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PLUGGING ASSEMBLIES FOR PLUGGING CASED WELLBORES

Abstract

A toolstring for plugging and perforating a wellbore includes a perforating gun extending between an uphole end and a downhole end longitudinally opposed to the uphole end, a plugging assembly extending between an uphole end and a downhole end longitudinally opposed to the uphole end of the plugging assembly, the plug assembly including a setting tool physically attached directly to the perforating gun, the setting tool including an elongate housing extending between an uphole end and a downhole end opposite the uphole end of the housing, an open passageway extending from the uphole end to the downhole end of the housing, and wherein the setting tool further includes an elongate mandrel positioned in the open passageway and having an uphole end and a downhole end opposite the uphole end of the mandrel, and a combustion chamber located within the elongate housing for receiving an energetic charge.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] The present application is a continuation of U.S. non-provisional patent application Ser. No. 18/211,508 filed Jun. 19, 2023, entitled “Plugging Assemblies for Plugging Cased Wellbores”, which is a continuation-in-part of U.S. non-provisional patent application Ser. No. 17/687,389 filed Mar. 4, 2022, entitled “Plugging Assemblies for Plugging Cased Wellbores”, now U.S. Pat. No. 11,708,731, issued Jul. 25, 2023, which claims benefit of U.S. provisional patent application No. 63/156,473 filed Mar. 4, 2021, entitled “Compact Setting Tool for a Downhole Plug,” all of which are incorporated herein by reference in their entirety for all purposes.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT [0002] Not applicable.
BACKGROUND
[0003] Subterranean wellbores may be drilled into hydrocarbon bearing, earthen formations in the interest of producing hydrocarbons from the wellbore. During completion operations for subterranean wellbores, it is conventional practice to install a tubular casing string in the wellbore and then perforate the casing string with perforating guns along the hydrocarbon bearing formation to provide many paths for formation fluids (e.g., hydrocarbons) to flow into a central passage of the casing string.
[0004] Typically, for a wellbore drilled for a long horizontal run along the hydrocarbon bearing formation, the wellbore is planned with many production zones along a horizontal run of more than a mile through what is sometimes referred to as a “tight” formation where the hydrocarbons available for production do not flow very freely. To ensure that each perforation in the casing string leads to a productive area within the hydrocarbon bearing formation, the perforations are subject to a hydraulic fracturing or “fracking” process where high pressure fluids and proppant are pumped into the casing string to enlarge and extend the fractures created by the perforation guns and to create deeper and more extensive paths to dramatically increase contact area therein and thereby productivity.
[0005] To isolate the production zones from each other, plugs are typically deployed by the fracking system on a wireline-deployed toolstring that also includes a number of perforating guns for blasting the perforations in the next adjacent production zone. It may be understood however that other devices, such as a packer, may also be used to create the desired isolation. Conventionally, plugs are set within the wellbore from the bottom end of the wireline toolstring where a standard format setting tool is attached to an adapter kit that is especially suited for the selected plug. The setting tool is powered by an energetic charge to axially compress the plug into a wider and axially shorter shape that drives slips into the casing to bite and lock the plug in place and seal the casing at the selected location in the wellbore.
[0006] It should be understood that toolstrings deployed using wireline systems have a limited

length. The toolstring is typically inserted into the wellbore by a wireline through which communication with the various tools allow an operator of the wireline system to know where the toolstring is positioned within the wellbore and to adjust its downhole position and orientation. Through the wireline, the actuation of the setting tool is accomplished by an electrical signal transmitted from the surface, through the wireline, to the toolstring. Following the actuation of the setting tool to set the plug downhole, the various perforating guns are subsequently fired together or in a series where the toolstring may be moved to preferred locations within the wellbore such that the perforations formed by the perforating guns may be located in an arrangement preferred by the operator of the well.

[0007] Typically, the length of the toolstring is limited by a wireline lubricator of the wireline system which is a pipe-like device positioned at the surface over the wellbore. Typically, wireline lubricators are 40 feet (ft) to 60 ft tall with valving and a bottom sealing device, and valving and a top sealing device. The toolstring must fit fully inside of the wireline lubricator pipe and therefore, the length of the toolstring is limited by the space provided between the top and bottom sealing devices. Moreover, the toolstring must be lifted vertically into the wireline lubricator which itself has to be lifted above the vertically oriented toolstring. Thus, the length of the toolstring is limited by a vertical lifting height of the crane used to lift the wireline lubricator and toolstring up into the wireline lubricator. As an example, if a wireline lubricator is 60 ft in length and the toolstring is 50 ft in length, then the crane will be required to lift an uphole end of the toolstring to a height of more than 110 ft in order to insert the toolstring into the wireline lubricator.

[0008] Given the limitations placed on the length of the toolstring, every tool in the toolstring must justify its existence in the string with low priority tools potentially being left out. Further, the length of each individual tool of the toolstring becomes relevant under this consideration including, for example, plugs, adapter kits and setting tools. Improvements which reduce the length of individual tools and thereby minimize the length of the toolstring may allow for the inclusion of other tools that would not have otherwise fit. For example, the added tools could create more perforations in the casing for more flow paths or may reduce the number of trips required for setting up the wellbore for production of hydrocarbons.

[0009] Considering the limited length of each toolstring and having to perform a fracking process on the well between the run of each toolstring, the process of completing the wellbore and bringing into production can take several days. One big consideration is the cost per hour for these operations and minimizing efforts and personnel required during this aspect of the completion process. Reducing on site workload and reducing complexity will always be highly desired by operating companies and their contractors.

SUMMARY OF THE DISCLOSURE

[0010] An embodiment of a toolstring for plugging and perforating a wellbore including casing and extending through a subterranean formation comprises a perforating gun extending between an uphole end and a downhole end longitudinally opposed to the uphole end; and a plugging assembly extending between an uphole end and a downhole end longitudinally opposed to the uphole end of the plugging assembly, the plugging assembly comprising a setting tool physically attached directly to the perforating gun, the setting tool comprising an elongate housing extending between an uphole end and a downhole end opposite the uphole end of the housing, an open passageway extending from the uphole end to the downhole end of the housing, and wherein the setting tool further includes an elongate mandrel positioned in the open passageway and having an uphole end and a downhole end opposite the uphole end of the mandrel, and a combustion chamber located within the elongate housing for receiving an energetic charge; and a plug attached to the setting tool, the plug comprising an elongate core with an uphole end and a downhole end opposite the uphole end of the core, a sealing element disposed fully around the core to seal against the casing, an anchoring system for anchoring the plug to the casing in a fixed position, a compression fitting disposed around the core at or near the uphole end of the core, a nose at the downhole end of the core, wherein the sealing element and the anchoring system have an initial configuration having an outer maximum run in diameter, and an expanded configuration having an outer maximum expanded diameter that is greater than the maximum run-in diameter. In some embodiments, the toolstring further comprises an adapter kit physically attached directly to the setting tool and the plug physically attached directly to the adapter kit. In some embodiments, the plug is physically attached directly to the setting tool. In certain embodiments, a downhole end of the perforating gun is mechanically connected to an uphole end of the setting tool. In certain embodiments, the perforating gun comprises an outer housing, and a downhole end of the housing of the perforating gun is mechanically connected to the uphole end of the mandrel of the setting tool. In some embodiments, the perforating gun comprises an outer housing, and a downhole end of the housing of the perforating gun is threadably connected to the uphole end of the mandrel of the setting tool. In some embodiments, the setting tool comprises a setting tool initiator contacting the energetic charge, the setting tool initiator configured to ignite the energetic charge to pressurize the combustion chamber in response to receiving a setting tool firing signal. In certain embodiments, the setting tool comprises a setting tool initiator received in an internal passage of the mandrel, the setting tool initiator configured to ignite the energetic charge to pressurize the combustion chamber in response to receiving a setting tool firing signal. In certain embodiments, the setting tool comprises a setting tool initiating cartridge comprising a cartridge chassis having an internal receptacle, a setting tool initiator, an electrical switch communicatively coupled to the setting tool initiator, wherein the setting tool initiator and electrical switch are each received in the internal receptacle of the cartridge chassis whereby the setting tool initiator and electrical switch axially overlap. In some embodiments, the setting tool initiating cartridge comprises a sacrificial electrical conductor electrically connected between the electrical switch and an uphole end of the toolstring, wherein a portion of the sacrificial electrical conductor is hydraulically exposed to a downhole end of the setting tool initiator so as to be severed electrically upon activation of the setting tool initiator. In some embodiments, the setting tool initiating cartridge comprises a setting tool pressure bulkhead connected to an uphole end of the cartridge chassis. In certain embodiments, the setting tool initiating cartridge comprises an insulating housing and an initiator electrical contact received in the insulating housing and connected to the setting tool initiator, wherein the insulating housing comprises one or more radial ports providing access to the initiator electrical contact. In certain embodiments, the setting tool initiating cartridge is received in and secured to an internal passage of the mandrel of the setting tool.

[0011] An embodiment of a toolstring for plugging and perforating a wellbore including casing and extending through a subterranean formation comprises a perforating gun extending between an uphole end and a downhole end longitudinally opposed to the uphole end; and a plugging assembly attached to the perforating gun and extending between an uphole end and a downhole end longitudinally opposed to the uphole end of the plugging assembly, the plugging assembly comprising a setting tool comprising an elongate housing extending between an uphole end and a downhole end opposite the uphole end of the housing, an open passageway extending from the uphole end to the downhole end of the housing, an elongate mandrel positioned in the open passageway and having an uphole end and a downhole end opposite the uphole end of the mandrel, a combustion chamber located within the elongate housing, an energetic charge located in an internal passage of the mandrel, and a setting tool initiator located in the internal passage of the mandrel and configured to ignite the energetic charge to pressurize the combustion chamber in response to receiving a setting tool firing signal; and a plug attached to the setting tool, the plug comprising an elongate core with an uphole end and a downhole end opposite the uphole end of the core, a sealing element disposed fully around the core to seal against the casing, an anchoring system for anchoring the plug to the casing in a fixed position, a compression fitting disposed around the core at or near the uphole end of the core, a nose at the downhole end of the core, wherein the sealing element and the anchoring system have an initial configuration having an outer maximum run in diameter, and an expanded configuration having an outer maximum expanded diameter that is greater than the maximum run-in diameter. In some embodiments, the setting tool initiator contacts the energetic charge. In some embodiments, the setting tool initiator comprises an electrical switch and an initiator communicatively coupled to the electrical switch. In certain embodiments, the electrical switch comprises a digitally addressable switch. In certain embodiments, the initiator is ballistically coupled to the energetic charge. In some embodiments, the energetic charge comprises an outer housing, a pair of primers located at opposing longitudinal end of the energetic charge, and energetic material contained within the outer housing of the energetic charge and located longitudinally between the pair of primers. In some embodiments, the setting tool initiator is ballistically coupled to one of the pair of primers of the energetic charge. In certain embodiments, the setting tool comprises a setting tool initiating cartridge comprising a cartridge chassis having an internal receptacle, the setting tool initiator, an electrical switch communicatively coupled to the setting tool initiator, wherein the setting tool initiator and electrical switch are each received in the internal receptacle of the cartridge chassis whereby the setting tool initiator and electrical switch axially overlap. In certain embodiments, the setting tool initiating cartridge comprises a sacrificial electrical conductor electrically connected between the electrical switch and an uphole end of the toolstring, wherein a portion of the sacrificial electrical conductor axially aligns with a downhole end of the setting tool initiator. In some embodiments, the setting tool initiating cartridge comprises a setting tool pressure bulkhead connected to an uphole end of the cartridge chassis. In some embodiments, the setting tool initiating cartridge comprises an insulating housing and an initiator electrical contact received in the insulating housing and connected to the setting tool initiator, wherein the insulating housing comprises one or more radial ports providing access to the initiator electrical contact.

[0012] An embodiment of a method for operating a toolstring for plugging and perforating a wellbore extending through a subterranean formation comprises (a) inserting an energetic charge into an internal passage of a setting tool of the toolstring; (b) ballistically coupling a setting tool initiator to the energetic charge, the setting tool initiator configured to ignite the energetic charge in response to receiving a setting tool firing signal; and (c) mechanically connecting a perforating gun of the toolstring directly to the setting tool. In certain embodiments, the internal passage of the setting tool comprises an internal passage of a mandrel of the setting tool, the mandrel being slidably coupled to an outer housing of the setting tool. In certain embodiments, (b) comprises inserting the setting tool initiator into the internal passage of the setting tool. In some embodiments, the internal passage of the setting tool comprises an internal passage of a mandrel of the setting tool, the mandrel being slidably coupled to an outer housing of the setting tool. In some embodiments, (c) comprises mechanically connecting a downhole end of the perforating gun directly to an uphole end of the setting tool. In certain embodiments, c) comprises mechanically connecting a downhole end of an outer housing of the perforating gun directly to an uphole end of a mandrel of the setting tool. In certain embodiments, the method further comprises (d) running the toolstring into the wellbore and setting a plug of the toolstring inside the wellbore; (e) pulling the toolstring from the wellbore following (d); (f) servicing the toolstring by replacing a setting tool initiating cartridge of the toolstring, the setting tool initiating cartridge comprising the setting tool initiator, with a new setting tool initiating cartridge including a new setting tool initiator whereby the new setting tool initiating cartridge is received in the internal passage of the setting tool; and (g) running the serviced toolstring into another wellbore following (f). In some embodiments, (f) comprises discarding the setting tool initiating cartridge replaced in the serviced setting tool by the new setting tool initiating cartridge. In some embodiments, the method further comprises (d) running the toolstring into the wellbore and setting a plug of the toolstring inside the wellbore; (e) activating the setting tool of the toolstring in the wellbore whereby the energetic charge is ignited by the setting tool initiator; (f) severing an electrical connection formed along a sacrificial electrical conductor of the setting tool in response to the activation of the setting tool; and (g) providing an electrically communicated indication at the surface of the severing of the electrical connection. In certain embodiments, the method further comprises (d) extending a probe of a measurement device through a radial port formed in an insulating housing of the setting tool to contact the probe with an initiator electrical contact of the setting tool received in the insulating housing whereby an electrical property of an electrical circuit of the setting tool is detected; and (e) comparing the detected electrical property with a predefined reference electrical property of the electrical circuit.

[0013] An embodiment of a toolstring assembly kit for assembly a toolstring used for plugging and perforating a well comprises a perforating gun; a thread protector attached to a bottom set of threads; a plug setting tool with an attached plug where the plug setting tool includes a top set of threads arranged to attach to the bottom set of threads of the perforating gun; and a second thread protector attached to the top set of threads of the plug setting tool; wherein the toolstring assembly kit is arranged such that the respective thread protectors may be removed from the bottom set of threads and the top set of threads to then screw the top set of threads and the bottom set of threads together.

[0014] An embodiment of a toolstring for plugging and perforating a wellbore including casing and extending through a subterranean formation comprising a perforating gun extending between an uphole end and a downhole end longitudinally opposed to the uphole end; and a plugging assembly extending between an uphole end and a downhole end longitudinally opposed to the uphole end of the plugging assembly, the plugging assembly comprising a setting tool coupled to the perforating gun, the setting tool comprising an elongate housing extending between an uphole end and a downhole end opposite the uphole end of the housing, an open passageway extending from the uphole end to the downhole end of the housing; an elongate mandrel positioned in the open passageway and having an uphole end and a downhole end opposite the uphole end of the mandrel, and an internal passage formed within the mandrel; a combustion chamber located within the elongate housing for receiving an energetic charge; and a setting tool initiator cartridge received in the internal passage of the mandrel, the setting tool initiator cartridge comprising a cartridge chassis defining an internal receptacle, a setting tool initiator received in the internal receptacle for igniting the energetic charge; a plug attached to the setting tool, the plug comprising an elongate core with an uphole end and a downhole end opposite the uphole end of the core, a sealing element disposed fully around the core to seal against the casing, an anchoring system for anchoring the plug to the casing in a fixed position, a compression fitting disposed around the core at or near the uphole end of the core, a nose at the downhole end of the core, wherein the sealing element and the anchoring system have an initial configuration having an outer maximum run in diameter, and an expanded configuration having an outer maximum expanded diameter that is greater than the maximum run-in diameter. In certain embodiments, the toolstring further comprises a setting tool adapter physically attached between the perforating gun and the setting tool whereby an uphole end of the setting tool adapter physically contacts the downhole end of the perforating gun and a downhole end of the setting tool adapter physically contacts the uphole end of the mandrel of the setting tool. In some embodiments, the setting tool adapter comprises a box-by-pin adapter having a box connector located at the uphole end of the setting tool adapter and a pin connector located at the downhole end of the setting tool adapter. In some embodiments, the setting tool adapter comprises an electrical switch electrically connected to the setting tool initiator and configured to activate the setting tool initiator in response to receiving a firing signal. In certain embodiments, the setting tool adapter furnishes a direct electrical connection between the perforating gun and the setting tool, and wherein the setting tool initiating cartridge comprises an electrical switch received in the internal receptacle of the cartridge chassis and electrically connected to the setting tool initiator whereby the electrical switch is configured to activate the setting tool initiator in response to receiving a firing signal.

[0015] An embodiment of a method for providing an ignition propellant driven plug into a well and plugging the well for perforating and fracking comprises (a) receiving a plug set assembly and a perforating gun to a site of the well; (b) arming the perforating gun for receiving a signal and detonating a shaped charge therein to create at least one perforation in the well; (c) arming the plug set assembly for receiving a signal and igniting the propellant for setting a plug in the well; (d) attaching the plug set assembly directly to the perforating gun via a single connection; (e) attaching the perforating gun and plug set assembly attached to one another as a toolstring to a wireline system; and (f) lifting and delivering the toolstring into the well by the wireline system.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] For a detailed description of exemplary embodiments of the disclosure, reference will now be made to the accompanying drawings in which:

[0017] FIG. **1** is an elevation view of a wellsite with a crane lifting a wireline lubricator with a toolstring suspended below about to be pulled into the wireline lubricator so that that after the lubricator is re-attached to the wellhead, the toolstring may be inserted into a wellbore;

[0018] FIG. **2** shows a conventional toolstring inserted into the well and progressing toward the bottom of the wellbore;

[0019] FIG. **3** shows the plug that was carried into the well by the toolstring now set in the casing and separated from the toolstring;

[0020] FIG. **4** shows a perspective view of a first prior art plug setting arrangement from U.S. Pat. No. 9,810,035 comprising a setting tool, an adapter kit and a plug;

[0021] FIG. **5** shows an elevation view partly in cross-section of a second prior art plug setting arrangement from U.S. Pat. No. 10,844,678 comprising a setting tool, an adapter kit and a plug;

[0022] FIG. **6** shows an elevation cross sectional view of a first embodiment of a plugging assembly including a compact setting tool directly attached to a plug with the plug in a run-in configuration;

[0023] FIG. **7** shows an elevation cross sectional view of the setting tool of FIG. **6** without the plug attached, but showing the compact setting tool in a mid-stroke position with a mandrel of the setting tool roughly half-way between an unstroked position and a stroked position;

[0024] FIG. **8** shows an elevation cross-sectional view of the setting tool of FIG. **6** with the mandrel of the setting tool in stroked position;

[0025] FIG. **9** shows an elevation cross-sectional view of the plug of FIG. **6** where the plug is in a set configuration;

[0026] FIG. **10** shows an elevation cross-sectional view of another embodiment of a plugging assembly including a setting tool and a plug, where the plug is shown in a run-in configuration;

[0027] FIG. **11** shows an elevation cross-sectional view of the setting tool of FIG. **10** with a mandrel of the setting tool in an unstroked position;

[0028] FIG. **12** shows a cross-sectional elevation view of the setting tool of FIG. **6** with the mandrel of the setting tool in a stroked position;

[0029] FIG. **13** shows an elevation cross-sectional view of another embodiment of a plugging assembly including a setting tool and a plug, where the plug is shown in a run-in configuration;

[0030] FIG. **14** shows an elevation cross-sectional view of a prior art toolstring;

[0031] FIG. **15** shows an elevation cross-sectional view of an embodiment of a toolstring including a perforating gun, a setting tool, and a plug in a run-in configuration;

[0032] FIG. **16** shows an elevation cross-sectional view of the perforating gun and setting tool of FIG. **15** in an activated configuration;

[0033] FIG. **17** shows an elevation cross-sectional view of the plug of FIG. **15** in a set configuration in a wellbore;

[0034] FIG. **18** shows an elevation cross-sectional view of an embodiment of an assembly kit including a perforating gun and a setting tool;

[0035] FIG. **19** shows a perspective view of an embodiment of a setting tool initiating cartridge;

[0036] FIG. **20** shows a side cross-sectional view of the setting tool initiating cartridge of FIG. **19**;

[0037] FIG. **21** shows a side cross-sectional view of another embodiment of a toolstring; and

[0038] FIG. **22** shows a side cross-sectional view of another embodiment of a toolstring.

DETAILED DESCRIPTION

[0039] The following discussion is directed to various exemplary embodiments. However, one skilled in the art will understand that the examples disclosed herein have broad application, and that the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to suggest that the scope of the disclosure, including the claims, is limited to that embodiment. Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. The drawing figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

[0040] In the following discussion and in the claims, the terms “including” and “comprising” are used in an open-ended fashion, and thus should be interpreted to mean “including, but not limited to . . . ” Also, the term “couple” or “couples” is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect connection via other devices, components, and connections. In addition, as used herein, the terms “axial” and “axially” generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms “radial” and “radially” generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a radial distance means a distance measured perpendicular to the central axis. Any reference to up or down in the description and the claims is made for purposes of clarity, with “up”, “upper”, “upwardly”, “uphole”, or “upstream” meaning toward the surface of the borehole and with “down”, “lower”, “downwardly”, “downhole”, or “downstream” meaning toward the terminal end of the borehole, regardless of the borehole orientation. Further, the term “fluid,” as used herein, is intended to encompass both fluids and gasses.

[0041] Referring now to FIG. **1**, a wireline system **5** is shown for deploying a toolstring **30** into a cased wellbore **10** in which a casing string or casing string **15** is installed. The view shown in FIG. **1** is near the surface **7** with the cased wellbore **10** extending far into the earth and potentially into an extended generally horizontal run through a hydrocarbon bearing formation. A surface rig or crane **11** of the wireline system **5** is positioned on a pad **13** adjacent the cased wellbore **10** for lifting a wireline lubricator **20** off the top of the valve tree **12** in preparation for lifting a toolstring **30** up into the lubricator **20** to begin the process of deploying the toolstring **30** into the wellbore. Wireline **28** of the wireline system **5** is fed through the wireline lubricator **20** to pull the toolstring **30** up into the wireline lubricator **20** whereupon the wireline lubricator **20** is then attached onto the top of a valve tree **12** whereby a bottom coupling **21** of lubricator **20** sealingly connects to a coupling **14** at the top of the valve tree **12**.

[0042] In the configuration shown in FIG. **1**, the cased wellbore **10** is sealed by one or more valves of the valve tree **12**. As is well known, pressure within cased wellbore **10** must be maintained in a controlled state at all times so that before any valve is opened, others are closed in a manner that maintains well pressure control. The position of wireline lubricator **20** is controlled by an operator of the crane **11** using a bridle **25** attached to an upper end of the wireline lubricator **20**, while the position of toolstring **30** is controlled by an operator of a wireline truck (not shown) via the wireline **28**. In FIG. **1**, the wireline operator has reeled in the wireline **28** to lift the toolstring **30** off of the surface **7** into a vertical orientation such that an upper end of the toolstring **30** is proximal to the bottom of a wireline sealing element **22** at the bottom end of the wireline lubricator **20**. The entire length of toolstring **30** must fit fully into the wireline lubricator **20** to allow the bottom coupling **21** of wireline lubricator **20** to sealingly connect to the coupling **14** of valve tree **12** to maintain well pressure control prior to insertion of the toolstring **30** into the cased wellbore **10** through the valve tree **12**.

[0043] The toolstring **30** includes a number of tools that are selected by an operator of the cased wellbore **10** and which, in this example, includes a plug **31** at the bottom thereof, an adapter kit **32** and a setting tool **33** where the adapter kit **32** is connected between the plug **31** and setting tool **33**. Above the setting tool **33** are a number of perforating or “perf” guns or **35** along with other tools that provide electronic communication with the setting tool **33** and the perforation guns **35** and other tools of toolstring **30** that provide the wellbore location of the toolstring **30** as well as other known functions. At the top of the toolstring **30** is a coupling device that attaches to the wireline **28**. The wireline **28** extends from the wireline truck, over a pair of sheaves **26** and **27**, and runs into the top of the lubricator **20** via a wireline sealing element **22** of the wireline lubricator **20**. Wireline **28** is typically quite long to permit the toolstring **30** to run potentially miles through the cased wellbore **10**. It may be understood that wellbores, including cased wellbore **10**, extend vertically downwards from the surface **7** and then curve horizontally such at a horizontal portion of the cased wellbore **10** extends a great length (e.g., a mile or more) horizontally through a hydrocarbon bearing zone in the earthen formation.

[0044] Turning briefly to FIG. **2**, the toolstring **30** is shown following its insertion through and past the valves in the valve tree **12** such that the toolstring **30** is positioned inside a vertical section of the cased wellbore **10** where well pressure is under the control of the wireline sealing element **22** (not shown in FIG. **2**). The toolstring **30** is lowered through the cased wellbore **10** by the wireline system **5** until the toolstring **30** reaches a predetermined depth.

[0045] Referring to FIG. **3**, the toolstring **30** is shown located at the predetermined depth. Once at the predetermined depth, the plug **31** of toolstring **30** is set so that later, when fluid pressure is applied by a fracking system (not shown) from the surface **7**, the fluid pressure is focused and limited to perforations created in the cased wellbore **10** above the set plug **31**. The isolation provided by the set plug **31** prevents the fluid pressure from the surface-based fracking system to pass easily into other perforations located downhole from the plug **31** that are already opened from a prior fracking cycle. In FIG. **3**, the plug **31** is shown as both set and disconnected from the remainder of the toolstring **30** which is located uphole from the set plug **31**. The plug **31** is set and firmly anchored to the casing string **15** to seal the cased wellbore **10**. Particularly, in this example, plug **31** seals a downhole production zone extending downhole from plug **31** to a previously set plug **17** (deployed and set using a previous toolstring). It may be understood that perforations **19** associated with the downhole production zone have previously been fracked and enlarged prior to the deployment of toolstring **30** into cased wellbore **10**. As such, it may be understood that additional fracked production zones (not shown in FIG. **3**) are formed downhole from the plug **17**.

[0046] Referring now to FIGS. **4** and **5** and as the present disclosure relates to setting plugs, two conventional plugging assemblies are shown. FIG. **4** shows a conventional plug A**1** disclosed in U.S. Pat. No. 9,810,035 while FIG. **5** illustrates a conventional plug A**2** disclosed in U.S. Pat. No. 10,844,678. Plugs A**1** and A**2** are attached to conventional adaptor kits K**1** and K**2**, respectively. Additionally, adapter kits K**1** and K**2** are attached to conventional setting tools S**1** and S**2**, respectively. The setting tools S**1** and S**2** may be exactly the same as there are a few standard designs. It is the adaptor kits, such as the adaptor kits K**1** and K**2** that are specially configured for the specific plug size and design and are a necessary and well-known component for conventional plugging assemblies. Indeed, there are multiple manufacturers of plugs that offer a number of differently designed plugs with many sized for the various casing sizes of wellbores. So, each plug requires its specific adaptor kit while most setting tools are designed for a small diameter well and used for all well diameters. And it is not uncommon for an adapter kit to be selected to adapt a setting tool made by a first manufacturer with a plug made by a second manufacturer. Fortunately, adaptor kits are typically the least complicated and least expensive of the three components of a plugging system so that those who supply adaptor kits may stock a significant variety to cover many of the various combinations of setting tools and plugs.

[0047] Referring now to FIG. **6** a first embodiment of a plugging assembly **38** of the present disclosure is shown for hydraulically separating a wellbore into separate uphole and downhole zones and which specifically does not include an adaptor kit or more particularly eliminates the adapter kit and saves the space on the toolstring normally occupied by an adapter kit. Particularly, in this exemplary embodiment, plugging assembly **38** includes a plug **40** and a setting tool **50**, where the plug **40** is attached directly to the setting tool **50** such that no intervening component, such as an adapter kit, is interposed between the plug **40** and setting tool **50**. It may be initially observed that the inventive plugging assembly **38** shown in FIG. **6** has a maximum length **39** that is substantially less than a maximum length L**2** of the conventional plugging assembly shown in FIG. **5**. This reduced length of plugging assembly **38** provides a significant advantage over conventional arrangements when considering the limits placed on the overall length of the toolstring as described above. Reconsider the needs for inserting toolstring **30** (shown in FIG. **1**) into a well pressure containment system (e.g., valve tree **12** shown in FIG. **1**) that requires a relatively long wireline lubricator **20** and a tall (and expensive) crane **11** to lift both the wireline lubricator **20** and toolstring **30** in the air to thereby pre-position the toolstring **30** inside the wireline lubricator **20**.

[0048] In this exemplary embodiment, plug **40** of plugging assembly **38** generally includes a mandrel **46** extending the length of the plug **40** from a proximal or uphole end of the plug **40** to a distal or downhole end of the plug **40**. In this exemplary embodiment, mandrel **46** occupies a central core of the plug **40** and thus may also be referred to herein as core **46**. Plug **40** additionally includes a bull-nose **47** attached at the distal end of the mandrel **46** of the plug **40** while the proximal end **49** of the mandrel **46** (also referred to herein as the "stem" end of mandrel **46**) of the plug **40** is received inside a shear cap **53** of the setting tool **50**. Plugging assembly **38** additionally includes an obturating member or ball **37** which may seat against the stem of mandrel **46** once plug **40** has shifted to the set configuration to thereby seal an open passageway of the mandrel **46**.

[0049] Referring briefly to FIG. **9**, when the setting tool **50** sets the plug **40**, the bull-nose **47** of plug **40** is pulled uphole (leftwards as shown in FIG. **6** but uphole relative to the cased wellbore **10**) while an uphole compression ring or fitting **45** of plug **40** is pressed by the setting tool **50** downhole along the outside of the mandrel **46** forcing an anchoring system or slips **41** of the plug **40**, which surround a radially outer periphery of the mandrel **46**, along inclined ramps **42** of the plug **40** to move the slips **41** radially outwards away from the mandrel **46** such that slips **41** bite into, and anchor against, the of cased wellbore **10**. Slips **41** anchor the plug **40** to the casing string **15** in a fixed position. As shown particularly in FIG. **9**, the slips **41** are radially expanded against the casing string **15**, an elastomeric sealing element **44** of plug **40** flexes or bulges radially outwards to seal against an inside wall or inner surface of the casing string **15**. In this exemplary embodiment, the mandrel **46** and a lock element or ring **43** of the plug **40** which surrounds the mandrel **46** have complementary sets of ratchet teeth on the periphery of the mandrel **46** and on the inside of the lock ring **43** so that, as the mandrel **46** is pulled relative to the lock ring **43** there is movement, but the mandrel **46** is not permitted to slide backwards towards its run-in position due to the complementary ratchet shaped teeth. This arrangement helps set the plug **40** more securely in the casing string **15**.

[0050] Returning back to FIG. **6**, in this exemplary embodiment, setting tool **50** generally includes housing **51** and a setting tool mandrel **52** that is arranged to move axially within and relative to the housing **51**. A distal end of the setting tool mandrel **52** that is oriented toward the plug **40** (located downhole from the setting tool **50**) includes a shear cap **53** in an exemplary arrangement but could, in other embodiment, have whatever shape and function to fit the plug being used with the setting tool **50**. The shear cap **53** may also be fully integrated with setting tool mandrel **52** such that mandrel **52** and shear cap **53** form an integral, monolithically formed member, or may be formed of separate members that are attached together as an assembly as shown in FIGS. **6-8**. The shear cap **53** is also connected to the uphole end of the plug mandrel **46** by at least one shear member **48**.

[0051] In this exemplary embodiment, setting tool mandrel **52** further includes a combustion chamber **54** in which is placed an energetic charge, not shown. The energetic charge may comprise a combustible material configured to generate highly pressurized combustion gasses upon initiation. The setting tool **50** and plug **40** of plugging assembly **38** are each shown in FIG. **6** in a run-in configuration, respectively, where the uphole end (left end in FIG. **6**) of the setting tool mandrel **52** is at a proximal end of the housing. The uphole end should be understood to be opposite the downhole end where the downhole end is furthest from the surface **7** and deepest in the cased wellbore **10** when installed in the wellbore **10** while the uphole end is closer to the surface **7** when plugging assembly **38** is installed in the wellbore **10**. In the run-in configuration, the combustible element is positioned within the combustion chamber **54** of the setting tool mandrel **52**.

[0052] In this exemplary embodiment, setting tool mandrel **52** includes one or more radially oriented channels or passages **57** which are open for the flow of fluids, and more particularly gases, from the combustion chamber **54** into an annular expansion chamber **55** located radially outside of the mandrel **52** and inside the housing **51**. The expansion chamber **55** is defined at each end by a pair of annular seals or O-rings **58** attached to the mandrel to seal against the inside of the housing **51** toward the proximal end of the expansion chamber **55**. A second set of annular seals or O-rings **59** is similarly attached to the housing to seal against the periphery of the setting tool mandrel **52** at the distal end of the expansion chamber **55**. O-rings **59** separate the expansion chamber **55** from an annular air chamber **56** located radially outside of the mandrel **52** and inside of the housing **51**.

[0053] Referring now to FIGS. **7** and **8**, the stroking of the setting tool **50** from the run-in configuration to a stroked configuration will be more fully explained. When the combustible element that has been described as positioned in combustion chamber **54** is triggered by a signal from the surface **7**, the triggered combustible element quickly creates hot and high-pressure gases which travel through the radial channels **57** of setting tool mandrel **52** to rapidly pressurize the expansion chamber **55** surrounding the mandrel **52**. As the expansion chamber **55** pressurizes, the expansion chamber **55** grows or extends axially such that the housing **51** moves relative to the setting tool mandrel **52** which imposes both a tensile force on the plug mandrel **46** through the connection of the shear cap **53** with the uphole end of the plug mandrel **46**, and a compressive force of the setting tool housing **51** pressing axially against the uphole compression fitting **45** of the plug **40**. The opposed axial movements of the setting tool mandrel **52** and the housing **51** in-turn creates compressive forces on the functional elements of the plug **40** as previously described to set the plug inside the casing string **15**.

[0054] As best seen in FIG. **7**, the shear cap **53** is pulled further uphole into the housing **51** toward the uphole end thereof. Setting tool **50** is shown in FIG. **7** in a mid-stroke configuration and it would be expected that the uphole end of the plug mandrel **46** would be pulled further into the setting tool housing **51**. It should also be pointed out that the uphole end of the plug mandrel **46** was inside the shear cap **53** in the run-in configuration and both were inside of the setting tool housing **51** before the stroking of the setting tool **50** began. Eventually, and potentially before the setting tool **50** reaches the stroked configuration, the resistance of the functional elements on the outside of the plug mandrel **46** such as, for example, the slips **41**, the ramps **42** and the elastomeric sealing element **44** against further axial compression will exceed the shear strength of the shear member **48** and the shear member **48** will sever from an unsevered configuration to a severed configuration allowing the stem end of the plug mandrel **46** to break away from the shear cap **53**. In response to the shearing of the shear member **48**, the setting tool **50** along with the rest of the toolstring **30** moves axially in the casing string **15** away from the plug **40** as the stroking of the setting tool has some remainder of its stroke to fully travel.

[0055] Setting tool **50** is shown in FIG. **8** in the stroked configuration where the radial channels **57** come into fluid communication of the vent holes **64** such that the remaining high-pressure gases are vented out of the pressure expansion chamber **55**. It should be noted that there is an accommodating annular space **56** located on the other side of the second set of O-rings **59** from the pressure expansion chamber **55** that reduces in size and specifically axially length as the pressure annular space grows in length. The accommodating annular space **56** is defined at its distal end by a third set of O-rings **62** of the setting tool **50**. In this exemplary embodiment, accommodating annular space **56** is formed upon the assembly of the setting tool **50** at its manufacturing facility and is filled with compressible air at atmospheric pressure existing at the time of assembly (e.g., less than 15 pounds per square inch absolute (PSIA)). This is helpful to the stroking of the setting tool **50** in that the stroking of the setting tool is not pulling the stem end of the mandrel **46** of the plug **40** with an incompressible fluid limiting the rate of which the stroking of the setting tool may occur. With the arrangement as shown, the pressure in the pressure annular space may exceed 10,000 psi and may approach 50,000 psi to drive the mandrel **52** upward relative to the housing at the ordinary air pressure in the accommodating annular space which thereby hardly resists the movement and that annular space closes down to a very minimal axial dimension at the end of the stroke.

[0056] Referring now to FIG. **10**, another embodiment of a plugging assembly **140** is shown generally including a plug **150** and a setting tool **200**. In this exemplary embodiment, plug **150** has a central or longitudinal axis **155** and generally includes sealing element **152**, a central core **160**, a first or uphole compression ring or fitting **170**, a second or downhole compression ring or fitting **172**, an anchoring system or slip assembly **174**, a compression sleeve **180**, and a locking assembly **182**. Core **160** extends centrally through plug **150** and comprises a proximal or uphole end **161**, a distal or downhole end **162** opposite uphole end **161**, a central passage or open passageway **163**, and generally cylindrical outer surface **164** extending between ends **161**, **162**. In this exemplary embodiment, the open passageway **163** of core **160** includes an annular seat **165** for receiving an obturating member or ball (not shown in FIG. **10**) configured to restrict fluid communication through open passageway **163** in at least one axial flow direction. Additionally, in this exemplary embodiment, one or more circumferentially spaced receptacles **166** are formed in the outer surface **164** of core **160**, each of which is configured to receive a frangible member or shear pin **167** configured to frangibly couple the core **160** to setting tool **200**.

[0057] Compression fittings **170** and **172** may each comprise a single, unitary or monolithically formed member, or a plurality of members coupled together. In this exemplary embodiment, uphole compression fitting **170** is shown as comprising several annular components coupled together. Additionally, compression fittings **170** and **172** are each positioned adjacent sealing element **152** while slip assembly **174** is positioned between the downhole compression fitting **172** and compression sleeve **180**. In this exemplary embodiment, slip assembly **174** includes a plurality of slip members **175** each including a plurality of engagement members or teeth **176**. The teeth **176** of slip assembly **174** are configured to engage or bite into the inner surface of a casing string (e.g., casing string **15** shown in FIG. **1**) upon the actuation of plug **150** by setting tool **200** to couple or affix the plug **150** to the casing string whereby relative movement between plug **150** and casing string is restricted.

[0058] In this exemplary embodiment, compression sleeve **180** is located at, and defines, a downhole end of the plug **150** and may also be referred to herein as a nose or nose cone **180**. However, it may be understood that in other embodiments compression sleeve **180** may not be located at the downhole end of plug **150**. Compression sleeve **180** of plug **150** is positioned at a terminal end of plug **150** and is coupled to the downhole end **162** of core **160**. Locking assembly **182** of plug **150** is configured to lock the plug **150** in a set configuration following stroking of the setting tool **200** from a run-in configuration of the tool **200** to a stroked configuration of the tool

200. Locking assembly **182** may engage uphole compression fitting **170** to restrict relative axial movement between locking assembly **182** and the uphole compression fitting **170** as well as the sealing element **152**. Locking assembly **182** may also comprise engagement members configured to matingly engage engagement members with core **160** to restrict relative movement between core **160** and locking assembly **182** following actuation of plug **150**, thereby locking the plug **150** in the set configuration.

[0059] Referring to FIGS. **10-12**, additional views of the setting tool **200** are shown in FIGS. **11** and **12**. As described above, setting tool **200** is configured to stroke from the run-in configuration to the stroked configuration to thereby actuate plug **150** from a run-in configuration shown to a set configuration whereby the sealing element **152** sealingly engages the inner surface of casing string. While setting tool **200** is described herein as being configured to actuate plug **150**, setting tool **200** may be used to actuate plugs that differ in configuration from plug **150**.

[0060] In this exemplary embodiment, setting tool **200** has a central or longitudinal axis **205** and generally comprises an outer or piston housing **202**, a mandrel **240** slidably received in the housing **202**, and an adapter or shear cap **270** coupled to the mandrel **240**. Housing **202** includes an uphole end **204**, a downhole end **206** opposite uphole end **204**, a central passage or open passageway **208** defined by a generally cylindrical inner surface **210** extending between ends **204**, **206**. No threaded or other connections are formed along the housing **202** between ends **204**, **206** thereof. Additionally, in this exemplary embodiment, housing **202** comprises an integral, monolithically formed member. The lack of threaded or other connections along housing **202** minimizes the time required for assembling setting tool **200** by obviating the need to, for example, rotatably couple together a plurality of housing sections to form a single housing assembly, or to rotatably couple the housing with an intermediate tubular member such as a setting sleeve of a wireline adapter kit. The removal of the setting sleeve of the wireline adapter kit also minimizes the overall length of the assembled setting tool **200** and plug **150**, making the assembly easier to transport to the wellsite as well as easier to deploy downhole within wellbore **4**.

[0061] In this exemplary embodiment, the inner surface **210** of housing **202** comprises a reduced diameter region or annular protrusion **212** on which a pair of annular seal assemblies **214** are positioned. Seal assemblies **214** may each comprise an elastomeric seal or O-ring positioned in an annular groove formed in the protrusion **212**. Additionally, protrusion **212** forms an annular first shoulder **213** and an annular second shoulder **215** on the inner surface **210** of housing **202**.

[0062] Further, in this exemplary embodiment, housing includes a plurality of radial ports **216** located proximal the downhole end **206** thereof and a plurality of radial receptacles **218** located at the uphole end **204**. Radial ports **216** may be circumferentially spaced from each other and are configured to provide for fluid flow between the open passageway **208** of housing **202** and an environment surrounding setting tool **200** (e.g., wellbore **4** when setting tool **200** is positioned therein). Each radial receptacle **218** may receive a frangible member or shear pin **220** which frangibly connects the mandrel **240** with the housing **202** such that relative axial movement therebetween is restricted. As will be discussed further herein, shear pins **220** are configured to retain housing **202** of setting tool **200** in a first position shown in FIG. **11** until it is desired to actuate housing **202** into a second position shown in FIG. **12** which is axially spaced from the first position.

[0063] As shown particularly in FIG. **11**, the housing **202** of setting tool **200** has a minimum inner diameter and a maximum outer diameter each located between the opposing ends **204**, **206** of housing **202**. In this exemplary embodiment, the maximum outer diameter of housing **202** is less than 5% larger than the minimum outer diameter of housing **202**. In certain embodiments, the maximum outer diameter is less than half an inch larger than the minimum outer diameter. In some embodiments, the maximum outer diameter is less than three eights of an inch larger than the minimum outer diameter. In certain embodiments, the maximum outer diameter is substantially equal to the minimum outer diameter. The relative consistency of the outer diameter of housing **202** may allow setting tool **200** to be utilized in a broader array of applications, including in applications in which the casing string has a relatively small inner diameter.

[0064] Mandrel **240** of setting tool **200** is slidably received in the open passageway **208** of housing **202** and generally includes an uphole end **242**, a downhole end **244** opposite uphole end **242**, and a central opening or passage **246** defined by a generally cylindrical inner surface **248**, a generally cylindrical outer surface **250** extending between ends **242**, **244**. No threaded or other connections are formed along the mandrel **240** between ends **242**, **244** thereof. Additionally, in this exemplary embodiment, mandrel **240** comprises an integral, monolithically formed member. The lack of threaded or other connections along mandrel **240** minimizes the amount of time required for assembling setting tool **200** by obviating the need to, for example, rotatably couple together multiple mandrel sections to form a complete mandrel assembly.

[0065] Central opening **246** of mandrel **240** extends partially through mandrel **240** from uphole end **242**, terminating at a terminal end **252** within mandrel **240**. Central opening **246** may receive an energetic charge **217** (shown in FIG. **10**) and thus may also be referred to herein as combustion chamber **246**. The energetic charge **217** may comprise a combustible material configured to generate highly pressurized combustion gasses upon initiation. In this exemplary embodiment, the inner surface **248** of central opening **246** comprises a releasable connector, such as a threaded connector, configured to matingly and releasably couple with a corresponding connector of a firing head of a toolstring (e.g., toolstring **30** shown in FIG. **1**) comprising the plugging assembly **140**. Additionally, mandrel **240** comprises a plurality of circumferentially spaced radial ports **256** which provide for fluid communication between central opening **246** of mandrel **240** and the open passageway **208** of housing **202**.

[0066] In this exemplary embodiment, the outer surface **250** of mandrel **240** comprises an annular expanded diameter region or protrusion **258** on which a pair of annular seal assemblies **260** are positioned. Seal assemblies **260** may each comprise an elastomeric seal or O-ring positioned in an annular groove formed in the protrusion **258**. In this configuration, seal assemblies **214** of housing **202** sealingly engage the outer surface **250** of mandrel **240** while the seal assemblies **260** of mandrel **240** sealingly engage the inner surface **210** of housing **202**, forming an annular expansion chamber **257**.

[0067] Expansion chamber **257** extends radially between the outer surface **250** of mandrel **240** and the inner surface **210** of housing **202**, and axially between the seal assemblies **214** of housing **202** and the seal assemblies **260** of mandrel **240**. Fluid communication is provided between expansion chamber **257** and the central opening **246** of mandrel **240** via radial ports **256** of mandrel **240**. As will be discussed further herein, central opening **246** of mandrel **240** may receive a combustible power cartridge (not shown in FIGS. **10-12**) configured to combust and thereby generate combustion gasses in response to being ignited by a firing head of the toolstring. The combustion gasses generated by the power cartridge upon ignition may be communicated to expansion chamber **257** via radial ports **256**.

[0068] The shear cap **270** of setting tool **200** is generally configured to couple the mandrel **240** of setting tool **200** with the core **160** of plug **150**. Shear cap **270** generally includes an uphole end **272** directly connected to mandrel **240**, a downhole end **274** opposite uphole end **272**, a central opening or passage **276** extending between ends **272**, **274**, and a generally cylindrical outer surface **278** extending between ends **272**, **274**. No threaded or other connections are formed along the shear cap **270** between ends **272**, **274** thereof. Additionally, in this exemplary embodiment, shear cap **270** comprises an integral, monolithically formed member. The lack of threaded or other connections along shear cap **270** minimizes the amount of time required for assembling setting tool **200** by obviating the need to, for example, rotatably couple together multiple shear cap sections to form a complete shear cap assembly.

[0069] Directly connecting the shear cap **270** to the mandrel **240** such that no intermediate members are positioned between mandrel **240** and shear cap **270** may also minimize the overall length of setting tool **200** by eliminating the need to include additional tubular members between mandrel **240** and shear cap **270**. Particularly, conventional setting tools may couple to a plug through a wireline adapter kit positioned therebetween and including a setting sleeve coupled to the housing of the conventional setting tool and a shear cap assembly coupled to the mandrel of the conventional setting tool. While the wireline adapter kit may allow some conventional setting tools to be adapted to varying plugs, the adapter kit increases the overall length of the conventional setting tool, adapter kit, and plug assembly, thereby increasing the costs of manufacturing, shipping, and deploying the assembly downhole. Conversely, shear cap **270** is integrated directly into setting tool **200**, obviating the need to couple setting tool **200** with a wireline adapter kit.

[0070] In this exemplary embodiment, shear cap **270** comprises a reduced diameter region or annular hub **280** at the uphole end **272** thereof. Hub **280** of shear cap **270** is received in a cylindrical opening or socket **262** formed in the downhole end **244** of mandrel **240**. A fastener **282** extends centrally through hub **280** and into a threaded receptacle **264** extending into mandrel **240** from a terminal end of socket **262**. Threads formed on an outer surface of fastener **282** may threadably engage threads formed on an inner surface of threaded receptacle **264** to thereby releasably or threadably connect the uphole end **272** of shear cap **270** to the downhole end **244** of mandrel **240** whereby relative axial movement between shear cap **270** and mandrel **240** is restricted.

[0071] Additionally, one or more anti-rotation pins **284** radially offset from central axis **205** extend axially between hub **280** of shear cap **270** and mandrel **240** to prevent rotation between shear cap **270** and mandrel **240**. Particularly, anti-rotation pins **284** allow shear cap **270** to be retained or locked in a predefined angular position relative to mandrel **240**. An annular first seal assembly **286** is positioned on hub **282** and sealingly engages an inner surface of the socket **262** of mandrel **240**. First seal assembly **286** may comprise an elastomeric seal or O-ring positioned in an annular groove formed in the hub **280**.

[0072] The combination of fastener **282** and anti-rotation pins **284** allows for the angular orientation of shear cap **270** relative to mandrel **240** to be controlled as desired while also eliminating the need for a threaded connection directly between the shear cap **270** and mandrel **240** and set screws extending radially therebetween which may be relatively difficult to assemble. Particularly, fastener **282** and anti-rotation pins **284** allow for shear cap **270** to be assembled with mandrel **240** while mandrel **240** is received within housing **202** which may not be possible with a connection requiring the assembly of radially extending set screws. However, while in this exemplary embodiment coupling of shear cap **270** with mandrel **240** is achieved via fastener **282** and anti-rotation pins **284**, in other embodiments, the mechanism for coupling shear cap **270** with mandrel **240** may vary. In still other embodiments, mandrel **240** and shear cap **270** may comprise a single integral, monolithically formed member and thus shear cap **270** may comprise a portion or section of the mandrel **240**.

[0073] In this exemplary embodiment, shear cap **270** additionally includes an annular pair of second seal assemblies **288** positioned on the outer surface **278** thereof, a plurality of circumferentially spaced radial ports **290**, and a plurality of circumferentially spaced receptacles **292**. Second seal assemblies **288** sealingly engage the inner surface **210** of housing **202**. Seal assemblies **288** may each comprise an elastomeric seal or O-ring positioned in an annular groove formed in the outer surface **278** of shear cap **270**. In this configuration, seal assemblies **214** of housing **202** sealingly engage the outer surface **250** of mandrel **240** while the seal assemblies **288** of shear cap **270** sealingly engage the inner surface **210** of housing **202**, forming an annular atmospheric or contraction chamber **259**. Contraction chamber **259** extends radially between the outer surface **250** of mandrel **240** as well as a portion of the outer surface **278** of shear cap **270**, and the inner surface **210** of housing **202**. Contraction chamber **259** extends axially between the seal assemblies **214** of housing **202** and the seal assemblies **288** of shear cap **270**. In this exemplary embodiment, contraction chamber **259** is filled with a compressible fluid (e.g., air) at atmospheric pressure prior to lowering a toolstring comprising the plugging assembly **140** downhole.

[0074] In this exemplary embodiment, an annular shock absorber **294** is positioned within contraction chamber **259**; however, in other embodiments, setting tool **200** may not include shock absorber **294**. As will be discussed further herein, the volume of contraction chamber **259** is reduced as housing **202** travels from the first position to the second position until the shock absorber **294** contacts the second shoulder **215** of housing **202**, thereby arresting the axial travel (in the direction of plug **150**) of housing **202** relative to mandrel **240**. Shock absorber may minimize the shock and/or stress transmitted to housing **202**, mandrel **240**, and shear chap **270** following impact between shock absorber **294** and the second shoulder **215** of housing **202**.

[0075] Radial ports **290** of shear cap **270** are radially aligned with the radial ports **216** of housing **202** whereby fluid may be readily communicated between the central opening **276** of shear cap **270** and the environment surrounding setting tool **200** (e.g., cased wellbore **10** when toolstring **30** is positioned therein). This fluid communication may allow for fluid to flow into central opening **276** of shear cap **270** as the setting tool **200** is removed from the wellbore (e.g., cased wellbore **10**) to thereby prevent a vacuum from forming in central opening **276** which may otherwise increase the difficulty in the retrieving toolstring from the wellbore.

[0076] Angular alignment between radial ports **290** of shear cap **270** and radial ports **216** of housing **202** may be maintained with housing **202** in the first position via the angular locking between shear cap **270** and mandrel **240** provided by anti-rotation pins **284** as well as the rotational locking provided between mandrel **240** and housing **202** by shear pins **220**. In other words, anti-rotation pins **284** and shear pins **220** allow for the shear cap **270** to be locked into a desired angular orientation relative to the housing **202** when housing **202** is in the first position.

[0077] Receptacles **292** of shear cap **270** are configured to receive the shear pins **167** shown in FIG. **10** to frangibly couple the core **160** of plug **150** with the shear cap **270** of setting tool **200**. Particularly, in this exemplary embodiment, the uphole end **161** of core **160** is at least partially received in the central opening **276** of shear cap **270** with receptacles **292** of shear cap **270** axially and circumferentially aligned with the receptacles **166** formed in core **160** whereby each shear pin **167** may be at least partially received in both one of the receptacles **292** and one of the receptacles **166**. In some embodiments, each shear pin **167** may be threaded to both one of the receptacles **292** and one of the receptacles **166**.

[0078] Shear pins **167** may be inserted into the receptacles **292** of shear cap **270** while shear cap **270** is received in the open passageway **208** of housing **202** following the coupling of shear cap **270** with mandrel **240** as described above. Particularly, housing **202** includes a plurality of circumferentially spaced apertures **222** positioned at downhole end **206** and which are circumferentially offset from radial ports **216**. Apertures **222** of housing **202** may be circumferentially aligned with receptacles **292** of shear cap **270** during assembly, allowing shear pins **167** to be inserted and threaded into receptacles **292** via the apertures **222** of housing **202** aligned therewith. Following the insertion of shear pins **167** into receptacles **292** of shear cap **270** and the receptacles **166** of core **160**, housing **202** may be rotated relative mandrel **240** to circumferentially align radial receptacles **218** of housing **202** with corresponding receptacles formed in mandrel **240** at uphole end **242**. Shear pins **220** may be inserted or threaded into and through radial receptacles **218** of housing **202** and the corresponding receptacles of mandrel **240** to provide a frangible connection which rotationally and axially locks housing **202** with mandrel **240**.

[0079] Referring still to FIGS. **10-12**, a toolstring comprising the plugging assembly **140** may be deployed into a wellbore (e.g. the cased wellbore **10** shown in FIG. **1**) to perforate a casing string (e.g., casing string **15** shown in FIG. **1**) at a desired location. Particularly, following the assembly of the toolstring, the string may be lowered through the wellbore via a surface assembly until the toolstring is disposed in a desired position in the wellbore. Plug **150** is disposed in the run-in configuration and mandrel **240** of setting tool **200** is located in the first position as the toolstring is lowered through the wellbore towards the desired position. At this desired position, a signal may be transmitted from the surface assembly through wireline **28** and to a component of a firing head of the toolstring where the firing head initiates the combustion of energetic charge **217** (shown in FIG. **10**) positioned in the central opening **246** of the mandrel **240** of setting tool **200**.

[0080] Combustion of the energetic charge **217** of setting tool **200** generates pressurized combustion gasses which flow into the expansion chamber **257** of setting tool **200**. The pressurized combustion gasses act against the first shoulder **213** of the protrusion **212** of housing **202**, thereby applying a net pressure force against housing **202** in a first or downhole axial direction (indicated by arrow **261** in FIG. **10**) directed towards the plug **150**. A net pressure force is also applied to mandrel **240** by the combustion gasses pressing against a shoulder **265** formed by the protrusion **258** of mandrel **240**. However, the net pressure force applied to mandrel **240** by the combustion gasses is in a second or uphole direction (indicated by arrow **263** in FIG. **10**) which is opposite the first direction **261** such that mandrel **240** travels uphole from a first or unstroked position within the open passageway **208** of housing **202** to a second or stroked position that is axially spaced from the unstroked position.

[0081] The net pressure force generated by the combustion gasses and applied to housing **202** also applies a shear force to the shear pins **220** until the increasing net pressure force overcomes the shear strength of shear pins **220** and thereby shears the shear pins **220**. In other words, shear pins **220** each have an unsevered configuration connecting the plug **150** with the setting tool **200** and a severed configuration in which the plug **150** is disconnected from the setting tool **200**. With the shearing of shear pins **220**, housing **202** is forced in the first direction **261** by the net pressure force applied by the combustion gasses towards plug **150**. The unstroked position of mandrel **240** and unsevered configuration of shear pins **220** correspond to a run-in configuration of the plug **150** in which plug **150** is connected to the setting tool **200** while the stroked position of mandrel **240** and severed configuration of shear pins **220** correspond to a set configuration of the plug **150** where the sealing element **152** and the slip assembly **174** of the plug **150** are deployed toward an inner surface of the casing string **15** and the shear pins **220** have severed to separate the setting tool **200** from the plug **150**.

[0082] Further, expansion chamber **257** is configured to assume different volumes depending on the configuration of the plug **150** and the position of mandrel **240**. Particularly, the unstroked position of mandrel **240** leads to the expansion chamber **257** having a first volume corresponding to the run-in configuration of the plug, and the stroked position of the mandrel **240** leads to the expansion chamber **257** having a second volume, which is larger than the first volume, corresponding to the set configuration of the plug. The expansion chamber **257** has a first longitudinal length corresponding to the first volume, and a second longitudinal length, which is greater than the first longitudinal length, corresponding to the second volume.

[0083] With the downhole end **206** of housing **202** being adjacent the uphole compression fitting **170** of plug **150**, the force applied to housing **202** in the first direction **261** by the combustion gasses is transferred to the uphole compression fitting **170**. With uphole compression fitting **170** being forced in the first direction **261** by the combustion gasses within setting tool **200**, compression sleeve **180** of plug **150** is coupled to mandrel **240** of setting tool **200** and thus are restricted from traveling in the first direction **261** (the combustion gasses applying a net pressure force against mandrel **240** in the opposing second direction **263**).

[0084] In this manner, housing **202** travels along first direction **261** from the first position to the second position. In this exemplary embodiment, as housing **202** reaches the second position, seal assemblies **260** of mandrel **240** may enter an expanded diameter region **219** of housing **202** whereby seal assemblies **260** are no longer in sealing engagement with the inner surface **210** of housing **202**. With seal assemblies **260** no longer sealing against the inner surface **210** of housing **202**, combustion gasses within expansion chamber **257** may vent to the wellbore. In other embodiments, housing **202** may not include expanded diameter region **219**.

[0085] As housing **202** travels towards the second position, sealing element **152** of plug **150** is clamped axially between compressing fittings **170**, **172** of plug **150**, whereby the sealing element is elastically deformed and radially expanded into sealing engagement with the inner surface of the casing string. Additionally, the slip members **175** of slip assembly **174** are clamped between second compression fitting **172** and compression sleeve **180**, whereby the slip members **175** travel radially outwards until they engage the casing string such that teeth **176** of slip members **175** bite into the inner surface of the casing string. With sealing element **152** in sealing engagement with the inner surface of the casing string and slip members **175** in engagement with the casing string, plug **150** is now in the set configuration. In this manner, the slip assembly **174** and sealing element **152** may be transitioned from a run-in configuration (shown in FIG. **6**) having an outer maximum run-in diameter to an expanded configuration (shown in FIG. **9**) having an outer maximum expanded diameter, where the maximum expanded diameter is greater than the maximum run-in diameter.

[0086] Subsequently, tension may be applied to wireline **28** from the surface assembly **11** sufficient to shear the shear pins **167** connecting the core **160** of plug **150** with the shear cap **270** of setting tool **200**, thereby separating setting tool **200** and the remainder of toolstring **30** from plug **150**, which remains locked to the casing string. An obturating member or ball (not shown in FIGS. **10-12**) may remain seated in the seat **165** of the core **160** of plug **150** such that plug **150** restrict fluid flow downhole across the plug **150**. In this configuration, a signal may be communicated from the surface assembly to a perforating gun of the toolstring whereby one or more shaped charges of perforating gun are detonated to perforate the casing string at the desired location.

[0087] Referring to FIG. **13**, another embodiment of a plugging assembly **300** is shown. Plugging assembly **300** incudes features in common with plugging assembly **140** described above, and shared features are labeled similarly. Plugging assembly **300** has a central or longitudinal axis **305** and generally includes a plug **310** and a setting tool **350** each having a central or longitudinal axis that is coaxial with the central axis **305** of plugging assembly **300**. Setting tool **350** is similar to setting tool **200** described above except that setting tool **350** comprises a mandrel **360** which includes an extension **370**. The extension **370** of mandrel **360** extends at least partially through the open passageway **163** of the core **160** of plug **310**. Although not shown in FIG. **13**, extension **370** may include a receptacle for receiving an obturating member or ball to seal the open passageway **163** following the setting of plug **310** and the disconnection of setting tool **350** from plug **310**.

[0088] Unlike setting tool **200** described above, the mandrel **360** of setting tool **350** connects to a nose **320** of the plug **310**. Particularly, extension **370** connects to the nose **320** through a shear member **380** connected radially between the nose **320** and a downhole end of the extension **370**. In this exemplary embodiment, shear member **380** comprises shear ring frangibly connected between the nose **320** and extension **370**, however, in other embodiments, the configuration of shear member **380** may vary. In this arrangement, plug **310** comprises a bottom-set plug in which the setting tool **350** connects to a downhole end of the plug **310** instead of to an uphole end of the plug **310**. Additionally, extension **370** applies an uphole directed compressive force directly to the nose **320** of plug **310** instead of through the core **160** of plug **310**. Conversely, the plug **150** described above comprises a top-set plug in which the setting tool **200** connects to the uphole end of plug **150**.

[0089] Referring now to FIG. **14**, another conventional arrangement for setting a plug **71** using a plug setting tool **73** and a properly sized and configured, conventional adaptor kit **72** adapted for the setting tool **73** and adapted for the size, type and brand of plug **71**. The setting tool **73** is connected to a firing head **74** which includes a switch in electrical communication with the wireline operator at the surface. The firing head **74** is connected at its upper end to the last gun **75** in a toolstring **70** (comprising plug **71**, setting tool **73**, and adapter kit **72**) via a conventional sub **75**A. Thus, as it relates to the present disclosure, the assembly of the bottom end of the toolstring **70**, multiple connections are made for these components as designated as connections C**1**, C**2** and C**3**.

[0090] Referring to FIG. **15**, an embodiment of a toolstring **400** is shown that includes, among other features, a perforating gun **410**, a setting tool **420**, and a plug **450**. It may be understood that the setting tool **420** connected to the plug **450** collectively forms a plugging assembly **421** of the toolstring **400**. In this exemplary embodiment, the toolstring **400** may comprise one or more perforating guns **410**, with the perforating gun **410** corresponding to a lowermost or “bottom” gun **410**. It may thus be understood that toolstring **400** may include additional perforating guns **410** (along with other components) not shown in FIG. **15**.

[0091] The bottom gun **410** of toolstring **400** includes an outer housing **414** that extends longitudinally between an uphole end and a downhole end **415** opposite the uphole end thereof. In this exemplary embodiment, the downhole end **415** of housing **414** forms or defines the downhole end of the bottom gun **410**. Additionally, bottom gun **410** includes a charge carrier **416** received in a central passageway of the housing **414** and which receives one or more perforating charges (not shown) for perforating a casing of a wellbore in which the toolstring **400** is deployed. In some embodiments, the bottom gun **410** includes a gun initiator configured to detonate the one or more perforating charges of the charge carrier **416** in response to receiving a firing signal (e.g., transmitted from surface assembly **11**) that is addressed to the bottom gun **410**.

[0092] In this exemplary embodiment, the setting tool **420** of toolstring **400** is physically attached directly to bottom gun **410** such that there are no intervening components (e.g., conventional sub **75**A, firing head **74**) positioned longitudinally between the bottom gun **410** and the setting tool **420**. Setting tool **420** generally includes an elongate housing **422** extending between an uphole end **423** and a downhole end **425** opposite the uphole end **423**, an open passageway **424** extending from the uphole end **423** to the downhole end **425**. In at least some instances, the downhole end **425** of housing **422** defines a downhole end of the setting tool **420**. Additionally, setting tool **420** includes an elongate mandrel **430** positioned in the open passageway **424** of housing **422** and having an uphole end **431** and a downhole end **433** opposite the uphole end **431** thereof. In at least some instances, the uphole end **431** of mandrel **430** defines an uphole end of the setting tool **420**.

[0093] An internal passage **432** is formed within the mandrel **430** of setting tool **420**, the internal passage **432** extending into mandrel **430** from the uphole end **431** thereof. In this exemplary embodiment, a setting tool initiating cartridge **440** and an energetic charge **448** are each received in the internal passage **432** (see FIG. **18**) of mandrel **430**, the setting tool initiating cartridge **440** configured to pressurize a combustion chamber **436** located within the passageway **424** of housing **422** (e.g., located at least partially within the internal passage **432** of mandrel **430** received in the passageway **424** of housing **422**) in response to receiving a firing signal addressed to the setting tool (e.g., transmitted from the surface assembly **11**).

[0094] In this exemplary embodiment, setting tool initiating cartridge **440** generally includes a carrier or chassis **442**, an addressable switch **446**, and an initiator **444**. Both the addressable switch **446** and the initiator **444** are physically supported and attached to the initiator chassis **442** which is received in the internal passage **432** of mandrel **430**. The addressable switch **446** is electrically connected to the bottom gun **410** via an electrical connector of the initiator chassis **442** whereby signals may be transmitted between the addressable switch **446** and the surface (e.g., between switch **446** and surface assembly **11**). The addressable switch **446** may comprise a digital switch including a processor and a memory containing instructions executable by the processor. For example, the memory of the addressable switch **446** may include an address by which the addressable switch **446** may be specifically, uniquely and independently addressed from the surface (e.g., from surface assembly **11**).

[0095] The addressable switch **446** is electrically connected to the initiator **444** whereby the addressable switch **446** may initiate the initiator **444** in response to receiving a firing signal addressed to the addressable switch **446**. Initiator **444** is ballistically coupled to the energetic charge **448** whereby the initiator **444** is configured, in response to being initiated by the addressable switch **446**, detonating the energetic charge **448** to rapidly pressurize the combustion chamber **436** and activate the setting tool **420**.

[0096] It may be noted that by positioning the setting tool initiating cartridge **440** within the internal passage **432** of mandrel **430**, the overall longitudinal length of toolstring **400** may be minimized. Particularly, in conventional toolstrings such as toolstring **60** shown in FIG. **14**, the switch responsible for triggering activation of the setting tool of the conventional toolstring is located external the setting tool in a separate sub or component of the conventional toolstring such as, for example, a firing head (e.g., firing head **65**A shown in FIG. **14**) coupled longitudinally between a perforating gun of the conventional toolstring and the setting tool of the conventional toolstring, where the firing head (or other external component housing the setting tool initiator) adds to the overall length of the conventional toolstring. By positioning the setting tool initiating cartridge **440** directly within the setting tool **420** itself (leveraging the space provided by the internal passage **432** of mandrel **430**), the length taken up by the firing head or similar component may instead be eliminated from the toolstring **400**.

[0097] The plug **450** of toolstring **400** is attached to the setting tool **420** and includes an elongate core **452** with an uphole end **453** and a downhole end **455** opposite the uphole end **453** thereof. In some embodiments, the uphole end **453** of core **452** defines an uphole end of the plug **450**. Additionally, plug **450** includes an annular sealing element **456** disposed fully around the core **452** to seal against the casing (e.g., casing string **15**), and an anchoring system **460** for anchoring the plug **450** to the casing in a fixed position. Further, in this exemplary embodiment, plug **450** includes a compression fitting **465** disposed around the core **452** at or near the uphole end **453** thereof, and a nose **469** at the downhole end **455** of the core **452**. In some embodiments, the nose **469** defines a downhole end of the plug **450** and of the toolstring **400**.

[0098] In this exemplary embodiment, the sealing element **456** and the anchoring system **460** of plug **450** have an initial configuration having an outer maximum run in diameter, and an expanded configuration having an outer maximum expanded diameter that is greater than the maximum run-in diameter. The run-in diameters of sealing element **456** and anchoring system **460** correspond to a run-in configuration of pug **450** while the expanded diameters of sealing element **456** and anchoring system **460** correspond to a set configuration of the plug **450**.

[0099] The plug **450** may be actuated from the run-in configuration to the set configuration in response to activating the setting tool **420**. Particularly, an operator of toolstring **400** may transmit (e.g., from surface assembly **11**) a firing signal addressed to the setting tool **420** of toolstring **400**, resulting in the activation of setting tool **420** whereby energetic charge **448** is ignited by setting tool initiating cartridge **440**. The ignition of energetic charge **448** results in a rapid pressurization of combustion chamber **436**, forcing the housing **422** of setting tool **420** downhole relative to mandrel **430** where the downhole end **425** of housing **422** presses against the compression fitting **465** of plug **450** to radially expand both the sealing element **456** and anchoring system **460** of plug **450** into engagement with casing (e.g., casing string **15**).

[0100] In some embodiments, in addition to automatically actuating plug **450** from the run-in configuration to the set configuration, the transmission of the firing signal (addressed to setting tool **420**) to the setting tool **420** to initiate the ignition of energetic charge **448** also results in the separation of toolstring **400** and the plug **450**. Particularly, the force applied to housing **422** of setting tool **420** as a result of the rapid pressurization of combustion chamber **436** results in the severing of a frangible connection **451** (e.g., comprising one or more shear members or pins) formed between the setting tool **420** and the plug **450** whereby the toolstring **400** may be retrieved from the wellbore (e.g., wellbore **10**) leaving the set plug **450** within the wellbore anchored to the casing (e.g., casing string **15**) located therein. In this exemplary embodiment, the frangible connection **451** is formed between the downhole end **425** of the housing **422** of setting tool **420** and the uphole end **453** of the core **452** of plug **450**; however, it may be understood that in other embodiments the frangible connection **451** formed between setting tool **420** and plug **450** may be at locations other than the location shown in FIG. **15**.

[0101] Further, and referring now to FIGS. **16** and **17**, following the activation of setting tool **420**, the setting tool **420** separates from the plug **450** whereby the plug **450** remains in the wellbore **10** while the remainder of the toolstring **400** is retrieved to the surface. In this configuration, plug **450** remains in the wellbore **10** separating an uphole portion of the wellbore **10** (e.g., the portion of the wellbore **10** extending uphole from plug **450**) from a previously perforated and fracked downhole portion of the wellbore **10** (e.g., the portion of the wellbore **10** extending downhole from plug **450**).

[0102] Toolstring **400** simplifies the jobsite handling and assembly of the equipment forming the toolstring **400** in the field where weather and environment are often a concern but there are also concerns about minimizing the number of people required to accomplish tasks in the field. Particularly, in this exemplary embodiment, the setting tool **420** that is directly connected to the bottom gun **410** via a single physical or mechanical connection (indicated by arrow **412** in FIG. **15**) and by that single mechanical connection **412** being directly connected to the plug **450**. In this exemplary embodiment, mechanical connection **412** comprises a threaded connection formed between corresponding threads of the housing **414** of bottom gun **410** (e.g., internal threads formed on the downhole end **415** of housing **414** as shown in FIG. **15**) and threads of the mandrel **430** of setting tool **420** (e.g., external threads formed on the uphole end **431** of mandrel **430** as shown in FIG. **15**). However, in other embodiments, mechanical connection **412** may comprise mechanical connections other than threaded connections such as, for example, splined connections, keyed connections, etc.

[0103] By configuring the setting tool **420** to be shipped to the well site already connected to the plug and ready to connect to the bottom gun **410**, field operators of toolstring **400** need only lay out or position the bottom gun **410** end-to-end with setting tool **420** and makeup (e.g., screw or thread together) the single threaded connection **412** in a minimal amount of time. By this arrangement, a minimum of two connections (e.g., connections C**2** and C**3** shown in FIG. **14**) are eliminated with respect to conventional toolstrings (e.g., toolstring **70** shown in FIG. **14**). In addition, embodiments of toolstrings disclosed herein provide further simplification whereby the adapter kit has been obviated or eliminated and the setting tool is delivered to the wellsite with the plug **450** attached thereto.

[0104] To further understand the simplification of the setting tool **420**, referring back to FIG. **14**, the plug **71**, adapter kit **72** and setting tool **72** of the conventional toolstring **70** are typically delivered to the field separately. As such, in this example, the field hands onsite must bring these components together and make five separate mechanical (e.g., threaded) connections: (1) the firing head **74** to the setting tool **73**; (2) the setting tool **73** to the adapter kit **72**; (3) the adapter kit **72** to the plug **71**; (4) sub **75**A to a bottom gun **75**; and (5) the firing head **74** to the sub **75**A. Since the setting tool **73** and bottom gun **75** require the ignition of a flammable energetic charge and detonation of explosives, respectively, the designs of components requires access for shipping in an inherently safe condition and arming them at the job site, there are clear motivations for requiring some assembly at the wellsite. But, by the design of the toolstring **400** shown in FIG. **15**, arming and assembly can be accomplished with one connection made up at the wellsite at **412**, substantially streamlining the process of assembling the toolstring **400** such that the time required for performing a perforating operation using the toolstring **400** may be reduced in comparison to perforating operations performed using conventional toolstrings such as toolstring **70**.

[0105] While in some embodiments it may be preferred to deliver toolstring **400** to the wellsite with plugging assembly **421** preassembled with only mechanical connection **412** needing to be made up to attach plugging assembly **421** to bottom gun **410**, in other embodiments it may be preferred to ship the components of plugging assembly **421** separately to the wellsite. For example, it may be more onerous and/or expensive to ship plugging assembly **421** preassembled due to the positioning of initiator **444** and energetic charge **448** in close proximity during shipping which may require the shipper to have a specialized license (e.g., a specific commercial driver's license) which may be of limited availability. Thus, in at least some instances, it may instead be preferred to ship these components (e.g., initiator **444** and energetic charge **448**) separately to avoid the requirement of procuring a shipper having a specialized license.

[0106] Referring now to FIG. **18**, an embodiment of a toolstring assembly kit **500** is shown generally including bottom gun **410** (the charge carrier of bottom gun **410** not shown in FIG. **18**), setting tool **420**, a setting tool initiating cartridge **510**, and an energetic charge **550**. Setting tool initiating cartridge **510** shares features and functionalities in common the setting tool initiating cartridge **440** described above and generally includes a setting tool pressure bulkhead **512**, an initiator chassis **520**, addressable switch **446**, and initiator **444**. In this exemplary embodiment, chassis **520** (along with switch **446** and initiator **444**) is pre-attached to the pressure bulkhead **512** which provides both pressure isolation and electrical communication therethrough. The energetic charge **550** generally includes a cylindrical outer housing or cover **552**, a pair of primers **554** located at opposing longitudinal ends **551** of the energetic charge **550**, and energetic material **556** located longitudinally between the pair of primers **554**. Primers **554** are generally configured to activate or ignite the energetic material **556** in response to the communication of a ballistic signal from the initiator **444** to the respective primer **554**.
[0107] In this exemplary embodiment, the perforating gun **410**, setting tool **420**, setting tool initiating cartridge **510**, and energetic charge **550** may each be shipped separately to a given wellsite for performing a perforating operation. During shipping, internal threads of the housing **414** of bottom gun **410** are protected by a pair of gun thread protectors **540** of assembly kit **500** that are inserted into the housing **414**. Additionally, during shipping, external threads of the mandrel **430** are protected by a mandrel thread protector **542** of assembly kit **500**. In this manner, the internal threads of housing **414** and the external threads of mandrel **430** may be protected from being inadvertently damaged during shipping to the wellsite.
[0108] Upon arriving at the wellsite, the energetic charge **550** may be manually inserted or slid into the passage **432** of the mandrel **430** of setting tool **420**. With energetic charge **550** received in passage **432** of mandrel **430**, the setting tool initiating cartridge **510** is manually inserted into the passage **432** of mandrel **430** adjacent the previously inserted energetic charge **550**. In this exemplary embodiment, the pressure bulkhead **512** of setting tool initiating cartridge **510** is threaded into the passage **432** of mandrel **430**; however, it may be understood that in other embodiments setting tool initiating cartridge **510** (including bulkhead **512**) may simply be slid into (rather than threaded into) the passage **432** of mandrel **430**. With setting tool initiating cartridge **510** received in the passage **432** of mandrel **430** along with energetic charge **550**, mechanical connection **412** may be formed between bottom gun **410** and setting tool **420** to complete the assembly of assembly kit **500** at the wellsite.
[0109] It may be appreciated that it does not matter which end **551** of energetic charge **550** is positioned adjacent the setting tool initiating cartridge **510** given that each end **551** of charge **550** is provided with a separate primer **554** for igniting the energetic material **556** of energetic charge **550**. In this manner, the energetic charge **550** cannot be inadvertently installed in an incorrect orientation (unlike conventional energetic charges comprising a primer located at only one end thereof) in the setting tool **420** which could potentially prevent successful activation of the setting tool **420**.
[0110] Referring now to FIGS. **19** and **20**, additional views of the setting tool initiating cartridge **510** are shown. Setting tool initiating cartridge **510** extends along a longitudinal or central axis **511**. In this exemplary embodiment, setting tool pressure bulkhead **512** extends between a first or uphole end **513** and a second or downhole end **515** longitudinally opposite uphole end **513**. Additionally, setting tool pressure bulkhead **512** defines an internal passage **516** extending between ends **513** and **515** and which houses a sealed, pressor-isolating electrical pass-thru or connector **518**. In this configuration, fluid pressure at the downhole end **515** of setting tool pressure bulkhead **512** is prevent from communicating through internal passage **516** to the uphole end **513** of the setting tool pressure bulkhead **512**. Additionally, one or more annular seal assemblies **517** are positioned along a radially outer surface or periphery of the setting tool pressure bulkhead **512**.
[0111] The initiator chassis **520** of setting tool initiating cartridge **510** has a central or longitudinal axis and extends between a first or uphole end **521** and a second or downhole end **523**

longitudinally opposite uphole end **521**. The uphole end **521** of initiator chassis **520** mechanically couples (e.g., via one or more fasteners) to the downhole end **515** of setting tool pressure bulkhead **512** in this exemplary embodiment. Initiator chassis **520** defines an internal receptacle **522** formed between ends **521** and **523** and which receives setting tool initiator **444** and addressable switch **446**. Additionally, setting tool initiating cartridge **510** includes an initiator electrical connector or contact pin **524** housed within a generally cylindrical, electrically insulating housing **526**, each of which is received in the internal receptacle **522** of initiator chassis **520**

[0112] In this exemplary embodiment, setting tool initiator **444** and addressable switch **446** axially overlap along the central axis **511** of setting tool initiating cartridge such that an orthogonal axis **519** extending orthogonally from central axis **511** intersects both the setting tool initiator **444** and addressable switch **446**. The axial overlap or stacking of setting tool initiator **444** and addressable switch **446** permits the advantageous minimization of the axial length of initiator chassis **520** as the chassis **520** would need to be axially lengthened to accommodate both the setting tool initiator **444** and addressable switch **446** should the initiator **444** and switch **446** not axially overlap. Additionally, in this exemplary embodiment, a longitudinal or central axis of the setting tool initiator **444** is offset from (e.g., extends parallel but offset from) the central axis **511** of setting tool initiating cartridge **510**. Similarly, in this exemplary embodiment, a longitudinal or central axis of the addressable switch **446** is offset from (e.g., extends parallel but offset from) the central axis **511** of setting tool initiating cartridge **510**. In other embodiments, the arrangement of the central axes of setting tool initiator **444** and addressable switch **446** may vary from that shown in FIGS. **19** and **20**.

[0113] In this exemplary embodiment, insulating housing **526** of setting tool initiating cartridge **510** includes one or more radially extending ports **528** configured to provide physical access to the initiator contact pin **524** without needing to disassemble the setting tool initiating cartridge **510**. Upon arriving at the wellsite and prior to being assembled with a corresponding setting tool mandrel (e.g., mandrel **430** of setting tool **420**), the setting tool initiating cartridge **510** may tested to ensure electrical continuity of a cartridge electrical circuit defined by, among other components, setting tool initiator **444**, addressable switch **446**, and initiator contact pin **524**. For example, an operator of setting tool initiating cartridge **510** may contact a probe (using one of the radial ports **528** of insulating housing **526**) of a measurement device such as a multimeter or similar device to detect an electrical property such as, for example, the electrical resistance of the cartridge electrical circuit. The operator may then determine, based on whether the detected resistance corresponds to a predefined reference resistance (e.g., whether the detected resistance falls within a predefined reference resistance range), whether the respective setting tool initiating cartridge **510** is suitable for operation. For example, if the detected resistance fails to correspond with the reference resistance, the operator may determine that a fault has occurred in the cartridge electrical circuit stemming from, for example, a lack of electrical continuity in the cartridge electrical circuit, a failure of one of the electrical components (e.g., setting tool initiator **444**, addressable switch **446**) of the cartridge electrical circuit, and the like. The faulty setting tool initiating cartridge **510** may then be replaced with an operational cartridge **510** before the faulty cartridge **510** is assembled with a corresponding setting tool mandrel and run into the wellbore, where discovering said fault in the faulty cartridge **510** will have significantly more expensive and time-consuming consequences (e.g., the entire tool string may need to be removed from the wellbore in order to replace the single faulty cartridge **510**).

[0114] In this exemplary embodiment, setting tool initiating cartridge **510** additionally includes a sacrificial electrical conductor or cable **530** (a component of the cartridge electrical circuit) which is electrically connected between the electrical connector **518** of setting tool pressure bulkhead **512** and addressable switch **446**. Particularly, sacrificial electrical cable **530** extends into the internal receptacle **522** of initiator chassis **520** via an uphole opening **525** of chassis **520** located at the uphole end **521** thereof. Sacrificial electrical cable **530** extends through the internal receptacle **522** of cartridge chassis **520** and exits receptacle **522** via one of a pair of downhole openings **527** of chassis **520** located at the downhole end **523** thereof. Additionally, sacrificial electrical cable **530** returns into the internal receptacle **522** of initiator chassis **520** via a second of the downhole openings **527** such that cable **530** may electrically connect to addressable switch **446**.

[0115] In the configuration described above, a portion of sacrificial electrical cable **530** (referred to herein as the "external portion" of cable **530**) is located external the internal receptacle **522** of initiator chassis **520** at the downhole end **523** thereof. In this arrangement, upon activation of initiator **444** (e.g., in response to the addressable switch **446** receiving a suitable firing signal), initiator **444** ejects a stream of high-pressure, high-temperature material from the downhole end **523** of initiator chassis **520** in proximity of the external portion of sacrificial electrical cable **530**. The high-temperature, high-pressure materials ejected from the downhole end **523** of initiator chassis **520** severs the electrical connection formed across sacrificial electrical cable **530**, thereby electrically disconnecting addressable switch **446** from the surface (e.g., from surface assembly **11**). The severing of the electrical connection across sacrificial electrical cable **530**, and the resulting disconnection of addressable switch **446**, may be registered by a surface assembly connected to the toolstring containing the respective setting tool initiating cartridge **510**. For example, a display of the surface assembly may indicate to an operator of the toolstring that addressable switch **446** is no longer present or connected to the surface assembly, indicating to the operator that the setting tool initiating cartridge **510** has successfully activated downhole. The severing of the electrical connection along sacrificial electrical cable **530** thus provides a surface indication to an operator of the toolstring comprising the respective cartridge **510** of the successful activation of the cartridge **510**.

[0116] In some embodiments, setting tool initiating cartridge **510** comprises a disposable component of the setting tool **420** shown in FIG. **18** such that, after running a toolstring comprising setting tool **420** into a wellbore (e.g., wellbore **20**) and setting a plug (e.g., plug **450**) of the toolstring using the setting tool **420**, the toolstring may be retrieved to the surface and serviced by replacing the original setting tool initiating cartridge **510** of setting tool **420** with a new setting tool initiating cartridge **510**. In this process of servicing the toolstring, the mandrel **430** and housing **414** of setting tool **420** may be kept (e.g., not replaced during servicing of the toolstring) such that the new setting tool initiating cartridge **510** is received in the internal passage **432** of the original mandrel **430** of setting tool **420**. The serviced toolstring may be then be run into another wellbore (e.g., the same wellbore or a different wellbore) to set a new plug therein.

[0117] Referring again to FIG. **18**, in some instances, it may be preferable to connect the setting tool **420** to the perforating gun **410** through an adapter configured to mate the setting tool **420** to the perforating gun **410**. Referring now to FIG. **21**, an embodiment of a toolstring **560** is shown including a setting tool adapter **570**. Particularly, in this exemplary embodiment, toolstring **560** generally includes perforating gun **410**, setting tool **420** (including setting tool initiating cartridge **510**), and setting tool adapter **570**. Toolstring **560** may additionally include a plug (e.g., plug **450**) not shown in FIG. **21** connected to the downhole end of setting tool **420** and which may be set of the setting tool **420** in response to an activation of the setting tool **420**.

[0118] In this exemplary embodiment, setting tool adapter **570** is generally cylindrical and extends between a first or uphole end **571** and a second or downhole end **573** longitudinally opposite uphole end **571**. Additionally, setting tool adapter **570** defines an internal passage **572** extending between ends **571** and **573** and which houses a sealed, pressor-isolating electrical pass-thru or connector **574**. In this configuration, fluid pressure at the downhole end **573** of setting tool adapter **570** is prevent from communicating through internal passage **572** to the uphole end **571** of the setting tool adapter **570**. Additionally, electrical connector **574** electrically connects the perforating gun **410** with the setting tool **420** of toolstring **560**.

[0119] In this exemplary embodiment, setting tool adapter **570** includes an annular uphole connector **576** located at the uphole end **571** thereof, and an opposing annular downhole connector **578** located at the downhole end **573** thereof. Downhole connector **578** of setting tool adapter **570** is configured to mechanically connect (e.g., threadably connect) to a corresponding connector formed on the uphole end **431** of the mandrel **430** of setting tool **420**. Additionally, the uphole connector **576** of setting tool adapter **570** is configured to mechanically connect (e.g., threadably connect) to the downhole end **415** of the outer housing **414** of perforating gun **410**. In this exemplary embodiment, setting tool adapter **570** comprises a pin-by-box adapter whereby the uphole connector **576** comprises a pin connector while the downhole connector **578** comprises a box connector. In other embodiments, setting tool adapter **570** may comprise a pin-by-pin adapter, a box-by-box adapter, and a box-by-pin adapter.

[0120] In this manner, setting tool adapter **470** may adapt setting tool **420** such that setting tool **420** may mechanically connect with perforating gun **410** through or via the setting tool adapter **570**. For example, the type of connector (e.g., the size or configuration of the connector) located at the uphole end **431** of the mandrel **430** of setting tool **420** may not be connectable to the type of connector located at the downhole end **415** of the outer housing **414** of perforating gun **410**, preventing perforating gun **410** from connecting directly with the uphole end **431** of the mandrel **430** of setting tool **420**. In such instances, setting tool adapter **470** may be utilized to form an indirect mechanical connection between the perforating gun **410** and setting tool **420** such that each component may be assembled along the same toolstring **560**.

[0121] Referring to FIG. **21**, another embodiment of a toolstring **580** is shown including a setting tool adapter **590**. Particularly, toolstring **580** is similar to the toolstring **560** shown in FIG. **22** except that, in this exemplary embodiment, electrical switch **446** is located within a central passage **592** of the setting tool adapter **590** rather than in the setting tool initiating cartridge **520**. Thus, in this exemplary embodiment, electrical switch **446** does not enter into signal (e.g., electrical) communication with setting tool initiator **444** until setting tool adapter **590** and setting tool **420** are physically attached together.

[0122] While exemplary embodiments have been shown and described, modifications thereof can be made by one skilled in the art without departing from the scope or teachings herein. The embodiments described herein are exemplary only and are not limiting. Many variations and modifications of the systems, apparatus, and processes described herein are possible and are within the scope of the disclosure presented herein. For example, the relative dimensions of various parts, the materials from which the various parts are made, and other parameters can be varied. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims. Unless expressly stated otherwise, the steps in a method claim may be performed in any order. The recitation of identifiers such as (a), (b), (c) or (1), (2), (3) before steps in a method claim are not intended to and do not specify a particular order to the steps, but rather are used to simplify subsequent reference to such steps.

Claims

1. A setting tool for setting a downhole plug in a wellbore extending through a subterranean formation, the setting tool comprising: an elongate housing extending between an uphole end and a downhole end opposite the uphole end and which defines an open passageway extending from the uphole end to the downhole end of the housing, and wherein the housing has a minimum outer diameter and a maximum outer diameter that is less than 5% larger than the minimum outer diameter; and an elongate mandrel positioned in the open passageway and having an uphole end and a downhole end opposite the uphole end, and a combustion chamber located within the elongate housing for receiving an energetic charge; wherein an inner surface of the downhole end of the housing defines a connector for coupling to the downhole plug.

2. The setting tool of claim 1, wherein the housing extends monolithically from the uphole end to the downhole end thereof.

3. The setting tool of claim 1, wherein the housing has a minimum outer diameter and a maximum outer diameter that is less than half an inch larger than the minimum outer diameter.
4. The setting tool of claim 1, wherein the housing has a minimum outer diameter and a maximum outer diameter that is less than three eights of an inch larger than the minimum outer diameter.
5. The setting tool of claim 1, wherein the minimum outer diameter of the housing is substantially equal to the maximum outer diameter.
6. The setting tool of claim 1, wherein the housing defines a plurality of radial ports providing a fluid flowpath between the open passageway and an external environment surrounding the setting tool.
7. The setting tool of claim 1, further comprising an energetic charge installed in the combustion chamber.
8. A plugging assembly for hydraulically separating a wellbore into separate uphole and downhole zones where the wellbore includes casing, the plugging assembly comprising: a downhole plug comprising an elongate core with an uphole end and a downhole end opposite the uphole end, a sealing element disposed fully around the core to seal against the casing, an anchoring system for anchoring the plug to the casing in a fixed position, a compression fitting disposed around the core at or near the uphole end of the core, a nose at the downhole end of the core, wherein the sealing element and the anchoring system have an initial configuration having an outer maximum run-in diameter, and an expanded configuration having an outer maximum expanded diameter that is greater than the maximum run-in diameter; and a setting tool comprising an elongate housing extending between an uphole end and a downhole end opposite the uphole end, an open passageway extending from the uphole end to the downhole end of the housing, and wherein the setting tool further includes an elongate mandrel positioned in the open passageway and having an uphole end and a downhole end opposite the uphole end, and a combustion chamber located within the elongate housing for receiving an energetic charge; wherein the housing of the setting tool has a minimum outer diameter and a maximum outer diameter that is less than 5% larger than the minimum outer diameter; wherein an inner surface of the downhole end of the housing defines a connector for engaging the compression fitting of the plug.
9. The setting tool of claim 8, wherein the housing of the setting tool extends monolithically from the uphole end to the downhole end thereof.
10. The setting tool of claim 8, wherein the housing of the setting tool has a minimum outer diameter and a maximum outer diameter that is less than half an inch larger than the minimum outer diameter.
11. The setting tool of claim 8, wherein the housing of the setting tool has a minimum outer diameter and a maximum outer diameter that is less than three eights of an inch larger than the minimum outer diameter.
12. The setting tool of claim 8, wherein the minimum outer diameter of the housing of the setting tool is substantially equal to the maximum outer diameter.
13. The setting tool of claim 8, further comprising an energetic charge installed in the combustion chamber of the setting tool.
14. The setting tool of claim 8, wherein: the setting tool is configured to apply a first axially compressive force in a downhole direction against the sealing element of the plug and simultaneously a second axially compressive force in an uphole direction against the sealing element of the plug; and the setting tool is configured to apply the first axially compressive force from the housing, through the compression fitting, and against an uphole end of the sealing element in the downhole direction, and from the mandrel, through the nose, and against a downhole end of the sealing element in the uphole direction.
15. A toolstring for plugging and perforating a wellbore including casing and extending through a subterranean formation, the toolstring comprising: a perforating gun extending between an uphole end and a downhole end longitudinally opposed to the uphole end; and a plugging assembly

connectable to the perforating gun and extending between an uphole end and a downhole end longitudinally opposed to the uphole end of the plugging assembly, the plugging assembly comprising: a setting tool comprising an elongate housing extending between an uphole end and a downhole end opposite the uphole end of the housing, an open passageway extending from the uphole end to the downhole end of the housing, and wherein the setting tool further includes an elongate mandrel positioned in the open passageway and having an uphole end and a downhole end opposite the uphole end of the mandrel, and a combustion chamber located within the elongate housing for receiving an energetic charge, wherein the housing has a minimum outer diameter and a maximum outer diameter that is less than 5% larger than the minimum outer diameter; and a downhole plug attached to the setting tool, the plug comprising an elongate core with an uphole end and a downhole end opposite the uphole end of the core, a sealing element disposed fully around the core to seal against the casing, an anchoring system for anchoring the plug to the casing in a fixed position, a compression fitting disposed around the core at or near the uphole end of the core, a nose at the downhole end of the core, wherein the sealing element and the anchoring system have an initial configuration having an outer maximum run-in diameter, and an expanded configuration having an outer maximum expanded diameter that is greater than the maximum run-in diameter.
16. The toolstring of claim 15, wherein the housing of the setting tool extends monolithically from the uphole end to the downhole end thereof.
17. The toolstring of claim 15, wherein the housing of the setting tool has a minimum outer diameter and a maximum outer diameter that is less than half an inch larger than the minimum outer diameter.
18. The toolstring of claim 15, wherein the housing of the setting tool has a minimum outer diameter and a maximum outer diameter that is less than three eights of an inch larger than the minimum outer diameter.
19. The toolstring of claim 15, wherein the minimum outer diameter of the housing of the setting tool is substantially equal to the maximum outer diameter.
20. The toolstring of claim 15, wherein: the setting tool is configured to apply a first axially compressive force in a downhole direction against the sealing element of the plug and simultaneously a second axially compressive force in an uphole direction against the sealing element of the plug; and the setting tool is configured to apply the first axially compressive force from the housing, through the compression fitting, and against an uphole end of the sealing element in the downhole direction, and from the mandrel, through the nose, and against a downhole end of the sealing element in the uphole direction.