defined within a subterranean formation. In addition, the casing string includes, contains, and/or is operatively attached to a plurality of motion-arresting structures that are spaced apart from one another along a (longitudinal) length of the casing string. The motion-arresting structures project from an inner surface of the casing string to define a plurality of reduced-area regions of the casing conduit.

[0081] Methods 200 may include locating an autonomous sealing device within the casing conduit at 205 and/or supplying a stimulant fluid to the casing conduit at 210. Methods 200 include conveying the autonomous sealing device within the casing conduit at 215 and may include detecting a variable associated with the autonomous sealing device at 220. Methods 200 further include determining that the autonomous sealing device is located within a target portion of the casing conduit at 225, expanding the autonomous sealing device at 230, retaining the autonomous sealing device on a selected motion-arresting structure at 235, and restricting fluid flow between an uphole portion of the casing conduit and a downhole portion of the casing conduit at 240. Methods 200 further may include stimulating the subterranean formation at 245, repeating the methods at 250, removing the autonomous sealing device from the casing conduit at 255, and/or producing a reservoir fluid from the subterranean formation at 260.

[0082] Locating the autonomous sealing device within the casing conduit at 205 may include locating any suitable autonomous sealing device, such as autonomous sealing device 150 of FIGS. 1-9, within the casing conduit in any suitable manner. As an illustrative, non-exclusive example, the locating at 205 may include placing the autonomous sealing device within the casing conduit and/or lubricating the autonomous sealing device into the casing conduit. Additionally or alternatively, the locating at 205 also may include transferring the autonomous sealing device from a surface region into the casing conduit.

[0083] Supplying the stimulant fluid to the casing conduit at 210 may include supplying any suitable stimulant fluid, illustrative, non-exclusive examples of which are disclosed herein, to the casing conduit. This may include pumping the stimulant fluid into the casing conduit. It is within the scope of the present disclosure that, when methods 200 include the supplying at 210, the supplying at 210 may include (at least substantially) continuously supplying the stimulant fluid to the casing conduit during a remainder of methods 200 and/or supplying the stimulant fluid to the casing conduit at least the conveying at 215, and the determining at 225, the expanding at 230, the retaining at 235, and/or the restricting at 240.

[0084] Conveying the autonomous sealing device within the casing conduit at 215 may include conveying while the autonomous sealing device is in a contracted configuration and/or conveying the autonomous sealing device through at least a portion of the plurality of reduced-area regions. As an illustrative, non-exclusive example, the conveying at 215 may include hydraulically conveying, such as by flowing the autonomous sealing device with the stimulant fluid that is provided during the supplying at 210. As another illustrative, non-exclusive example, the conveying at 215 also may include mechanically conveying, such as by tractoring the autonomous sealing device into, along, and/or through the casing conduit. As yet another illustrative, non-exclusive example, the conveying at 215 may include conveying the autonomous sealing device along the (longitudinal) length of the casing string under the influence of gravity.

[0085] It is within the scope of the present disclosure that the conveying at 215 may include conveying at any suitable speed and/or velocity, including relatively high speeds and/or velocities. As illustrative, non-exclusive examples, the conveying at 215 may include conveying at a speed and/or velocity of at least 2 meters per second (m/s), at least 4 m/s, at least 6 m/s, at least 8 m/s, at least 10 m/s, at least 12 m/s, at least 14
Detecting the variable associated with the autonomous sealing device at 220 may include detecting any suitable variable that may be associated with the autonomous sealing device. This may include detecting with any suitable detector and/or utilizing any suitable autonomous controller, such as autonomous controller 160 of FIG. 1. Illustrative, non-exclusive examples of the variable associated with the autonomous sealing device are disclosed herein. When methods 200 include the detecting at 220, it is within the scope of the present disclosure that the determining at 225 may be based, at least in part, on the detecting at 220 and/or based, at least in part, on the variable associated with the autonomous sealing device.

Determining that the autonomous sealing device is located within the target portion of the casing conduit at 225 may include determining in any suitable manner. As an illustrative, non-exclusive example, the determining at 225 may include determining that the variable associated with the autonomous sealing device is equal to, is greater than, and/or is less than a threshold value. As more specific but still illustrative, non-exclusive examples, the determining at 225 may include determining that the autonomous sealing device has reached a target depth within the subterranean formation, determining that the autonomous sealing device has traversed a target (longitudinal) length of the casing conduit and/or of the casing string, determining that the autonomous sealing device has been conveyed through a target number of reduced-area regions, and/or determining that the autonomous sealing device has been conveyed past a target number of casing collars (such as casing collar 41 of FIGS. 1-9).

Expanding the autonomous sealing device at 230 may include expanding the autonomous sealing device based, at least in part, on the determining at 225 and/or expanding the autonomous sealing device responsive to the determining at 225. The expanding at 230 may include automatically expanding, such as by expanding without the autonomous sealing device receiving an external input.

It is within the scope of the present disclosure that the expanding at 230 may include completely expanding prior to the retaining at 235. However, it is also within the scope of the present disclosure that the expanding at 230 may include partially expanding prior to the retaining at 235, with complete expansion to the expanded state being accomplished subsequent to the retaining at 235.

The retaining at 235 may be initiated such that the autonomous sealing device is retained on the selected motion-arresting structure. As such, initiation of the expanding at 235 may be based, at least in part, on the velocity and/or acceleration of the autonomous sealing device within the casing conduit and/or upon a distance between the autonomous sealing device and the selected motion-arresting structure.

It is within the scope of the present disclosure that the expanding at 235 may be accomplished in any suitable manner. As an illustrative, non-exclusive example, the expanding at 235 may include triggering an expansion mechanism, such as expansion mechanism 158 of FIG. 1. Illustrative, non-exclusive examples of which are disclosed herein.

Retaining the autonomous sealing device on the selected motion-arresting structure at 235 may include retaining the autonomous sealing device on any suitable motion-arresting structure, such as motion-arresting structure 100 of FIGS. 1-9. As an illustrative, non-exclusive example, and subsequent to the expanding at 230, the autonomous sealing device may no longer be sized to pass through the plurality of reduced area regions, causing the autonomous sealing device to be retained on the selected motion-arresting structure. As another illustrative, non-exclusive example, the retaining at 235 may include causing a motion of the autonomous sealing device along the (longitudinal) length of the casing string. As an additional illustrative, non-exclusive example, the retaining at 235 may include mechanically, physically, and/or directly contacting the autonomous sealing device with the selected motion-arresting structure to retain the autonomous sealing device on the selected motion-arresting structure.

Restricting fluid flow between the upheole portion of the casing conduit and the downhole portion of the casing conduit at 240 may include restricting, blocking, limiting, occluding, and/or eliminating the fluid flow with the autonomous sealing device. This may include forming a fluid seal between the autonomous sealing device and the selected motion-arresting structure and/or forming a fluid seal between the autonomous sealing device and the inner surface of the casing string. As an illustrative, non-exclusive example, the restricting at 240 may include fluidly isolating the upheole portion of the casing conduit from the downhole portion of the casing conduit. This may include resisting fluid flow from the upheole portion of the casing conduit into the downhole portion of the casing conduit and/or resisting fluid flow from the downhole portion of the casing conduit into the upheole portion of the casing conduit.

Stimulating the subterranean formation at 245 may include stimulating the subterranean formation in any suitable manner. As illustrative, non-exclusive examples, the stimulating may include fracturing the subterranean formation and/or acid treating the subterranean formation. This may include supplying the stimulant fluid to the subterranean formation and/or acid treating the subterranean formation, and it is within the scope of the present disclosure that the stimulant fluid may be supplied to the subterranean formation subsequent to the retaining at 235, responsive to the retaining at 235, and/or responsive to a pressure within the casing conduit exceeding a threshold stimulating pressure.

As an illustrative, non-exclusive example, the stimulating at 245 may include translating a sliding sleeve at 246. This may include opening an injection conduit, such as injection conduit 132 of FIGS. 1-2 and 4-5, that is associated with the sliding sleeve, such as sliding sleeve 130 of FIGS. 1-2 and 4-5, to establish fluid communication, via the injection port, between the casing conduit and the subterranean formation. Additionally or alternatively, this also may include opening a sleeve port, such as sleeve port 76 of FIGS. 1 and 8-9, that is associated with a hydraulically actuated sleeve, such as hydraulically actuated sleeve 74 of FIGS. 1 and 8-9.

As yet another illustrative, non-exclusive example, the stimulating at 245 also may include perforating the casing string at 247. As an illustrative, non-exclusive example, the autonomous sealing device may be operatively attached to and/or may include a perforation device, such as perforation device 170 of FIGS. 1 and 5-6, and the perforating at 247 may include creating a perforation within the casing string to establish fluid communication, via the perforation, between the casing conduit and the subterranean formation.

Repeating the methods at 250 may include repeating any suitable portion of methods 200. As an illustrative, non-exclusive example, the autonomous sealing device may be a
first autonomous sealing device, the selected motion-arresting structure may be a first selected motion-arresting structure, the downhole portion of the casing conduit may be a first downhole portion of the casing conduit, and the uphole portion of the casing conduit may be a first uphole portion of the casing conduit. Under these conditions, the repeating at 250 may include repeating at least the conveying at 215, the determining at 225, the expanding at 230, the retaining at 235, and the restricting at 240 to retain a second (or subsequent) autonomous sealing device on a second (or subsequent) selected motion-arresting structure that is uphole from the first motion-arresting structure and to restrict fluid flow between a second (or subsequent) uphole portion of the casing conduit and a second (or subsequent) downhole portion of the casing conduit.

Additionally, the stimulating at 245 may include stimulating a first region of the subterranean formation and the repeating at 250 may include repeating the stimulating at 245 to stimulate a second (or subsequent) region of the subterranean formation that is uphole from the first region of the subterranean formation.

It is within the scope of the present disclosure that autonomous sealing devices and motion-arresting structures according to the present disclosure may be utilized with and/or within any suitable systems and/or methods. As illustrative, non-exclusive examples, hydrocarbon wells 30 according to the present disclosure further may include perforating a casing string with the perforation gun, chemically treating any suitable portion of hydrocarbon well 30 and/or of subsurface region 20, and/or collecting and/or recording any suitable data and/or process parameter that is related to hydrocarbon well 30 and/or to subsurface region 20. Furthermore, such methods may do so in conjunction with and/or independent of the utilization of the specific configuring and/or locating of the motion-arresting structures.

In the present disclosure, several of the illustrative, non-exclusive examples have been discussed and/or presented in the context of flow diagrams, or flow charts, in which the methods are shown and described as a series of blocks, or steps. Unless specifically set forth in the accompanying description, it is within the scope of the present disclosure that the order of the blocks may vary from the illustrated order in the flow diagrams, including with two or more of the blocks (or steps) occurring in a different order and/or concurrently. It is also within the scope of the present disclosure that the blocks, or steps, may be implemented as logic, which also may be described as implementing the blocks, or steps, as logic. In some applications, the blocks, or steps, may represent expressions and/or actions to be performed by functionally equivalent circuits or other logic devices. The illustrated blocks may, but are not required to, represent executable instructions that cause a computer, processor, and/or other logic device to respond, to perform an action, to change states, to generate an output or display, and/or to make decisions.

As used herein, the term “and/or” placed between a first entity and a second entity means one of (1) the first entity, (2) the second entity, and (3) the first entity and the second entity. Multiple entities listed with “and/or” should be construed in the same manner, i.e., “one or more” of the entities so conjoined. Other entities may optionally be present other than the entities specifically identified by the “and/or” clause, whether related or unrelated to those entities specifically identified. Thus, as a non-limiting example, a reference to “A and/or B,” when used in conjunction with open-ended language such as “comprising” may refer, in one embodiment, to A only (optionally including entities other than B); in another embodiment, to B only (optionally including entities other than A); in yet another embodiment, to both A and B (optionally including other entities). These entities may refer to elements, actions, structures, steps, operations, values, and the like.

As used herein, the phrase “at least one,” in reference to a list of one or more entities should be understood to mean at least one entity selected from any one or more of the entity in the list of entities, but not necessarily including at least one of each and every entity specifically listed within the list of entities and not excluding any combinations of entities in the list of entities. This definition also allows that entities may optionally be present other than the entities specifically identified within the list of entities to which the phrase “at least one” refers, whether related or unrelated to those entities.
specifically identified. Thus, as a non-limiting example, “at least one of A and B” (or, equivalently, “at least one of A or B,” or, equivalently “at least one of A and/or B”) may refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including entities other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including entities other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other entities). In other words, the phrases “at least one,” “one or more,” and “and/or” are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions “at least one of A, B, and C,” “at least one of A, B, or C,” “one or more of A, B, and C,” “one or more of A, B, or C” and “A, B, and/or C” may mean A alone, B alone, C alone, A and B together, A and C together, B and C together, A, B, and C together, and optionally any of the above in combination with at least one other entity.

0106 In the event that any patents, patent applications, or other references are incorporated by reference herein and (1) define a term in a manner that is inconsistent with and/or (2) are otherwise inconsistent with, either the non-incorporated portion of the present disclosure or any of the other incorporated references, the non-incorporated portion of the present disclosure shall control, and the term or incorporated disclosure therein shall only control with respect to the reference in which the term is defined and/or the incorporated disclosure was present originally.

0107 As used herein the terms “adapted” and “configured” mean that the element, component, or other subject matter is designed and/or intended to perform a given function. Thus, the use of the terms “adapted” and “configured” should not be construed to mean that a given element, component, or other subject matter is simply “capable of” performing a given function but that the element, component, and/or other subject matter is specifically selected, created, implemented, utilized, programmed, and/or designed for the purpose of performing the function. It is also within the scope of the present disclosure that elements, components, and/or other recited subject matter that is recited as being adapted to perform a particular function may additionally or alternatively be described as being configured to perform that function, and vice versa.

INDUSTRIAL APPLICABILITY

0108 The systems and methods disclosed herein are applicable to the oil and gas industry.

0109 It is believed that the disclosure set forth above encompasses multiple distinct inventions with independent utility. While each of these inventions has been disclosed in its preferred form, the specific embodiments thereof as disclosed and illustrated herein are not to be considered in a limiting sense as numerous variations are possible. The subject matter of the inventions includes all novel and non-obvious combinations and subcombinations of the various elements, features, functions and/or properties disclosed herein. Similarly, where the claims recite “a” or “a first” element or the equivalent thereof, such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements.

1. A hydrocarbon well, comprising:
   a wellbore that extends within a subterranean formation;
   a casing string that extends within the wellbore and has an inner surface, which defines a portion of a casing conduit;
   a plurality of motion-arresting structures that are spaced apart from one another along a portion of a longitudinal length of the casing string, wherein the plurality of motion-arresting structures projects from the inner surface of the casing string to define a plurality of reduced-area regions of the casing conduit; and
   an autonomous sealing device that defines a contracted configuration and an expanded configuration, wherein the autonomous sealing device:
   (i) is sized to flow through the plurality of reduced-area regions when in the contracted configuration;
   (ii) is sized to be retained on a selected motion-arresting structure of the plurality of motion-arresting structures upon transitioning to the expanded configuration; and
   (iii) restricts fluid flow between an uphole portion of the casing conduit and a downhole portion of the casing conduit upon being retained on the selected motion-arresting structure.

2. The well of claim 1, wherein the autonomous sealing device is programmed to transition to the expanded configuration responsive to being located within a target portion of the casing conduit.

3. The well of claim 1, wherein the autonomous sealing device is not operatively attached to any of a wireline, a working line, and tubing.

4. The well of claim 1, wherein the autonomous sealing device is configured to form a fluid seal with the selected motion-arresting structure to restrict the fluid flow when the autonomous sealing device is in the expanded configuration.

5. The well of claim 4, wherein the selected motion-arresting structure defines a sealing surface that is sized to form the fluid seal with the autonomous sealing device.

6. The well of claim 1, wherein the autonomous sealing device is configured to form a fluid seal with the inner surface of the casing string to restrict the fluid flow when the autonomous sealing device is in the expanded configuration.

7. The well of claim 1, wherein the autonomous sealing device includes an expansion mechanism that is configured to transition the autonomous sealing device to the expanded configuration.

8. The well of claim 7, wherein the expansion mechanism includes at least one of an explosive charge, a mechanical actuator, an electric actuator, a hydraulic actuator, a chemical reaction, and a material that swells upon contact with a wellbore fluid.

9. The well of claim 1, wherein the autonomous sealing device is further configured to transition from the expanded configuration to a retracted configuration, wherein, in the retracted configuration, the autonomous sealing device is sized to flow through the plurality of reduced-area regions and permits fluid flow between the uphole portion of the casing conduit and the downhole portion of the casing conduit.

10. The well of claim 1, wherein, subsequent to transitioning to the expanded configuration, the autonomous sealing device is further configured to at least one of break apart and dissolve to permit fluid flow between the uphole portion of the casing conduit and the downhole portion of the casing conduit.
11. The well of claim 1, wherein the autonomous sealing device is further configured to release a supplemental material into the casing conduit subsequent to transitioning to the expanded configuration.

12. The well of claim 11, wherein the well includes a plurality of autonomous sealing devices, and further wherein each of the plurality of autonomous sealing devices includes a unique tracer material that comprises the supplemental material.

13. The well of claim 1, wherein the autonomous sealing device at least one of includes and is operatively attached to a perforation device that is configured to create a perforation within the casing string.

14. The well of claim 1, wherein the plurality of motion-arresting structures include a plurality of isolation rings that are operatively attached to the inner surface of the casing string, wherein the plurality of isolation rings define a plurality of similarly sized reduced-area regions.

15. The well of claim 1, wherein the plurality of motion-arresting structures includes a plurality of stops that project from the inner surface of the casing string.

16. The well of claim 1, wherein each of the plurality of reduced-area regions of the casing conduit defines a respective transverse cross-sectional area that is at least 50% and less than 99% of a transverse cross-sectional area of the portion of the casing conduit that is defined by the inner surface of the casing string.

17. The well of claim 1, wherein the plurality of motion-arresting structures includes a plurality of sliding sleeves, wherein each of the plurality of sliding sleeves is associated with a respective injection port that extends between the casing conduit and the wellbore, wherein each of the plurality of sliding sleeves is configured to selectively restrict fluid flow through the respective injection port prior to the autonomous sealing device being retained thereon, and further wherein each of the plurality of sliding sleeves is configured to selectively permit fluid flow through the respective injection port responsive to the autonomous sealing device being retained thereon.

18. The well of claim 1, wherein the well further includes a hydraulically actuated sleeve that is located upstream from the selected motion-arresting structure, wherein the hydraulically actuated sleeve is associated with a sleeve port that extends between the casing conduit and the wellbore, wherein the hydraulically actuated sleeve is configured to selectively transition from a closed configuration, wherein the hydraulically actuated sleeve resists a fluid flow through the sleeve port, and an open configuration, wherein the hydraulically actuated sleeve permits fluid flow through the sleeve port responsive to a pressure differential between a portion of the casing conduit that is proximal to the hydraulically actuated sleeve and a portion of the subterranean formation that is proximal to the hydraulically actuated sleeve exceeding a threshold sleeve actuation pressure.

19. The well of claim 1, wherein the autonomous sealing device includes an autonomous controller that is programmed to control the operation of the autonomous sealing device.

20. The well of claim 19, wherein the autonomous controller is programmed to determine a location of the autonomous sealing device within the casing conduit and to transition the autonomous sealing device to the expanded configuration based, at least in part, on the determined location.

21. A method of restricting fluid flow between an upstream portion of a casing conduit and a downstream portion of the casing conduit, wherein the casing conduit is partially defined by a casing string that extends within a wellbore that is defined within a subterranean formation, and further wherein the casing string includes a plurality of motion-arresting structures, wherein the plurality of motion-arresting structures is spaced apart from one another along a portion of a longitudinal length of the casing string and project from an inner surface of the casing string to define a plurality of reduced-area regions of the casing conduit, the method comprising:

- conveying an autonomous sealing device through the casing conduit, wherein the conveying includes conveying the autonomous sealing device through a portion of the plurality of reduced-area regions while the autonomous sealing device is in a contracted configuration;
- determining that the autonomous sealing device is located within a target portion of the casing conduit;
- responsive to the determining, expanding the autonomous sealing device to an expanded configuration;
- retaining the autonomous sealing device on a selected motion-arresting structure of the plurality of motion-arresting structures; and
- restricting fluid flow between an upstream portion of the casing conduit and a downstream portion of the casing conduit with the autonomous sealing device.

22. The method of claim 21, wherein the method further includes supplying a stimulant fluid to the casing conduit, and further wherein the conveying includes flowing the autonomous sealing device within the stimulant fluid.

23. The method of claim 21, wherein the method further includes detecting a variable associated with the autonomous sealing device.

24. The method of claim 23, wherein the variable associated with the autonomous sealing device includes at least one of a speed of the autonomous sealing device within the casing conduit, an acceleration of the autonomous sealing device within the casing conduit, a deceleration of the autonomous sealing device within the casing conduit, a pressure proximal to the autonomous sealing device within the casing conduit, a location of the autonomous sealing device along the length of the casing string, a depth of the autonomous sealing device below a ground surface, and a number of casing collars that the autonomous sealing device has traveled past while located within the casing conduit.

25. The method of claim 23, wherein the determining is based, at least in part, on the variable associated with the autonomous sealing device.

26. The method of claim 21, wherein the expanding includes automatically expanding without receiving an external input by the autonomous sealing device.

27. The method of claim 21, wherein the restricting includes forming a fluid seal with the selected motion-arresting structure.

28. The method of claim 21, wherein the restricting includes forming a fluid seal with the inner surface of the casing string.

29. The method of claim 21, wherein the method further includes removing the autonomous sealing device from the casing conduit.

30. The method of claim 29, wherein the removing includes transitioning the autonomous sealing device from the expanded configuration to a retracted configuration to permit the removing, wherein, in the retracted configuration,
the autonomous sealing device is sized to be conveyed through the plurality of reduced-area regions.

31. The method of claim 29, wherein the removing includes at least one of shrinking the autonomous sealing device, retracting the autonomous sealing device, breaking apart the autonomous sealing device, and dissolving the autonomous sealing device to permit the removing.

32. The method of claim 21, wherein the method further includes stimulating the subterranean formation.

33. The method of claim 32, wherein the stimulating includes supplying a stimulant fluid to the subterranean formation.

34. The method of claim 33, wherein the plurality of motion-arresting structures includes a plurality of sliding sleeves, wherein each of the plurality of sliding sleeves is associated with a respective injection port that extends between the casing conduit and the wellbore, wherein each of the plurality of sliding sleeves is configured to selectively restrict fluid flow through the respective injection port prior to the autonomous sealing device being retained thereon, wherein each of the plurality of sliding sleeves is configured to selectively permit fluid flow through the respective injection port responsive to the autonomous sealing device being retained thereon, and further wherein the supplying includes translating a sliding sleeve that is associated with the selected motion-arresting structure to permit the fluid flow through the injection port that is associated with the selected motion-arresting structure.

35. The method of claim 33, wherein the casing string includes a hydraulically actuated sleeve that is located upstream from the selected motion-arresting structure, wherein the hydraulically actuated sleeve is associated with a sleeve port that extends between the casing conduit and the wellbore, wherein the hydraulically actuated sleeve is constructed to selectively transition from a closed configuration, wherein the hydraulically actuated sleeve resists a fluid flow through the sleeve port, and an open configuration, wherein the hydraulically actuated sleeve permits a fluid flow through the sleeve port, responsive to a pressure differential between a portion of the casing conduit that is proximal to the hydraulically actuated sleeve and a portion of the subterranean formation that is proximal to the hydraulically actuated sleeve exceeding a threshold sleeve actuation pressure, and further wherein the supplying includes transitioning the hydraulically actuated sleeve from the closed configuration to the open configuration to permit the fluid flow through the sleeve port.

36. The method of claim 33, wherein the autonomous sealing device is operatively attached to a perforation device, and further wherein the stimulating includes perforating the casing string to permit the supplying.

37. The method of claim 21, wherein the autonomous sealing device is a first autonomous sealing device, wherein the selected motion-arresting structure is a first selected motion-arresting structure, wherein the downhole portion of the casing conduit is a first downhole portion of the casing conduit, wherein the uphole portion of the casing conduit is a first uphole portion of the casing conduit, and further wherein the method includes repeating at least the conveying, the determining, the expanding, the retaining, and the restricting to retain a second, or subsequent, autonomous sealing device on a second, or subsequent, selected motion-arresting structure that is uphole from the first motion-arresting structure and to restrict fluid flow between a second, or subsequent, uphole portion of the casing conduit and a second, or subsequent, downhole portion of the casing conduit.

38. The method of claim 21, wherein the method further includes producing a reservoir fluid from the subterranean formation.

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