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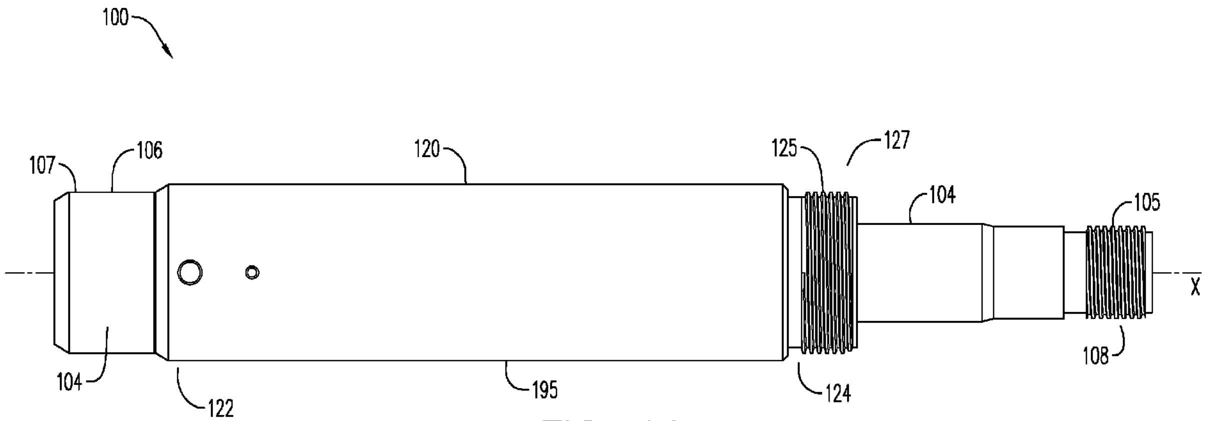

FIG. 1A

(57) Abrégé/Abstract:
A single use setting tool (100) for actuating a tool (102) in a wellbore includes an inner piston (104) extending through a central bore of an outer sleeve (120). The inner piston (104) has a seal adapter portion (107) and a piston cavity (114) housing an initiator holder (138) for receiving a push-in detonator. A gas diverter channel is open to and extends from the piston cavity through an annular wall of the piston, to transfer gas pressure to a gas expansion chamber for stroking the outer sleeve. A method of actuating a wellbore tool (102) with a single use setting tool (100) includes inserting an initiator (118) into the initiator holder (138), attaching a tandem seal adapter to the seal adapter portion of the inner piston (104), and relaying an electrical signal to a line-in portion of the initiator, to initiate the initiator (118). The single use setting tool (100) may be used in a wellbore tool string.

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(54) **Title:** A SINGLE USE SETTING TOOL FOR ACTUATING A TOOL IN A WELLBORE

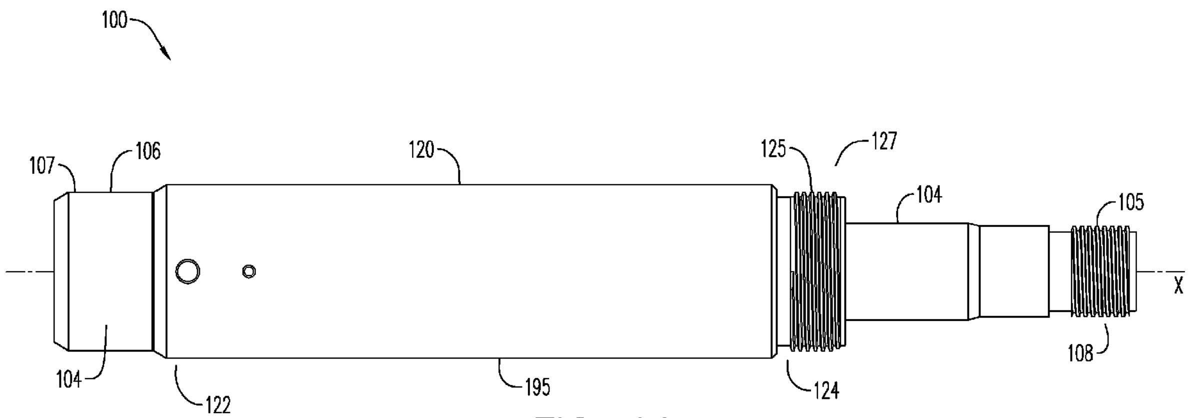

FIG. 1A

(57) **Abstract:** A single use setting tool (100) for actuating a tool (102) in a wellbore includes an inner piston (104) extending through a central bore of an outer sleeve (120). The inner piston (104) has a seal adapter portion (107) and a piston cavity (114) housing an initiator holder (138) for receiving a push-in detonator. A gas diverter channel is open to and extends from the piston cavity through an annular wall of the piston, to transfer gas pressure to a gas expansion chamber for stroking the outer sleeve. A method of actuating a wellbore tool (102) with a single use setting tool (100) includes inserting an initiator (118) into the initiator holder (138), attaching a tandem seal adapter to the seal adapter portion of the inner piston (104), and relaying an electrical signal to a line-in portion of the initiator, to initiate the initiator (118). The single use setting tool (100) may be used in a wellbore tool string.

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A SINGLE USE SETTING TOOL FOR ACTUATING A TOOL IN A WELLBORE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to United States Patent Application No. 16/858,041 filed April 24, 2020. This application claims the benefit of United States Provisional Patent Application No. 62/847,488 filed May 14, 2019. This application claims the benefit of United States Provisional Patent Application No. 62/862,867 filed June 18, 2019. This application claims the benefit of United States Provisional Patent Application No. 62/908,747 filed October 1, 2019. The entire contents of each application listed above are incorporated herein by reference.

BACKGROUND OF THE DISCLOSURE

[0002] Oil and gas are extracted by subterranean drilling and introduction of machines into the resultant wellbore. It is often advantageous or required that portions of a wellbore be sealed off from other portions of the wellbore. Among other functions, a running or setting tool is utilized to place plugs at locations inside the wellbore to seal portions thereof from other portions.

[0003] Primarily used during completion or well intervention, a plug isolates a part of the wellbore from another part. For example, when work is carried out on an upper section of the well, the lower part of the wellbore must be isolated and plugged; this is referred to as zonal isolation. Plugs can be temporary or permanent. Temporary plugs can be retrieved whereas permanent or frac plugs can only be removed by destroying them with a drill. There are a number of types of plugs, e.g., bridge plugs, cement plugs, frac plugs and disappearing plugs. Plugs may be set using a setting tool conveyed on wire-line, coiled tubing or drill pipe.

[0004] In a typical operation, a plug can be lowered into a well and positioned at a desired location in the wellbore. A setting tool may be attached to and lowered along with the plug or it may be lowered after the plug, into an operative association therewith. The setting tool may include a power charge and a piston; activation of the power charge results in a substantial force by means of combustion being exerted on the setting tool piston. When it is desired to set the plug, the power charge is initiated, resulting in the power charge burning, pressure being generated and the piston being subjected to a substantial force. The piston being constrained to movement in a single direction, the substantial force causes the piston to move axially and actuate the plug to seal a desired area of the well. The substantial force exerted by the power charge on the piston can also shear one or more shear pins or similar frangible members that serve certain functions, e.g., holding the piston in place prior to activation and separating the setting tool from the plug.

[0005] The force applied to a plug by the power charge and/or setting tool piston must be controlled; it must be sufficient to set the plug or to similarly actuate other tools but excessive force may damage the setting tool, other downhole tools or the wellbore itself. Also, even a very strong explosive force can fail to actuate a tool if delivered over a too short time duration. Even if a strong force over a short time duration will actuate a tool, such a set-up is not ideal. That is, a power charge configured to provide force over a period of a few seconds instead of a few milliseconds is sometimes preferred; such an actuation is referred to as a “slow set”. Favorable setting characteristics may be provided with either a fast set or a slow set, depending on the tool being set and other parameters.

[0006] Existing setting tools and techniques involve multiple components, many of which need to have precise tolerances. Thus, current setting tools are complex, heavy, of substantial axial length and expensive. The complexity and important functions served by setting tools has resulted in the need, primarily driven by economic and efficiency considerations, of a reusable setting tool. That is, the substantial number of expensive components and importance of ‘knowing,’ from an engineering perspective, exactly how a setting tool is going to operate under a particular set of circumstances, resulted in the need to reuse a setting tool a number of times. Thus, a typical setting tool is retrieved from the wellbore after use and ‘reset’ prior to its next run down the wellbore. Resetting a setting tool involves fairly laborious steps performed by a skilled operator to prepare, i.e., clean the used tool, replace the consumable parts and otherwise place the setting tool in ‘usable’ condition. Consumable parts in a setting tool may include the power charge, power charge initiating/boosting elements, elastomers, oil, burst discs and/or shear elements/screws. The combustible/explosive nature of the power charge as well as the initiating/booster elements present another set of issues regarding the need for a skilled operator/resetting.

[0007] In view of the disadvantages associated with currently available setting tools, there is a need for a safe, predictable and economical setting tool in the wellbore industry. Economy may be achieved with fewer parts operating in a simpler manner. The fewer/simpler parts may be fabricated from less expensive materials and subject to less stringent engineering tolerances though, nonetheless, operate as safely and predictably as current tools. The cost savings for this setting tool will make it economically feasible to render the tool single use, resulting in even greater cost savings from having to clean and reset the setting tool, eliminating the skilled work required to do so as well as the supply chain for consumable elements of the reusable setting tool.

BRIEF DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0008] In an aspect, the disclosure relates to a single use setting tool for actuating a tool in a wellbore. The single use setting tool is a two-piece tool having an inner piston with a piston proximal end and a piston distal end opposite the piston proximal end, and a piston annular wall. The piston proximal end includes a seal adapter portion and the piston annular wall defines a piston cavity within which at least a portion of an initiator holder is positioned. The initiator holder is configured for receiving and retaining an initiator in a first position that is within the piston proximal end and coaxial with the seal adapter portion. A gas diverter channel is open to and extends from the piston cavity through the piston annular wall. There is an outer sleeve having a sleeve proximal end and a sleeve distal end opposite the sleeve proximal end, and a sleeve central bore extending from the sleeve proximal end to the sleeve distal end. A portion of the inner piston including the piston cavity is positioned within the sleeve central bore and the inner piston and the outer sleeve are configured for axially sliding relative to one another. Finally, an expansion chamber is defined by an inner portion of the outer sleeve and an outer portion of the annular wall of the inner piston, and the gas diverter channel is open to the expansion chamber through the outer portion of the annular wall of the inner piston.

[0009] In an aspect, the disclosure relates to a method of actuating a wellbore tool with a single use setting tool. The method includes connecting the single use setting tool to the wellbore tool and the single use setting tool includes an inner piston having a piston proximal end including a seal adapter portion, a piston distal end opposite the piston proximal end, and a piston annular wall that defines a piston cavity. The seal adapter portion is configured for connecting to a first connecting portion of a seal adapter. The seal adapter includes a seal adapter inner bore and an electrical feedthrough bulkhead positioned within the inner bore of the seal adapter. A power charge and an initiator holder are positioned within the piston cavity. A gas diverter channel is open to and extends from the piston cavity through the piston annular wall, and there is an outer sleeve having a sleeve proximal end, a sleeve distal end, and a sleeve central bore extending from the sleeve proximal end to the sleeve distal end. A portion of the inner piston including the piston cavity is positioned within the sleeve central bore and the inner piston and the outer sleeve are configured for axially sliding relative to one another. An expansion chamber is defined by an inner portion of the outer sleeve and an outer portion of the annular wall of the inner piston, and the gas diverter channel is open to the expansion chamber through the outer portion of the annular wall of the inner piston. The method further includes inserting an initiator into the initiator holder and connecting the first connecting portion of the seal adapter to the seal adapter portion of the inner piston. The seal adapter and the electrical feedthrough bulkhead are together configured such that a first electrical connection of the electrical feedthrough bulkhead is in electrical communication with a line-in portion of the initiator when the seal adapter is connected to the seal adapter portion of the inner piston. Then connecting a second connecting portion of the seal adapter to an upstream wellbore tool, and the seal adapter and the electrical feedthrough bulkhead are together configured such that a second electrical connection of the electrical feedthrough bulkhead is in electrical communication with an electrical relay of the upstream wellbore tool when the seal adapter is connected to the upstream wellbore tool. Then deploying the upstream wellbore tool, single use setting tool, and wellbore tool into a wellbore. When a desired position is reached, relaying an electrical signal from the electrical relay of the upstream wellbore tool to the initiator via the electrical feedthrough bulkhead and initiating the initiator in response to receiving the electrical signal from the first electrical connection of the electrical feedthrough bulkhead at the line-in portion of the initiator.

[0010] In an aspect, the disclosure relates to a wellbore tool string. The wellbore tool string includes a seal adapter with an inner bore and an electrical feedthrough bulkhead positioned within the seal adapter inner bore. The wellbore tool string further includes a single use setting tool including an inner piston and an outer sleeve. The inner piston has a piston proximal end including a seal adapter portion, a piston distal end opposite the piston proximal end, and a piston annular wall that defines a piston cavity. The seal adapter portion is configured for connecting to a first connecting portion of the seal adapter. A power charge and an initiator holder are positioned within the piston cavity. A gas diverter channel is open to and extends from the piston cavity through the piston annular wall. The outer sleeve has a sleeve proximal end, a sleeve distal end, and a sleeve central bore extending from the sleeve proximal end to the sleeve distal end. A portion of the inner piston including the piston cavity is positioned within the sleeve central bore and the inner piston and the outer sleeve are configured for axially sliding relative to one another. An expansion chamber is defined by an inner portion of the outer sleeve and an outer portion of the annular wall of the inner piston, and the gas diverter channel is open to the expansion chamber through the outer portion of the annular wall. An initiator is received in the initiator holder and includes an electrically contactable line-in portion and a first electrical connection of the electrical feedthrough bulkhead is in electrical contact with the electrically contactable line-in portion of the initiator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A more particular description will be rendered by reference to exemplary embodiments that are illustrated in the accompanying figures. Understanding that these drawings depict exemplary embodiments and do not limit the scope of this disclosure, the exemplary embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0012] FIG. 1A is a plan view of a single use setting tool for actuating a tool in a wellbore, according to an exemplary embodiment;

[0013] FIG. 1B is a perspective, quarter-sectional view of the single use setting tool of FIG. 1;

[0014] FIG. 2 is a detailed, quarter-sectional view of the single use setting tool of FIG. 1;

[0015] FIG. 3A is a side, cross-sectional view of the single use setting tool, according to an exemplary embodiment;

[0016] FIG. 3B is a perspective view of a power charge for use in the single use setting tool;

[0017] FIG. 4 is a detailed, cross-sectional view of a portion of the single use setting tool, according to an exemplary embodiment;

[0018] FIG. 5A is a detailed, cross-sectional side view of the proximal end of the single use setting tool, according to an exemplary embodiment;

[0019] FIG. 5B is a detailed, cross-sectional side view of the proximal end of the single use setting tool, according to an exemplary embodiment, subsequent to the melting/consumption of the initiator holder during operation of the setting tool thus disconnecting the igniter from the line in;

[0020] FIG. 6 is a breakout view of the two-piece, single use setting tool according to an exemplary embodiment;

[0021] FIG. 7 is a cross sectional view of a single use setting tool including a shock absorbing assembly according to an exemplary embodiment;

[0022] FIG. 7A is a perspective view of an outer sleeve for a single use setting tool according to an exemplary embodiment;

[0023] FIG. 8 is a cross sectional view of a single use setting tool including a shock absorbing assembly according to an exemplary embodiment;

[0024] FIG. 9 is a cross sectional view of a single use setting tool including a stroke limiting wedge according to an exemplary embodiment;

[0025] FIG. 9A is a cross sectional view of a single use setting tool at mid-stroke including a stroke limiting wedge with retainer according to an exemplary embodiment;

[0026] FIG. 9B is a cross sectional view of a single use setting tool at end of stroke including a stroke limiting wedge with retainer according to an exemplary embodiment;

[0027] FIG. 10 is a bottom perspective view of a booster holder according to an exemplary embodiment;

[0028] FIG. 11 is a top perspective view of the booster holder of FIG. 10;

[0029] FIG. 12 is a side view of the booster holder of FIG. 10;

[0030] FIG. 13 is a top plan view of the booster holder of FIG. 10;

[0031] FIG. 14 is a perspective view of a hexagonally shaped power charge and container according to an exemplary embodiment;

[0032] FIG. 15 is a cross sectional view of a power charge with a booster holder and booster pellet inserted therein, according to an exemplary embodiment;

[0033] FIG. 16 is a cross-sectional view of a hexagonally shaped power charge positioned within a cavity of an inner piston of a single use setting tool according to an exemplary embodiment;

[0034] FIG. 17 shows a single use setting tool as part of a wellbore tool string according to an exemplary embodiment;

[0035] FIG. 18 shows a piston connection to a setting sleeve mandrel according to an exemplary embodiment;

[0036] FIG. 19 shows a perspective view of a single use setting tool with a shock blocking structure according to an exemplary embodiment;

[0037] FIG. 20 shows a perspective view of a single use setting tool with a shock blocking structure according to an exemplary embodiment; and,

[0038] FIG. 21 shows a cross-sectional view of a single use setting tool with an axial vent according to an exemplary embodiment.

[0039] Various features, aspects, and advantages of the exemplary embodiments will become more apparent from the following detailed description, along with the accompanying drawings in which like numerals represent like components throughout the figures and detailed description. The various described features are not necessarily drawn to scale in the drawings but are drawn to emphasize specific features relevant to some embodiments.

[0040] The headings used herein are for organizational purposes only and are not meant to limit the scope of the disclosure or the claims. To facilitate understanding, reference numerals have been used, where possible, to designate like elements common to the figures.

DETAILED DESCRIPTION

[0041] Reference will now be made in detail to various embodiments. Each example is provided by way of explanation and is not meant as a limitation and does not constitute a definition of all possible embodiments.

[0042] In the description that follows, the terms “setting tool,” “mandrel,” “initiator,” “power charge,” “piston,” “bore,” “grooves,” “apertures,” “channels,” and/or other like terms are to be interpreted and defined generically to mean any and all of such elements without limitation of industry usage. Such terms used with respect to embodiments in the drawings should not be understood to necessarily connote a particular orientation of components during use.

[0043] For purposes of illustrating features of the exemplary embodiments, examples will now be introduced and referenced throughout the disclosure. Those skilled in the art will recognize that these examples are illustrative and not limiting and is provided purely for explanatory purposes. In the illustrative examples and as seen in FIGS. 1–21, single use setting tools for actuating a tool in a wellbore are disclosed. The single use setting tools do not require a separate firing head or power charge, rather an ignition system and power charge are a part of the single use setting tools. A bulkhead seal and an electrical connector are connected within a proximal end of the single use setting tools for setting off the power charge. Further to the structure and usage of the initiator, U.S. Patent No. 9,581,422, commonly owned by DynaEnergetics Europe GmbH, is incorporated herein by reference in its entirety. Although U.S. Patent No. 9,581,422 describes a "detonator," this component is more accurately referred to as an initiator or igniter when used with a power charge because the power charge herein does not explode; rather, the power charge deflagrates, i.e., is consumed by combustion. The initiator 118 (FIG. 1B) presented herein may contain different energetic material than the detonator of U.S. Patent No. 9,581,422 but is otherwise of the same structure.

[0044] FIGS. 1A and 1B show an exemplary embodiment of a single use setting tool 100 according to this disclosure. The exemplary embodiment shown in FIGS. 1A and 1B includes, among other things and without limitation, an inner piston 104 and an outer sleeve 120. The inner piston 104 includes a proximal end 106 and a distal end 108 opposite the proximal end 106 and extends through a central bore 126 formed within the outer sleeve 120. In the exemplary embodiment, the inner piston 104 and the outer sleeve 120 are generally cylindrical and coaxially assembled about a center axis *x*. The proximal end 106 of the inner piston extends beyond a sleeve proximal end 122 of the outer sleeve 120. The distal end 108 of the inner piston 104 and a portion of a distal rod 109 of the inner piston 104 extend beyond a sleeve distal end 124 opposite the sleeve proximal end 122 of the outer sleeve 120.

[0045] The proximal end 106 of the inner piston 104 includes and transitions into a seal adapter portion 107 of the inner piston 104. In the exemplary embodiment, the seal adapter portion 107 is an integral portion of the inner piston 104 formed as an area of increased diameter with an inner threaded portion 508 for receiving and connecting to a seal adapter (e.g., a "tandem seal adapter (TSA)") 512 (FIGS. 5A and 5B). For purposes of this disclosure, "integral" and "integrally" respectively mean a single piece and formed as a single piece. The distal end 108 of the inner piston 104 includes an external threaded portion 105 for connecting to a wellbore tool such as a plug setting sleeve 602 (FIG. 17) as discussed further below.

[0046] The sleeve distal end 124 of the outer sleeve 120 includes and transitions into a plug-setting sleeve connecting portion 127 of the outer sleeve 120. In the exemplary embodiment, the plug-setting sleeve connecting portion 127 is an integral portion of the outer sleeve 120 formed as an area of reduced diameter with an outer threaded portion 125 for being received within and connecting to a tool 102 such as a plug-setting sleeve 602 (FIG. 17) as discussed further below.

[0047] While the exemplary embodiments are being described for ease in understanding with reference to, e.g., connecting portions and connections between the single use setting tool 100 and particular wellbore tools such as the seal adapter 512 and the plug-setting sleeve 602, neither the use of the single use setting tool 100 nor the various connective components thereof is so limited. The single use setting tool 100 may be used or connected according to this disclosure with a variety of actuatable wellbore tools.

[0048] For purposes of this disclosure, relative terms such as "proximal end", "distal end", "portion" or "section" (of a component), and the like as used throughout this disclosure are used for aiding in the description of the various components and configurations of the exemplary embodiments and without limitation regarding, for example, points of delineation, separation, or arrangement or formation.

[0049] FIG. 1B illustrates a perspective, partial quarter-sectional view of the single use setting tool 100 for actuating the tool 102 in a wellbore. The inner piston 104 includes an intermediate section 110 positioned between the proximal end 106 and the distal rod 109 which extends to the distal end 108. The distal rod 109 is a portion of the inner piston 104 having an outer diameter D2 (FIG. 6) that is less than an outer diameter D4 (FIG. 6) of the intermediate section 110, as explained further below. The inner piston 104 may be formed as an integral component. The intermediate section 110 of the inner piston 104 has an annular wall 112 enclosing a cavity 114. The cavity 114 is configured to receive a power charge 116 therein. An initiator 118 may be wholly positioned in the proximal end 106 of the inner piston 104 adjacent the power charge 116. The initiator 118 is used to initiate combustion of the power charge 116 to form a combustion gas pressure inside the cavity 114.

[0050] With continuing reference to FIGS. 1A and 1B, and further reference to FIG. 2, the outer sleeve 120 is configured to slideably receive the inner piston 104 within the central bore 126. A generally annular expansion chamber 128 may be defined by an inner portion 130 (FIG. 2) of the outer sleeve 120 and an outer portion 132 of the annular wall 112 of the inner piston 104. This generally annular expansion chamber 128 within the single use setting tool 100 is illustrated in greater detail in FIG. 2.

[0051] Turning once more to FIG. 2, a perspective, partial quarter-sectional detail view of a portion of the single use setting tool 100 is shown. The outer sleeve 120 is the outermost structure shown in FIG. 2 and the expansion chamber 128, according to an exemplary embodiment, is shown in detail. Also shown in detail in FIG. 2 is a gas diverter channel 134 extending through the annular wall 112 of the inner piston 104. The gas diverter channel 134 is configured to allow gas pressure communication between the cavity 114 containing the power charge 116 and the expansion chamber 128. Accordingly, in the circumstance where the combusting portion of the power charge 116 has an unimpeded gas pressure path to channel 134, the combustion gas will pass through the gas diverter channel 134 and into the expansion chamber 128. Increasing amounts of gaseous combustion products will increase the pressure in the cavity 114, the gas diverter channel 134 and the expansion chamber 128. The expansion chamber 128 is so named because it is adapted to expand in volume as a result of axial movement of the outer sleeve 120 relative to the inner piston 104. The increasing gas pressure in the expansion chamber 128 will exert an axial force on outer sleeve 120 and the inner piston 104, resulting in the outer sleeve 120 sliding axially toward the tool 102 and the expansion chamber 128 increasing in volume.

[0052] Referring again to FIG.1B, the initiator 118 is configured for positioning in an initiator holder 138. Initiator 118 may be of the type described in U.S. Patent No. 9,581,422 (previously mentioned), which is incorporated herein by reference in its entirety, and comprise an initiator head 146 and an initiator shell 136. The initiator shell 136 may contain an electronic circuit board (not shown) and, ignition element, e.g., a fuse head (not shown), capable of converting an electrical signal into a deflagration, pyrotechnical flame, or combustion, and an ignitable material (not shown) for being ignited by the ignition element. With reference to FIG. 5A showing an exemplary arrangement of the initiator 118 and the initiator holder 138 that may be provided in the exemplary embodiment of a single use setting tool 100 as shown in FIG. 1B, the initiator holder 138 includes an axial body portion 143 that defines a channel 137 extending axially through the initiator holder 138 and is configured for receiving the initiator shell 136 therein. The initiator holder 138 further includes an initiator holder head portion 145 which receives the initiator head portion 146 when the initiator 118 is inserted into the initiator holder 138. The initiator head 146 includes an electrically contactable line-in portion 147 through which electrical signals may be conveyed to the electronic circuit board of initiator 118.

[0053] The initiator holder 138 may be configured for positioning the initiator shell 136, and more particularly the ignitable material therein, adjacent the power charge 116 within the inner piston cavity114. In an aspect, the initiator holder 138 may include fins 141 extending radially away from the axial body 143 of the initiator holder 138. The fins 141 secure and/or orient the initiator holder 138 within the inner piston cavity 114 by abutting the annular wall 112, and in certain exemplary embodiments the fins 141 may be fit within corresponding grooves or retaining structures (not shown) on the inner portion 130 of the outer sleeve 120. The energetic portion of initiator 118 is positioned sufficiently close to power charge 116 so as ignition thereof will initiate combustion of power charge 116. The material used to fabricate the initiator holder 138 may be a material, e.g., a polymer or a low-melting point solid material, that will be consumed, melted, fragmented, disintegrated, or otherwise degraded by initiation of the initiator 118 and/or combustion of power charge 116. In such an exemplary embodiment, combustion of the power charge 116 will consume, melt or otherwise degrade initiator holder 138 sufficiently such that initiator holder 138 will, essentially, be consumed during combustion of the power charge 116.

[0054] FIGS. 5A and 5B are cross-sectional, side views of proximal end 106 of inner piston 104 containing initiator 118 and initiator holder 138 prior to and after combustion of the power charge, respectively. The proximal end 106 of piston 104 is adapted, e.g., utilizing threads 508 and/or press fit/o-rings 510, to receive or otherwise have connected thereto the seal adapter 512 containing a bulkhead assembly 514. Seal adapter 512 is not a firing head because it does not house an igniter/initiator. Bulkhead assembly 514 may be of the type described in U.S. Patent No. 9,605,937 and/or U.S. Patent Publication No. 2020/0032626 A1, each of which is commonly owned by DynaEnergetics Europe GmbH, which are incorporated herein by reference in their entirety. A proximal contact pin 518 of the bulkhead assembly 514 is adapted to receive electrical signals from the surface (or an upstream tool as the case may be), which signals are conveyed through the bulkhead assembly 514 to a distal contact pin 516. Once the seal adapter 512 is connected to the proximal end 106 of the setting tool 100, nothing may enter the setting tool 100 from the proximal end 106 other than the electrical signal conveyed by the bulkhead assembly 514. Thus, the bulkhead assembly 514 effectively isolates (e.g., from gas pressure, fluid, and the like) the setting tool 100 from an upstream gun or tool. The bulkhead assembly 514 also functions to align its distal contact pin 516 with the line-in electrical contact 147 of the initiator 118, thus conveying electrical signals from the surface (or upstream tool) to the initiator 118.

[0055] It should be noted that currently available setting tools have a separate firing head or firing head adapter in the position occupied in the present embodiment by the seal adapter 512 and the bulkhead assembly 514. A firing head is a device which includes a housing enclosing a variable configuration of elements for detonating an explosive charge. In the context of a setting tool, the ‘explosive charge’ may or may not really be explosive and, for that reason, is more likely to be referred to as a “power charge.” The housing of a firing head for use with a setting tool would either be connected directly to a mandrel or connected to the mandrel via a firing head adapter. Either way, the firing head housing is connected in such a way that the element that begins the detonation is sufficiently close to the power charge. In an exemplary embodiment, the setting tool 100 does not require a firing head.

[0056] The differences between FIG. 5A and FIG. 5B illustrate a shot confirmation operation of the single use setting tool 100, in an exemplary embodiment. As illustrated in FIG. 5A, initiator holder 138 is present in the proximal end 106 of the single use setting tool 100 before initiation of power charge 116 and distal contact pin 516 of the bulkhead assembly 514 is in electrical contact with the line-in electrical contact 147 of initiator 118. FIG. 5B illustrates in a highly stylized fashion the proximal end 106 after initiation and combustion of the power charge 116. After initiation and during combustion of power charge 116, initiator holder 138 is degraded and substantially vanishes, allowing initiator 118 to drop to the bottom of the cavity 114 in inner piston 104. That is, the initiator 118 is no longer in electrical contact with the distal contact pin 516 of bulkhead assembly 514.

[0057] In an exemplary embodiment, the single use setting tool 100 may allow shot confirmation based on the initiator 118 having electrically disconnected from the distal contact pin 516 of the bulkhead 514. Absence of the connection between the initiator 118 and the distal contact pin 516 of the bulkhead 514 may indicate that initiation of the initiator 118 and/or combustion of the power charge 116 has successfully occurred. In current setting tools, the igniter may be destroyed to one extent or another by initiation of the igniter and/or the combustion of the power charge. However, an electronic circuit board of the igniter sometimes survives the ignition/burn and remains functional. Thus, electrical signals from the surface may be received and acknowledged by the circuitry of a spent igniter in current setting tools even after an effective ignition and/or combustion of its power charge. This circumstance presents a potentially dangerous misunderstanding and/or expensive false signal regarding whether or not the setting tool has actuated and whether a retrieved setting tool still has a live initiator. In the embodiment illustrated in FIGS. 5A and 5B, the disengagement of the distal contact pin 516 of the bulkhead 514 from the line-in portion 147 of initiator head 146 physically disconnects the electronic circuit board contained in initiator shell 136 completely from the electronic signals originating at the surface and relayed through the bulkhead 514 to the initiator 118. Thus, regardless of whether or not the electronic circuit board survives the initiation of the initiator 118 and/or combustion of the power charge 116, a false signal would not be detected at the surface controls. This is a shot confirmation operation that solves certain shortcomings in conventional setting tools. The shot confirmation is achieved by both electric and mechanical disconnections.

[0058] FIG. 3A is a side cross-sectional view of the single use setting tool 100, according to an exemplary embodiment. The single use setting tool 100 may also include one or more gas flow paths 142 (see also FIG. 16) disposed between an exterior surface 144 of the power charge 116 and the annular wall 112 of the inner piston 104 in a radial direction of the single use setting tool 100. The gas flow paths 142 may be embodied as a groove(s) formed in the exterior surface 144 of the power charge 116 (FIG. 3B), or as a groove(s) formed in the annular wall 112 (FIG. 3A) of the inner piston 104, or a combination of both. The one or more gas flow paths 142 may extend axially along a substantial length of the power charge 116. The gas flow path 142 is configured to allow gas pressure communication along an axial length of the power charge 116 and with the gas diverter channel 134. Typically, the power charge 116 combusts from the proximal end 116a (FIG. 7), adjacent the initiator 118, toward the distal end 116b (FIG. 7), adjacent the gas diverter channel 134. However, the combustion of the power charge 116 is not limited directionally—for example, the power charge 116 may combust from the distal end 116b toward the proximal end 116a, such as described in U.S. Provisional Patent Application No. 62/853,824 file May 29, 2019, which is commonly owned by DynaEnergetics Europe GmbH and incorporated herein by reference, in its entirety.

[0059] In typical setting tools, no gas pressure path exists for the combustion gas produced from combustion of the power charge to reach the gas diverter channel. A time delay occurs before the combustion of the power charge opens up such a gas pressure path. The pressure built up in the chamber prior to access to the gas diverter channel being opened is delivered in a single pulse. Thus, current setting tools often have problems delivering a "slow set" or steady setting motion, i.e., a setting tool configured to provide force over a period of a few seconds instead of a few milliseconds. Thus, the favorable setting characteristics achievable with a slow set may be difficult or impossible to achieve with currently available setting tools.

[0060] In an exemplary embodiment, the gas flow path 142 provides an immediate or far earlier gas pressure path from the combusting proximal end of power charge 116 to the gas diverter channel 134. The gas flow path 142 prevents a large build-up of gas pressure in the cavity 114 that is blocked from reaching the gas diverter channel 134 by the unburned power charge 116. Thus, the current problem of pressure build-up being delivered as a single pulse may be avoided with the gas flow path 142. Rather, depending almost entirely on the combustion rate of the power charge 116, the axial force exerted on outer sleeve 120 may be increased relatively gradually, over the course of seconds, thus enabling a simple and economical means of achieving slow set delivery of force by the single use setting tool 100 on tool 102 (FIG. 1B).

[0061] As illustrated in FIGS. 3A and 3B, the power charge 116 may include an indentation 140 adjacent the initiator 118 and/or initiator holder 138. By providing a slight offset between initiator 118 and the surface of power charge 116, the indentation 140 is configured to increase the reliability that the initiator 118 initiates the combustion of the power charge 116. Further, indentation 140 may be filled or lined with a booster charge (not shown), the chemical makeup of the booster charge being more sensitive to initiation than the chemical makeup of the power charge 116.

[0062] FIG. 3B is a perspective view illustrating the power charge 116, the gas flow path 142, and the indentation 140, according to an exemplary embodiment. As stated, the indentation or cylindrical recess 140 in the power charge 116 may provide igniter room to build a flame. In an exemplary embodiment, if there is not enough distance/stand-off between the igniter and the compound, the flame from the igniter may not have the opportunity to achieve a threshold level to initiate combustion of the power charge 116. In addition, the surface area increase resulting from the indentation 140 may aid ignition of the power charge 116.

[0063] The power charge of currently available reusable setting tools must be a separate unit, provided separately from the setting tool to enable the resetting of a 'spent' setting tool. According to an exemplary embodiment, the power charge 116 may be configured to be integral with and non-removable from the single use setting tool 100. This configuration has the potential to achieve cost savings in the construction and supply chain for setting tool 100.

[0064] The power charge 116 may include a combustible material selected from the following materials: black powder and a black powder substitute. The combustible material may also be selected from the following materials: Pyrodex, Goex Clear Shot, binding agents, wheat flour, potassium nitrate, sodium nitrate, epoxy resin, graphite powder, and Triple Seven.

[0065] In an exemplary embodiment, the initiator 118 may be configured to be inserted into the single use setting tool 100 at a wellsite immediately prior to the single use setting tool 100 being inserted into the wellbore.

[0066] Referring again to FIG. 2 and in an exemplary embodiment, a first seal 148 and a second seal 150 positioned at opposite ends of the expansion chamber 128 function to seal the expansion chamber 128. The first seal 148 and the second seal 150 may be configured for ensuring that the expansion chamber 128 remains gastight but without impairing the ability of the outer sleeve 120 to slide axially relative to the inner piston 104. In the exemplary embodiment shown in FIG. 2, the first seal 148 is positioned relative to the intermediate section 110 of the inner piston 104 and the inner portion 130 of the outer sleeve 120 and the second seal 150 is positioned relative to a sealing section 524 (FIG. 6) of the outer sleeve 120 and the distal rod 109 of the inner piston 104. Each of the first seal 148 and the second seal 150 may include one or more O-rings 149.

[0067] In an exemplary embodiment illustrated in FIG. 3A, the single use setting tool 100 may include a shear element 152 connected to the inner piston 104 and the outer sleeve 120. The shear element 152 may be configured to prevent premature axial sliding of the outer sleeve 120 relative to the inner piston 104. Shearing of the shear element 152 allows the axial sliding of the outer sleeve 120 relative to the inner piston 104 subsequent to the formation of the combustion gas in the expansion chamber 128 exceeding a threshold pressure. That is, once the gas pressure in expansion chamber 128 reaches a threshold pressure, the force pushing axially against outer sleeve 120 will cause the shear pin 152 to shear. The outer sleeve 120 will then be free to move axially relative to inner piston 104.

[0068] The single use setting tool 100, in an exemplary embodiment, may also include a pressure vent 154 as illustrated in FIG. 3A. The pressure vent 154 may extend through the outer sleeve 120 adjacent the piston proximal end 122. The pressure vent 154 may be configured to release the combustion gas pressure in the expansion chamber 128 subsequent to the axial sliding of the outer sleeve 120 along a sufficient axial distance relative to the inner piston 104. The sufficient axial distance may include a distance sufficient for outer sleeve 120 to exert a desired force on the tool 102 in the wellbore over a desired distance. For example, movement of the outer sleeve 120 a particular distance results in the pressure vent 154 passing over the first seal 148 portion. Once the pressure vent 154 moves past the first seal 148, the gas pressure in the expansion chamber 128 may escape therefrom through the pressure vent 154. The venting of the gas pressure in the expansion chamber 128 quickly eliminates the axial force being exerted on the outer sleeve 120. Optionally, a bung (not shown) may be disposed in the pressure vent 154 to the prevent pressure vent 154 from being a route for contaminants to enter the single use setting tool 100. The bung would be removed automatically by the pressure exerted through the pressure vent 154 when first exposed to the expansion chamber 128.

[0069] FIG. 4 is a cross-sectional, partial, magnified view of an expansion chamber 128 according to an exemplary embodiment. As with the expansion chamber 128 shown in FIG. 1 and FIG. 2, the expansion chamber 128 of FIG. 4 is generally annular and may be defined by the inner portion 130 of the outer sleeve 120 and the outer portion 132 of the annular wall 112 of the inner piston 104. Further, the assembly may also include a first seal 148 and a second seal 150 positioned at opposite ends of the expansion chamber 128 and augmented by O-rings 149. The gas diverter channel 135 extends a substantial distance along an axial direction of the inner piston 104 of the single use setting tool 100. The effect of one or more such axially extending gas diverter channels 135 is very similar to the effect of the gas flow path 142 in FIG. 3A. That is, the pressurized gas developed by the combustion of the power charge 116 is provided with a gas pressure path to the gas diverter channel 135 much earlier than in available setting tools. Thus, the current problem of pressure build-up being delivered as a single pulse may be avoided with the axially extending gas diverter channels 135. Rather, depending almost entirely of the combustion rate of the power charge 116, the axial force exerted on the outer sleeve 120 may be increased relatively gradually, over the course of seconds, thus enabling a simple and economical means of achieving slow set delivery of force by the outer sleeve 120 on the tool 102.

[0070] The single use setting tool 100 embodiment shown in FIG. 4 includes the inner piston intermediate section 110 that includes the annular wall 112, and the distal rod 109. In the exemplary embodiments shown in FIGS. 1B and 4, it is understood that the annular wall 112 of the inner piston 104 is an annular wall of both the intermediate section 110 and the distal rod 109 (see FIG. 1B) in the integral inner piston 104 piece. Accordingly, a portion of each of the cavity 114 and the power charge 116 may be enclosed by the annular wall 112 with respect to both the intermediate section 110 and the distal rod 109. The intermediate section 110 has a greater outside diameter D4 (FIG. 6) than the outside diameter D2 of the distal rod 109.

[0071] In an exemplary embodiment, the setting tool is single use. The choice of materials to be used in the setting tool is completely altered by the fact that the setting tool is for one-time use. Little to no consideration is given to wear and tear issues. Also, any engineering needed as part of resetting, i.e., re-dressing and refilling with consumed parts, is not required. Further, the setting device has fewer and simpler parts, i.e., going from tens of highly precise machined parts of high quality materials that need to function over and over again (in existing setting tools) to a one time use item of significantly fewer and less highly engineered parts. These factors result in a substantial reduction in unit cost. In addition, there is no requirement for maintenance and training as to reuse/re-dressing/refilling. The single use setting tool as disclosed herein is, compared to currently available setting tools, simpler, comprising fewer parts, far less expensive, works without a firing head, is single use and provides shot confirmation.

[0072] With reference now to FIG. 6, the simplified two-piece design of an exemplary single use setting tool according to the disclosure, such as the single use setting tool 100 shown in

FIGS. 1A and 1B, is shown in break-out fashion. For purposes of this disclosure, "two-piece design" refers generally to the inner piston 104 and the outer sleeve 120 (as shown in FIG. 6) being the two major structural components of the exemplary single use setting tool. Exemplary embodiments of a single use setting tool according to the disclosure obviate the need for a firing head and therefore allow the inner piston 104 to connect directly to a seal adapter 512, eliminating not only a firing head mechanism but adapters that many conventional setting tools require for connecting to a firing head.

[0073] The inner piston 104 and the outer sleeve 120 shown in FIG. 6 are substantially similar to the exemplary embodiments shown and described with reference to FIGS. 1A-2. However, the exemplary embodiment of the inner piston 104 shown in FIG. 6 includes first and second gas diverter channels 134 in communication with a free volume portion 523 (FIG. 7) of the cavity 114 within the inner piston 104, as described further below.

[0074] While not necessarily indicative or limiting of a method for manufacturing or assembling a single use setting tool according to this disclosure and to aid in understanding the relationship between components, inner piston 104 may be inserted distal end 108 first in a direction *d* into the central bore 126 of the outer sleeve 120. As previously discussed, the inner piston 104 and the outer sleeve 120 including the central bore 126 are, in an exemplary embodiment, cylindrically shaped and configured to fit together coaxially about an axis *x*. Accordingly, a passage 525 through the sealing section 524 of the outer sleeve 120 may have a diameter D1 that is sufficient for allowing the distal end 108 and the distal rod 109, having a diameter D2, to be received through the passage 525 from the central bore 126 to a distal bore 526 of the outer sleeve 120 while still forming the second seal 150. The central bore 126 of the outer sleeve 120 may have a diameter D3 for receiving the intermediate section 110, having a diameter D4, of the inner piston 104 while still forming the first seal 148. The diameter D3 of the central bore 126 and the diameter D4 of the intermediate section 110 of the inner piston 104 are each greater than the diameter D1 of the passage 525 through the sealing section 524, due to a protrusive shoulder 527 that extends inward from the inner portion 130 of the outer sleeve 120 as part of the sealing section 524. This configuration in certain exemplary embodiments, for example as shown and described with respect to FIG. 2, defines in part the expansion chamber 128 of the setting tool 100.

[0075] The outer sleeve 120 includes a shear element aperture 513a extending from an outer surface 125 of the outer sleeve 120 to the central bore 126 and the inner piston 104 includes a shear element notch 513b in an outer surface 517 of the inner piston 104. The shear element aperture 513a is aligned with the shear element notch 513b when the inner piston 104 is positioned within the central bore 126. The shear element aperture 513a and the seal element notch 513b are together configured for receiving the shear element 152 that extends between and is positioned within each of the shear element aperture 513a and the shear element notch 513b to secure the inner piston 104 within the central bore 126.

[0076] With reference now to FIG. 7, an exemplary embodiment of a single use setting tool 100 according to the disclosure may include a configuration substantially as previously described with respect to FIGS. 1A-2, including an outer sleeve 120 and an inner piston 104 positioned within central bore 126 of the outer sleeve 120. The inner piston 104 may include a cavity 114 and a power charge 116 positioned within the cavity 114 as previously discussed. First and second pressure vents 154 extend through the outer sleeve 120 into the inner bore 126 for venting excess pressure from consumption of the power charge 116, as previously discussed. In the exemplary embodiment that FIG.7 shows, a free volume portion 523 exists within the cavity 114 between a distal end 116b of the power charge 116 and the first and second gas diverter channels 134, which are open to each of the cavity 114 and a gas expansion chamber 128 for actuating the outer sleeve 120 and the inner piston 104 to slide axially relative to one another.

[0077] The initiator holder 138 is positioned at least in part within the inner piston cavity 114 and receives and retains the initiator 118 therein. The initiator holder 138 is positioned to receive and retain the initiator 118 substantially coaxially with the seal adapter portion 107 and the inner piston cavity 114. In an exemplary embodiment, such as shown in FIG. 7 and with reference back to FIGS. 5A and 5B, the initiator 118 and/or the initiator holder 138 may be positioned such that a portion of the initiator 118 and/or the initiator holder 138, such as the initiator head 146 and/or the line-in portion 147 of the initiator 118, may extend into the seal adapter portion 107 of the inner piston 104; in particular, an open interior area 519 of the seal adapter portion 107. In other exemplary embodiments, the initiator 118 and the initiator holder 138 may be positioned entirely within the inner piston cavity 114.

[0078] The initiator holder 138 may include a coupling end 139 adjacent to the power charge 116, for robustly securing the initiator 118 in position for initiating the power charge 116 and keeping pressure contained between the coupling end 139 and the gas diverter channels 134 during consumption of the power charge 116, for example after the initiator holder 138 has been degraded according to embodiments including a shot confirmation as previously discussed. The initiator holder 138 may include a fluted section 119 opposite the coupling end 139. The fluted section 119 may provide both a wider profile for helping to orient and center the initiator holder 138 within the inner piston cavity 114 and an enlarged surface against which the seal adapter 512 may abut when it is inserted in the seal adapter portion 107.

[0079] In a further aspect, the initiator holder 138 may include a ground bar connection 121 that may electrically contact and ground, e.g., the shell 136 of the initiator 118 to the annular wall 112 of the inner piston 104.

[0080] The exemplary embodiment that FIG. 7 shows includes a shock absorbing assembly 530. The shock absorbing assembly 530 dampens shock that may be generated upon actuation of a wellbore tool by the single use setting tool 100. In particular, but without limitation, when the single use setting tool 100 is used with the plug setting sleeve 602 and the plug 603 (as discussed below), separation of the plug 603 from the plug setting sleeve 602 results in a substantial amount of shock, as explained further below, that may damage or reduce the lifetime of the reusable setting sleeve 602 and/or a setting sleeve mandrel 610 (FIG. 18) component thereof. Excessive shock is known to occur when single use setting tools are used, because single use setting tools do not contain, e.g., oil cushions that are provided but must be refilled/replaced in reusable setting tools.

[0081] The shock absorbing assembly 530 in the exemplary embodiment of FIG. 7 includes a shock dampener 531 and a rigid retainer 532. The shock dampener 531 in the exemplary embodiment is a cushioning component that may be formed from, without limitation, a polymer or plastic. In an aspect, the shock dampener 531 may be cylindrical pad. The rigid retainer 532 holds the shock dampener 531 in place and is also a stabilizing and shock-distributing component that may be formed from metal or any known material consistent with this disclosure. In an aspect, the rigid retainer 532 may be, without limitation, a retaining ring such as a steel ring, a c-clip, or the like. Each of the shock dampener 531 and the rigid retainer 532 in the exemplary embodiment is formed such that the distal rod 109 of the inner piston 104 may pass through them—for example, the shock dampener 531 and the rigid retainer 532 may be annular elements through which the distal rod 109 passes.

[0082] With reference now to FIG. 7A, a perspective view of an exemplary outer sleeve 120 for use with a single use setting tool 100 according to, e.g., the exemplary embodiments shown in FIGS. 7 and 8 is shown from the distal end 124 of the outer sleeve 120. In an aspect, the exemplary outer sleeve 120 may include a retaining ring groove 655 formed in the inner portion 130 of the outer sleeve 120 and positioned within the distal bore 526 of the outer sleeve 120. The retaining ring groove 655 may position and hold the rigid retainer 532 in place.. Accordingly, the shock absorber assembly 530 will remain in place relative to the outer sleeve 120 as the outer sleeve 120 strokes over the inner piston 104.

[0083] With reference now to FIG. 8, the exemplary single use setting tool 100 as described with respect to FIG. 7 is shown with an alternative exemplary embodiment of the shock absorbing assembly 530. In the exemplary embodiment shown in FIG. 8, the shock dampener 531 is an o-ring and the rigid retainer is a steel ring 532 according to the same purposes and principles as described with respect to FIG. 7.

[0084] The shock absorbing assembly 530 has been described according to certain exemplary embodiments but is not limited thereto and may include various materials, components, and configurations consistent with the disclosure.

[0085] With reference now to FIG. 9, the exemplary single use setting tool 100 as described with respect to FIG. 7 is shown excepting the shock absorbing assembly 530. In the exemplary embodiment shown in FIG. 9, the distal rod 109 portion of the inner piston 104 includes one or more wedges 533 that may be, without limitation, discrete features on the outer surface 517 of the inner piston 104 or a continuous feature about its periphery. The one or more wedges 533 may be integrally formed or machined as part of the inner piston 104 or may be formed or attached thereto according to any known technique consistent with this disclosure. The wedge 533 may be made from any material consistent with a particular application. In certain exemplary embodiments, the wedge 533 may be made from a relatively soft material such as, without limitation, plastic, composite, and the like, to serve as a brake and a shock absorber for the outer sleeve 120 in use as it strokes over the inner piston 104 as explained further below. For ease of reference in the disclosure, the singular term wedge 533 may include the one more wedges as described.

[0086] In the exemplary embodiment of FIG. 9, the wedge 533 is an annular and wedge-shaped attachment that is attached to the distal rod 109 portion of the inner piston 104. The wedge 533 in the exemplary embodiment may be made of plastic and/or composite. The wedge 533 extends away from the outer surface 517 of the inner piston 104, e.g., at a position on the distal rod 109, such that the diameter D2 of the distal rod 109 at the position of the wedge 533, plus the length to which the wedge 533 extends away from the outer surface 517 of the distal rod 109, is greater than the diameter D1 of the passage 525 through the sealing section 524 of the outer sleeve 120. Accordingly, when outer sleeve 120 slides axially relative to the inner piston 104 during use as discussed above and explained further below, wedge 533 will contact a protrusive shoulder 527' of the sealing section 524 of the outer sleeve 120 and prevent further movement of the outer sleeve 120 relative to the inner piston 104. This limits the stroke length of the outer sleeve 120 to a length at which the wedge 533 engages the shoulder 527' and prevents further movement of the outer sleeve 120. Reducing the stroke length of the outer sleeve 120 may be beneficial for reducing the amount of shock generated during detachment of the actuated tool because reducing the stroke length reduces the amount of distance along which the inner piston 104 can relatively accelerate into the distal bore 526 of the outer sleeve 120 (FIGS. 9A and 9B).

[0087] With reference now to FIGS. 9A and 9B, cross sectional views around the sealing section 524 of the outer sleeve 120 of an exemplary single use setting tool 100 similar to that shown in FIG. 9 are shown as when the outer sleeve 120 is in mid-stroke (FIG. 9A) and at the end of the stroke (FIG. 9B). In mid-stroke, the wedge 533 has not yet contacted the protrusive shoulder 527' and the outer sleeve 120 continues to stroke. At the end of the stroke, the wedge 533 has contacted the protrusive shoulder 527' and a portion of the wedge 533 is compressed between the inner piston 104 and the sealing section 524, within the passage 525 through the sealing section 524.

[0088] In addition to the features shown in FIG. 9, the exemplary embodiments shown in FIGS. 9A and 9B include a wedge retaining ring 533a for keeping the wedge 533 from sliding off of the inner piston 104, particularly after the wedge 533 contacts the protrusive shoulder

527'. The wedge retaining ring 533a is retained in a wedge retaining ring groove 533b that is formed in the outer surface 517 of the inner piston 104. FIGS. 9A and 9B also show the retaining ring groove 655 for the retaining ring 532 portion of the shock absorber assembly 530 shown and described with respect to FIGS. 7 and 8. The exemplary embodiments shown in FIGS. 9-9B may be used in conjunction with the shock absorbing assembly 530. In such embodiments, the wedge 533 will prevent further stroking of the outer sleeve 120 when it jams against the shock absorbing assembly 530.

[0089] With reference again to FIG. 7, the power charge 116 in the exemplary embodiment shown in FIG. 7 includes the indentation 140 at a proximal end 116a of the power charge 116. A booster 528 is positioned within the indentation 140 in sufficient proximity to the initiator 118 such that initiation of the initiator 118 will initiate the booster 528 to release additional energy. Boosters are well-known in the art and the booster 528 may be any known booster, including charges, energetic materials, or chemically reactive materials. The booster 528 may be larger and release more energy than an ignition source in the initiator 118. The booster 528 may improve the efficiency and/or reliability of igniting the power charge by providing an additional energy source against additional surface area of the power charge 116.

[0090] In certain exemplary embodiments, the booster 528 is a booster pellet made from energetic material.

[0091] In the exemplary embodiment of FIG. 7, the booster 528 is positioned and held in place by a booster holder 529. The booster holder 529 is positioned between the initiator 118 and the power charge 116 and is configured for receiving and positioning the booster 528 within the indentation 140 of the power charge 116.

[0092] With reference to FIGS. 10-13, exemplary embodiments of the booster holder 529 may include a booster receiver 232, a booster holder top 234 and an opening 236 in the booster holder top 234. The booster receiver 232 may extend from an underside 235 of booster holder top 234. The booster receiver 232 is sized to receive and retain a booster 528 of the type previously discussed—for example, a booster pellet in certain exemplary embodiments. The booster 528 may be of a material in which it is easier to begin deflagration/energetic release than the material in the power charge 116. Deflagration of the booster 528 releases sufficient energy sufficiently close to a portion of the power charge 116 that the energetic material of the power

116 begins a self-sustaining deflagration or consumption that causes generation of gas pressure according to the operation of the single use setting tool 100 as described throughout this disclosure. In an aspect, the power charge 116 may be disposed in a container 170 (FIG. 14) that protects and holds together the power charge 116.

[0093] With reference now to FIGS. 10-13, 14, and 15, in an exemplary embodiment the power charge 116 may be positioned within the container 170 and the booster holder 529 may be inserted into the power charge 116, e.g., within a body 178 of the power charge 116. In an aspect of the exemplary embodiment as shown in FIG. 15, the booster holder 529 may be completely surrounded, but for the booster holder top 234, by the energetic material of the power charge body 178. The booster holder 529 may be retained in place by engaging the power charge body 178 and/or the power charge container 170. In an exemplary embodiment and as shown in FIGS. 14 and 15, the booster holder top 234 may function as the top of the power charge container 170.

[0094] The material for the power charge container 170 may be rigid or semi-rigid so as to retain the desired power charge shape. Many polymers would be an appropriate choice for the container 170. Exemplary materials may be polypropylene (for standard applications) and polyamide (for high temperature applications). The material and dimensions of the container 170 are selected such that the container 170 will melt or otherwise break-down quickly when exposed to the energy (heat and pressure) generated by combustion of the power charge 116. Thus, the container 170 will not impede pressurized gas generated by the power charge 116 from accessing the gas diverter channels 134.

[0095] The booster holder 529 functions to retain the booster 528 in close proximity to the power charge body 178, i.e., the energetic material, at a proximal end 116a of the power charge 116. In an aspect of the exemplary embodiments, the power charge 116 having a booster holder 529 according to FIGS. 14 and 15 may be positioned in the cavity 114 of the inner piston 104 of the single use setting tool 100 such that the initiator 118 is adjacent the booster holder 529. Specifically, the ignition source of the initiator 118 may be adjacent and/or aligned with the opening 236 through the booster holder top 234 and thereby with the booster 528 in the booster receiver 232 of the booster holder 529. The exemplary arrangement may enhance reliability and efficiency for causing deflagration (i.e., ignition) of the power charge 116.

[0096] With continuing reference to FIGS. 14 and 15, and further reference to FIG. 16, in an aspect of the exemplary embodiments, the power charge 116 (and the container 170 in embodiments including the container 170) has, without limitation, a hexagonally-shaped transverse cross-section along, e.g., line A-A in FIG. 14. For the purposes of this disclosure, the phrase “hexagonally-shaped power charge” may refer to a power charge having a hexagonally-shaped transverse cross-section. In FIG. 16, the cross-sectional view of the hexagonally-shaped power charge 116 is shown as it would be received in the cavity 114 of the inner piston 104 according to the exemplary embodiments.

[0097] While FIG. 16 shows a hexagonally-shaped power charge 116, it will be understood that the power charge 116 is not limited to having a hexagonally-shaped transverse cross-section. The power charge 116 in various exemplary embodiments may have a cross-section according to any shape or configuration including, without limitation, polygonal, circular, symmetric or asymmetric, and the like, consistent with the disclosure.

[0098] As shown in FIG. 16, the power charge 116 is sized and shaped such that vertices 191 of the hexagonally-shaped power charge 116 within the cavity of the inner piston 104 are positioned to abut or contact the annular wall 112 of the cavity 114 to provide a secure fit of the power charge 116 within the cavity 114. Flat sides 192 of the hexagonally-shaped power charge 116 (i.e., radial outer surfaces of the hexagonally-shaped power charge) are thereby spaced apart from the annular wall 112, creating gas flow channels 190 that extend axially along the length of the cavity 114. Expanding combustion gas resulting from the combustion of the power charge 116 is able to flow into and axially through these gas flow channels 190 to the gas diverter channels 134 and the expansion chamber 128 of the single use setting tool 100, especially during early stages of combusting the power charge 116. The size, shaped, and configuration of the power charge 116 may be varied to provide gas flow channels 190 with a particular volume for achieving a desired speed at which axial movement between the outer sleeve 120 and the inner piston 104 occurs and progresses, based on the speed and volume at which the combustion gases will reach the expansion chamber 128. For example, slow-set setting tools in which the setting takes place relatively gradually as opposed to abruptly may be preferable for actuating a tool against a resistance created by the tool, or generally reducing the amount of shock created during actuation and/or separation of the tool.

[0099] In an aspect, the gas flow channel 190 and the gas flow path 142 discussed with respect to FIGS. 3A and 3B are similar in form and function.

[0100] With reference now to FIG. 17, an exemplary arrangement of a tool string 600 including a single use setting tool 100 according to the disclosure may include a perforating gun 601 (which may be the last in a string of perforating guns or other wellbore tools above, i.e., upstream, of the single use setting tool 100), the seal adapter 512, the single use setting tool 100, a plug setting sleeve 602, and a plug 603. In the exemplary tool string 600 that FIG. 17 shows, the perforating gun 601 is connected to the second connecting portion 522 of the seal adapter 512 and the seal adapter portion 107 of the inner piston 104 is connected to the first connecting portion 521 of the seal adapter 512. The bulkhead 514 is positioned within the bore 515 through the seal adapter 512 and relays an electrical signal from an electrical connector (not shown) in the perforating gun 601 to the line-in portion 147 of the initiator 118. Accordingly, for purposes of this disclosure, “bulkhead 514” and “electrical feedthrough bulkhead 514” and variations thereof, such as “electrical feedthrough bulkhead assembly 514,” may be used interchangeably. The proximal contact pin 518 of the bulkhead 514 is in electrical contact with the electrical connector in the perforating gun 601 and, within the bulkhead, the distal contact pin 516 of the bulkhead 514. The proximal contact pin 518 relays the electrical signal from the electrical connector in the perforating gun 601 to the line-in portion 147 of the initiator head 146, via the distal contact pin 516 which is in electrical contact with the line-in portion 147. The electrical signal may be a signal for triggering initiation of the initiator 118.

[0101] The single use setting tool 100 may connect to the plug setting sleeve 602 by, without limitation, a threaded connection between the external threads 125 of the outer sleeve distal end 124 and complementary threading on a connecting portion 604 of the plug setting sleeve 602. In addition, the inner piston 104 may connect to a setting sleeve mandrel 610 of the plug setting sleeve 602 as are known in the art. For example, the external threads 105 on the distal end 108 of the inner piston 104 may threadingly connect to a complementary threaded portion on a connecting portion 611 of the setting sleeve mandrel 610.

[0102] In another aspect, the plug setting sleeve 602 includes a plurality of shear studs 612 that connect the plug setting sleeve 602 to a plug mandrel 605 of the plug 603, thereby mounting the setting sleeve 602 to the plug 603. As previously mentioned, releasing the plug 603 from the setting sleeve 602 is an abrupt and shock-generating event because release occurs when the outer sleeve 120 has put enough pressure on the plug setting sleeve 602 to break the shear studs 612. The requisite pressure is generated by the inner piston 104 and the outer sleeve 120 exerting respective, opposing forces according to the operation of the single use setting tool 100 as described herein. The inner piston 104 is exerting a pulling force in a direction '*b*' on the setting sleeve mandrel 610 while the outer sleeve 120 and the plug setting sleeve 602 are stroking in a direction '*a*' over the inner piston 104 and the setting sleeve mandrel 610. When the shear studs 612 break and the plug 603 is released, the sudden removal of resistance against the stroke of the outer sleeve 120 causes rapid acceleration of the outer sleeve 120 in the direction '*a*' and corresponding relative acceleration of the inner piston 104 and the setting sleeve mandrel 610 in the direction '*b*'. When the outer sleeve 120 reaches the end of its stroke length and comes to an abrupt halt, substantial shock is generated by, for example, sudden impact between or stress or forces on the connection between the setting sleeve 602 and the setting sleeve mandrel 610 and impact between portions of the outer sleeve 120 and/or the inner piston 104 and the setting sleeve mandrel 610 and/or the end 613 of the setting sleeve mandrel 610. This shock may damage, deform, or simply reduce the useful life of both the plug setting sleeve 602 and the setting sleeve mandrel 610, both of which may be reusable components although the single use setting tool 100 is not.

[0103] Upon initiation of the initiator 118 which may be, for example, in response to receiving the electrical signal, the power charge 116 is consumed and the outer sleeve 120 is slid axially, relative to the inner piston 104 as previously described, in a direction '*a*'. Accordingly, the outer sleeve 120 pushes the plug setting sleeve 602 in the direction '*a*' and thereby creates compression forces on the plug 603 which causes the plug 603 to expand and set.

[0104] With reference now to FIG. 18, an isolated view of the connection between the inner piston 104 and the plug setting sleeve 602 is shown according to an exemplary embodiment. It should be noted that the view shown in FIG. 18 represents the state of the single use setting tool 100 and plug setting sleeve 602 after the plug 603 has been released—i.e., after the outer sleeve 120 has finished its stroke and the shear studs 612 have broken between the setting sleeve 602 and the plug mandrel 605. As shown in FIG. 18, the inner piston 104 and the connecting portion 611 of the setting sleeve mandrel 610 have been retracted into the distal bore 526 at the outer sleeve distal end 124.

[0105] FIG. 18 also shows in further detail the threaded connections between the external threads 125 of the outer sleeve distal end 124 and complementary threading on the connecting portion 604 of the plug setting sleeve 602 and the external threads 105 of the distal end 108 of the inner piston 104 and the complementary threaded portion on the connecting portion 611 of the setting sleeve mandrel 610.

[0106] With continuing reference to FIG. 18, an exemplary embodiment of a single use setting tool 100 may include a shock blocking structure 650 such as shock blocking pins 650 as will be further explained with respect to FIG. 19. As shown in FIG. 18, the shock blocking pins 650 are positioned adjacent to an end 613 of the mandrel 610 in relatively close proximity, especially when compared with the shock absorbing assemblies 530 discussed with respect to FIGS. 7 and 8. Positioning the shock blocking structures 650 (i.e., shock blocking pins 650) closer to the mandrel 610 enhances dissipation of the shock generated during separation of the plug 603 by impacts between, e.g., the outer sleeve 120 and the inner piston 104 and/or the setting sleeve mandrel 610, and the distal end 108 of the inner piston 104 and the connecting portion 611 of the setting sleeve mandrel 610, within which the distal end 108 of the inner piston 104 is received. The shock blocking pins 650 absorb and dissipate the shock at a position adjacent to the end 613 of the setting sleeve mandrel 610 and thereby reduce damaging propagation of the shock forces. However, the disclosure is not limited to any particular spacing or relationship between a shock blocking structure and a mandrel and includes any such configurations consistent with the principle and purpose of the exemplary embodiments.

[0107] In another exemplary embodiment, a single use setting tool 100 including a shock blocking structure 650 as shown in FIG. 18 and discussed further below with respect to FIGS. 19 and 20 may include, in addition to the shock blocking structure 650, a shock absorbing assembly 530 such as shown and described with respect to FIGS. 7, 8, 9A, and 9B. Accordingly, in an aspect of the exemplary embodiment the retaining ring groove 655 may be formed in the inner portion 130 of the outer sleeve 120 as previously discussed with respect to FIG. 7A.

[0108] With reference now to FIG. 19, a full depiction of the exemplary single use setting tool 100 with shock blocking pins 650 is shown. The single use setting tool 100 shown in FIG. 19 includes generally the same components and configurations as have been previously described with respect to the exemplary embodiments of a single use setting tool 100 throughout the disclosure and such description will not be repeated here. In relevant part, the single use setting tool 100 shown in FIG. 19 includes shock blocking pins 650 arranged on the distal rod 109 at a position towards the distal end 108 of the inner piston 104. As mentioned with respect to FIG. 18, positioning the shock blocking structures 650 as close to the end 613 of the setting sleeve mandrel 610 when the setting sleeve mandrel 610 is connected to the distal end 108 of the inner piston 104 may provide enhanced shock dissipating benefits. However, plug setting adapters (i.e., plug setting sleeves) from different manufacturers may have mandrel connections that vary by a degree of tolerance such that they are non-standardized. In particular, mandrels on plug setting adapters frequently have set screws to clamp down on a piston to which they are attached and thereby provide a more robust connection than through, e.g., threaded connections alone. The set screws may seat within a recessed band on the piston, such as the recessed band 651 on the inner piston 104 shown in FIG. 19. It may be beneficial to make the recessed band 651 especially wide in a direction from the distal end 108 to the proximal end 106 of the inner piston, to accommodate different positions of set screws on mandrels from various manufacturers for use with the shock blocking pins 650.

[0109] With reference now to FIG. 20, an exemplary embodiment of a single use setting tool 100 including a shock blocking ring 652 is shown. The configuration, principles, and purpose of the exemplary embodiment that FIG. 20 shows are the same as discussed with respect to FIG. 19. However, the shock blocking structure of the exemplary embodiment that FIG. 20 shows is a shock blocking ring 652 extending circumferentially around the inner piston 104 at a position on the distal rod 109 as previously discussed with respect to FIG. 19. The shock blocking ring 652 may be a ring of solid material, a spring ring, a coil ring, or other known components consistent with the disclosure. The shock blocking ring may be one shock blocking ring 652 or a plurality of shock blocking rings 652 stacked together or spaced at intervals along the distal rod 109.

[0110] In the exemplary embodiments as shown and described with respect to FIGS. 19 and 20, the shock blocking structures 650, 652 may be made from metal, for example stainless steel, carbon steel, and the like. Other known materials may be substituted without departing from the principles and purpose of the disclosure. In addition, the exemplary shock blocking structures 650, 652—i.e., pins, rings, spring rings, coil springs—are by way of example and not limitation. Any configuration, shape, number of structures, orientation, etc. of shock blocking structures 650, 652 may be used consistent with this disclosure.

[0111] In a further aspect of an exemplary embodiment, the initiator holder 138 may be formed from a material that is destructible upon initiation of the initiator 118, and the initiator 118 and the initiator holder 138 together are positioned such that the initiator 118 will move out of electrical communication with the distal contact 516 and thereby provide a shot confirmation—i.e., confirmation that the initiator 118 has been initiated and a live initiator is no longer present in the setting tool.

[0112] The disclosure also relates to a method of actuating the wellbore tool 102 with the single use setting tool 100. For example, an exemplary method may include connecting the single use setting tool 100 to the wellbore tool 102, which may occur either before or after the single use setting tool 100 and the wellbore tool 102 has arrived at the well site. The single use setting tool 100 may be according to an exemplary embodiment disclosed herein. Attaching the single use setting tool 100 to the wellbore tool 102 may include attaching the threaded portion 105 of the distal end 108 of the inner piston 104 and the threaded portion 125 of the outer sleeve distal end 124 respectively to complimentary connectors on the wellbore tool 102. Once the single use setting tool 100 is connected to the wellbore tool 102, and the assembly is present at the wellbore site, the initiator 118 may be inserted into the initiator holder 138, which is accessible through the proximal end 106 of the inner piston 104.

[0113] In the case where the single use setting tool 100 and the wellbore tool 102 are components in a tool string, after the initiator 118 is inserted the seal adapter portion 107 of the inner piston 104 may be connected to the first connecting portion 521 of the seal adapter 512. An upstream wellbore tool, wireline connector, or other components as are known in the art may then be connected to the second connecting portion 522 of the seal adapter 512. When the full tool string 600 is assembled it is deployed into the wellbore. At an appropriate time as determined by elapsed time, measured distance, located position, or by other techniques as are known in the art, the single use setting tool 100 may be initiated by relaying an electrical signal through the tool string 600 to the single use setting tool 100, ultimately via the bulkhead 514 in the seal adapter 512 as previously described. The initiator 118 may initiate in response to receiving the electrical signal, and in certain embodiments the method further includes confirming, after initiating the initiator, that the electrical communication between the first electrical connection of the electrical feedthrough bulkhead assembly and the initiator has been terminated. The confirmation may be provided by, for example and as discussed above, disintegration of the initiator holder 138 causing the initiator 118 to fall from a first position in which the line-in portion 147 of the initiator head is in contact with the distal contact pin 516 of the bulkhead 514 to a second position in which the line-in portion 147 of the initiator head 146 is not in contact with the distal contact pin 516 of the bulkhead 514.

[0114] In an exemplary embodiment, a method of actuating the wellbore tool 102 with a single use setting tool 100 according to the exemplary embodiments presented throughout the disclosure may include connecting the single use setting tool 100 to the wellbore tool 102, for example as shown and described with respect to FIG. 18, connecting the piston distal end 108 to a wellbore tool connection such as the mandrel connecting portion 611 via a complementary threaded connection to the external threads 105 of the distal end 108 of the inner piston 104, and connecting the outer sleeve distal end 124 to a plug setting sleeve connecting portion 604 via a complimentary threaded connection to the external threads 125 of the sleeve distal end 124. In an aspect, the single use setting tool 100 will be provided with the power charge 116 and the initiator holder 138 already in place within the inner piston cavity 114. Accordingly, the initiator 118 may be inserted by, e.g., pushing the initiator 118 into the initiator holder 138.

[0115] Upon inserting the initiator 118, the first connecting portion 521 of the seal adapter 512 may be connected to the seal adapter portion 107 of the inner piston 104. The seal adapter 512 may include the electrical feedthrough bulkhead 514 positioned within the bore 515 of the seal adapter 512, as previously described. Upon connecting the first connecting portion 521 of the seal adapter 512 to the seal adapter portion 107, the distal contact pin 516 of the bulkhead 514 is automatically placed in electrical communication with the line-in portion 147 of the initiator 118, due to the coaxial alignment of the seal adapter 512, the bulkhead 514, and the initiator 118, in particular the line-in portion 147 of the initiator 118 (as positioned by the initiator holder 138). In the case of use with a further wellbore tool string, the second connecting portion 522 of the seal adapter 512 may then be connected to an upstream wellbore tool, and, upon connecting the second connecting portion 522 of the seal adapter 512 to the upstream wellbore tool, the proximal contact pin 518 of the bulkhead 514 is placed in electrical communication with an electrical relay of the upstream wellbore tool, again by an alignment between the electrical relay and the bulkhead 514/seal adapter 512. When the tool string including the upstream wellbore tool(s), the single use setting tool 100, the wellbore tool 602, and any other components is assembled, the tool string may be deployed into the wellbore. Upon reaching the desired position for actuating the wellbore tool 602, the method includes relaying an electrical signal from the surface or other component within the tool string, through the electrical relay of the upstream wellbore tool, to the initiator 118 via the electrical feedthrough bulkhead 514. The initiator 118 is initiated in response to receiving the electrical signal from the distal contact pin 516 of the electrical feedthrough bulkhead 514 at the line-in portion 147 of the initiator 118.

[0116] In an aspect, an exemplary method may further include inserting the power charge 116 and the initiator holder 138, if they are not already present, into the inner piston cavity 114 by, e.g., inserting through the open proximal end 106 of the inner piston 104—i.e., through the inner area 519 of the seal adapter portion 107.

[0117] In an aspect, an exemplary method may further include confirming, after initiating the initiator 118, that the electrical communication between the distal contact pin 516 of the electrical feedthrough bulkhead 514 and the initiator 118 has been terminated.

[0118] In further aspects of the disclosure, the power charge composition (by weight percent (wt. %)) may include, without limitation: $NaNO_3$ (Sodium Nitrate) (40% - 75%) or KNO_3 (Potassium Nitrate) (40% - 75%) as 1 to 1 alternatives; Pyrodex (0% - 10%); Wheat Flower (15% to 45%); and, Epoxy Binder (10% to 30%). The booster material (i.e., fast burning material) may include, without limitation: Pyrodex or black powder (50% - 100%) and KNO_3 (Potassium Nitrate) (0% - 50%).

[0119] With reference now to FIG. 21, a cross-sectional view of an exemplary embodiment of a single use setting tool 100 according the exemplary embodiments shown and described with respect to FIGS. 18-20 is shown. FIG. 21 illustrates, similar to FIG. 18, the outer sleeve 120 and a portion of the inner piston 104 after the plug 603 has been released and the inner piston 104 is retracted within the outer sleeve 120. As shown in FIG. 21, the exemplary embodiments according to the disclosure, individually or variously, may provide benefits such as dual pressure vents, which include pressure vents 154 and an axial pressure vent 654 formed as a gap that is created between the sealing section 254 of the outer sleeve 120, including the second seal 150, and a tapered region 653 of the distal rod 109. The axial pressure vent 654 is formed after the single use setting tool 100 has actuated the tool 102, such that in the retracted (post-actuation) position of the inner piston 104 relative to the outer sleeve 120 the tapered region 653 of the distal rod 109 is aligned with the sealing section 254 of the outer sleeve 120. The tapered region 653 of the distal rod 109 dips low enough below the sealing section 254 and the second seal 150 so as to create a gap, i.e., the axial pressure vent 654, therebetween. The axial pressure vent 654 is open to the central bore 126 within the outer sleeve 120 such that excess or remaining pressure in the central bore 126 may escape through the axial pressure vent 654. The dual pressure bleed allows more effective release of pressure from the spent single use setting tool 100, and the pressure bleed may be done at the surface of the wellbore because oil cushions and other components of a reusable setting tool, or additional components of a more complicated disposable setting tool, do not impede the pressure bleed. While the exemplary embodiment that FIG. 21 shows includes shock blocking structures 650 similar to the exemplary embodiments shown in FIGS. 18-20, the dual pressure bleed as described above is not limited thereto and forms an aspect of the various exemplary embodiments of a single use setting tool as presented throughout the disclosure.

[0120] The exemplary embodiments also do not require a firing head and may be assembled in a “plug and go” fashion due to the configuration of the electrically contactable initiator 118 (i.e., initiator 118 having the electrically connectable line-in portion 147) and the seal adapter 512 which puts the initiator 118 in electrical communication with the bulkhead 514 and, thereby, a relay for the electrical initiation signal. For example, when used with the exemplary embodiments of a single use setting tool 100 as presented throughout the disclosure, the modular initiator 118 and bulkhead assembly 514 as described herein and, as previously mentioned, with reference to U.S. Patent Nos. 9,581,422 and 9,605,937, among others, allows the initiator 118 to be pushed into the initiator holder 138 through the open proximal end 106 of the inner piston 104, i.e., through the inner area 519 of the seal adapter portion 107. The initiator holder 138 positions the initiator 118 and the line-in portion 147 of the initiator head 146 coaxially with the seal adapter portion 107 such that when the seal adapter 512 including the exemplary electrical feedthrough bulkhead 514 is connected to the seal adapter portion 107, a first electrical contact (e.g., distal contact pin 516) is automatically placed in electrical contact with the electrically contactable line-in portion 147 of the initiator head portion 146. When the seal adapter 512 is connected on its opposite end to an upstream wellbore tool having a complementary electrical connection/relay, the second electrical contact (e.g., proximal contact pin 518) of the bulkhead 514 is automatically placed in electrical contact with that electrical connection/relay. The above assembly and benefits form various aspects of an exemplary single use setting tool 100 as presented throughout the disclosure, and a method for using the same.

[0121] In addition, the initiator holder 138 by the same aspects of the exemplary embodiments positions the initiator 118 coaxially with the inner piston cavity 114 and the ignition components (such as booster 528) and power charge 116 therein.

[0122] While the exemplary embodiments have been described according to the initiator holder 138 positioning the initiator 118 and/or electrically contactable line-in portion 147 of the detonator head 146 coaxially with the seal adapter portion 107 and/or inner piston cavity 114, the disclosure is not limited thereto. Operation of a “plug-and-go” system, e.g., with a push-in initiator, as explained above, includes alignments, shapes, and configurations according to those principles and consistent with this disclosure.

[0123] The aspects of the exemplary embodiments as presented above further allow the initiator 118 to initiate in response to receiving an electrical signal directly, via the bulkhead 514, from an upstream tool, in the absence of a firing head. The absence of a firing head and any necessary adapters for the firing head also helps to shorten the length of the single use setting tool 100.

[0124] This disclosure, in various embodiments, configurations and aspects, includes components, methods, processes, systems, and/or apparatuses as depicted and described herein, including various embodiments, sub-combinations, and subsets thereof. This disclosure contemplates, in various embodiments, configurations and aspects, the actual or optional use or inclusion of, e.g., components or processes as may be well-known or understood in the art and consistent with this disclosure though not depicted and/or described herein.

[0125] The phrases "at least one,” "one or more” and "and/or" are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions "at least one of A, B and C,” "at least one of A, B, or C,” "one or more of A, B, and C,” "one or more of A, B, or C," and "A, B, and/or C" means A alone, B alone, C alone, A and B together, A and C together, B and C together, or A, B, and C together.

[0126] In this specification and the claims that follow, reference will be made to a number of terms that have the following meanings. The terms "a" (or "an") and "the" refer to one or more of that entity, thereby including plural referents unless the context clearly dictates otherwise. As such, the terms "a" (or "an"), "one or more" and "at least one" can be used interchangeably herein. Furthermore, references to "one embodiment," "some embodiments," "an embodiment," and the like are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term such as "about" is not to be limited to the precise value specified. In some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Terms such as "first," "second," "upper," "lower," etc. are used to identify one element from another, and unless otherwise specified are not meant to refer to a particular order or number of elements.

[0127] As used herein, the terms "may" and "may be" indicate a possibility of an occurrence within a set of circumstances; a possession of a specified property, characteristic, or function; and/or qualify another verb by expressing one or more of an ability, capability, or possibility associated with the qualified verb. Accordingly, usage of "may" and "may be" indicates that a modified term is apparently appropriate, capable, or suitable for an indicated capacity, function, or usage, while taking into account that in some circumstances the modified term may sometimes not be appropriate, capable, or suitable. For example, in some circumstances an event or capacity can be expected, while in other circumstances the event or capacity cannot occur - this distinction is captured by the terms "may" and "may be."

[0128] As used in the claims, the word "comprises" and its grammatical variants logically also subtend and include phrases of varying and differing extent such as for example, but not limited thereto, "consisting essentially of" and "consisting of." Where necessary, ranges have been supplied, and those ranges are inclusive of all sub-ranges therebetween. It is to be expected that the appended claims should cover variations in the ranges except where this disclosure makes clear the use of a particular range in certain embodiments.

[0129] The terms "determine," "calculate," and "compute," and variations thereof, as used herein, are used interchangeably and include any type of methodology, process, mathematical operation or technique.

[0130] This disclosure is presented for purposes of illustration and description. This disclosure is not limited to the form or forms disclosed herein. In the Detailed Description of this disclosure, for example, various features of some exemplary embodiments are grouped together to representatively describe those and other contemplated embodiments, configurations, and aspects, to the extent that including in this disclosure a description of every potential embodiment, variant, and combination of features is not feasible. Thus, the features of the disclosed embodiments, configurations, and aspects may be combined in alternate embodiments, configurations, and aspects not expressly discussed above. For example, the features recited in the following claims lie in less than all features of a single disclosed embodiment, configuration, or aspect. Thus, the following claims are hereby incorporated into this Detailed Description, with each claim standing on its own as a separate embodiment of this disclosure.

[0131] Advances in science and technology may provide variations that are not necessarily express in the terminology of this disclosure although the claims would not necessarily exclude these variations.

CLAIMS

What is claimed is:

1. A single use setting tool for actuating a tool in a wellbore, the single use setting tool comprising:

an inner piston having a piston proximal end, a piston distal end opposite the piston proximal end, and a piston annular wall, wherein the piston proximal end includes a seal adapter portion and the piston annular wall defines a piston cavity;

an initiator holder, wherein at least a portion of the initiator holder is positioned within the piston cavity and the initiator holder is configured for receiving and retaining an initiator in a first position within the piston proximal end and coaxial with the seal adapter portion;

a gas diverter channel open to and extending from the piston cavity through the piston annular wall;

an outer sleeve having a sleeve proximal end, a sleeve distal end, and a sleeve central bore extending from the sleeve proximal end to the sleeve distal end, wherein a portion of the inner piston including the piston cavity is positioned within the sleeve central bore and the inner piston and the outer sleeve are configured for axially sliding relative to one another; and,

an expansion chamber defined by an inner portion of the outer sleeve and an outer portion of the annular wall of the inner piston, wherein the gas diverter channel is open to the expansion chamber through the outer portion of the annular wall of the inner piston.

2. The single use setting tool of claim 1, further comprising an initiator provided within the initiator holder, wherein the initiator includes an initiator head and an electrically contactable line-in portion of the initiator head.

3. The single use setting tool of claim 2, wherein the initiator is configured for initiating without a firing head, in response to an electrical signal relayed to the line-in portion of the initiator head.

4. The single use setting tool of claim 2, wherein the electrically contactable line-in portion of the initiator is coaxial with the seal adapter portion.

5. The single use setting tool of claim 2, further comprising a booster holder positioned between the initiator and the power charge, wherein an indentation is formed in the power charge, and the booster holder is configured for retaining a booster charge and positioning the booster charge within the indentation.

6. The single use setting tool of claim 2, wherein the initiator holder is formed from material that is destructible upon initiation of the initiator and, in response to the destruction of the initiator holder upon initiation of the initiator, the initiator moves from the first position to a second position in which the initiator is not coaxial with the seal adapter portion.

7. The single use setting tool of any of the previous claims, further comprising a shock blocker structure positioned at the piston distal end.

8. The single use setting tool of any of the previous claims, further comprising a power charge positioned within the piston cavity.

9. The single use setting tool of claim 8, further comprising a gas flow path between an external surface of the power charge and the piston annular wall, wherein the gas flow path is open to one of the gas diverter channel and the expansion chamber.

10. The single use setting tool of claim 9, wherein the power charge is a hexagonally-shaped power charge, and the gas flow path is provided between a radial outer surface of the hexagonally-shaped power charge and the piston annular wall.

11. The single use setting tool of any of the previous claims, wherein the outer sleeve includes a shear element aperture extending from an outer surface of the outer sleeve to the sleeve central bore and the inner piston includes a shear element notch in an outer surface of the inner piston, wherein the shear element aperture is aligned with the shear element notch and the shear element aperture and the seal element notch are together

configured for receiving a shear element extending between and positioned within each of the shear element aperture and the shear element notch.

12. A method of actuating a wellbore tool with a single use setting tool, comprising:

connecting the single use setting tool to the wellbore tool, wherein the single use setting tool includes

an inner piston having a piston proximal end including a seal adapter portion, a piston distal end opposite the piston proximal end, and a piston annular wall that defines a piston cavity, wherein the seal adapter portion is configured for connecting to a first connecting portion of a seal adapter, wherein the seal adapter includes a seal adapter inner bore and an electrical feedthrough bulkhead positioned within the inner bore of the seal adapter,

a power charge positioned within the piston cavity,

an initiator holder positioned within the piston cavity,

a gas diverter channel open to and extending from the piston cavity through the piston annular wall,

an outer sleeve having a sleeve proximal end, a sleeve distal end, and a sleeve central bore extending from the sleeve proximal end to the sleeve distal end, wherein a portion of the inner piston including the piston cavity is positioned within the sleeve central bore and the inner piston and the outer sleeve are configured for axially sliding relative to one another, and

an expansion chamber defined by an inner portion of the outer sleeve and an outer portion of the annular wall of the inner piston, wherein the gas diverter channel is open to the expansion chamber through the outer portion of the annular wall of the inner piston;

inserting an initiator into the initiator holder;

connecting the first connecting portion of the seal adapter to the seal adapter portion of the inner piston, wherein the seal adapter and the electrical feedthrough bulkhead are together configured such that a first electrical connection of the electrical feedthrough bulkhead is in electrical communication with a line-in portion of the initiator when the seal adapter is connected to the seal adapter portion of the inner piston;

connecting a second connecting portion of the seal adapter to an upstream wellbore tool, wherein the seal adapter and the electrical feedthrough bulkhead are together configured such that a second electrical connection of the electrical feedthrough bulkhead is in electrical communication with an electrical relay of the upstream wellbore tool when the seal adapter is connected to the upstream wellbore tool;

deploying the upstream wellbore tool, single use setting tool, and wellbore tool into a wellbore;

relaying an electrical signal from the electrical relay of the upstream wellbore tool to the initiator via the electrical feedthrough bulkhead; and,

initiating the initiator in response to receiving the electrical signal from the first electrical connection of the electrical feedthrough bulkhead at the line-in portion of the initiator.

13. The method of claim 12, further comprising confirming, after initiating the initiator, that the electrical communication between the first electrical connection of the electrical feedthrough bulkhead and the initiator has been terminated.

14. A wellbore tool string comprising:

a seal adapter comprising:

a seal adapter inner bore; and,

an electrical feedthrough bulkhead positioned within the seal adapter inner bore;

a single use setting tool comprising:

an inner piston having a piston proximal end including a seal adapter portion, a piston distal end opposite the piston proximal end, and a piston annular wall that defines a piston cavity, wherein the seal adapter portion is configured for connecting to a first connecting portion of the seal adapter;

a power charge positioned within the piston cavity;

an initiator holder positioned within the piston cavity;

a gas diverter channel open to and extending from the piston cavity through the piston annular wall;

an outer sleeve having a sleeve proximal end, a sleeve distal end, and a sleeve central bore extending from the sleeve proximal end to the sleeve distal end, wherein a portion of the inner piston including the piston cavity is positioned within the sleeve central bore and the inner piston and the outer sleeve are configured for axially sliding relative to one another;

an expansion chamber defined by an inner portion of the outer sleeve and an outer portion of the annular wall of the inner piston, wherein the gas diverter channel is open to the expansion chamber through the outer portion of the annular wall; and,

an initiator received in the initiator holder, wherein the initiator includes an electrically contactable line-in portion and a first electrical connection of the electrical feedthrough bulkhead is in electrical contact with the electrically contactable line-in portion of the initiator.

15. The wellbore tool string of claim 14, further comprising a downstream wellbore tool, wherein the sleeve distal end includes a sleeve connecting portion connected to the downstream wellbore tool.

16. The wellbore tool string of claim 15, wherein the downstream wellbore tool is a setting sleeve for a plug.

17. The wellbore tool string of claim 16, wherein the piston distal end is connected to a mandrel of the setting sleeve.

18. The wellbore tool string of claim 17, wherein the single use setting tool further comprises a shock blocker structure positioned at the piston distal end and adjacent to a connecting end of the mandrel.

19. The wellbore tool string of any of claims 14-18, further comprising an upstream wellbore tool, wherein

the electrical feedthrough bulkhead includes a second electrical connection,

the second electrical connection of the electrical feedthrough bulkhead is in electrical contact with a contactable electrical connection of the upstream wellbore tool, and

the first electrical connection of the electrical feedthrough bulkhead is in electrical communication with the second electrical connection of the electrical feedthrough bulkhead.

20. The wellbore tool string of claim 19, wherein the upstream wellbore tool is a perforating gun.

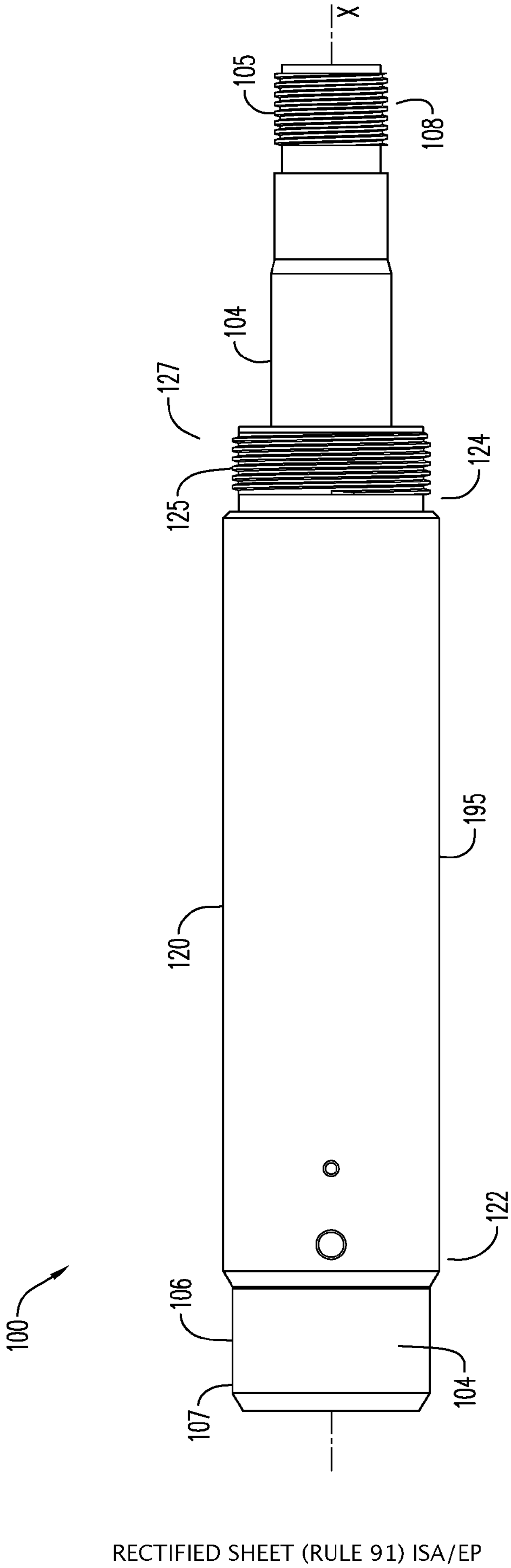

FIG. 1A

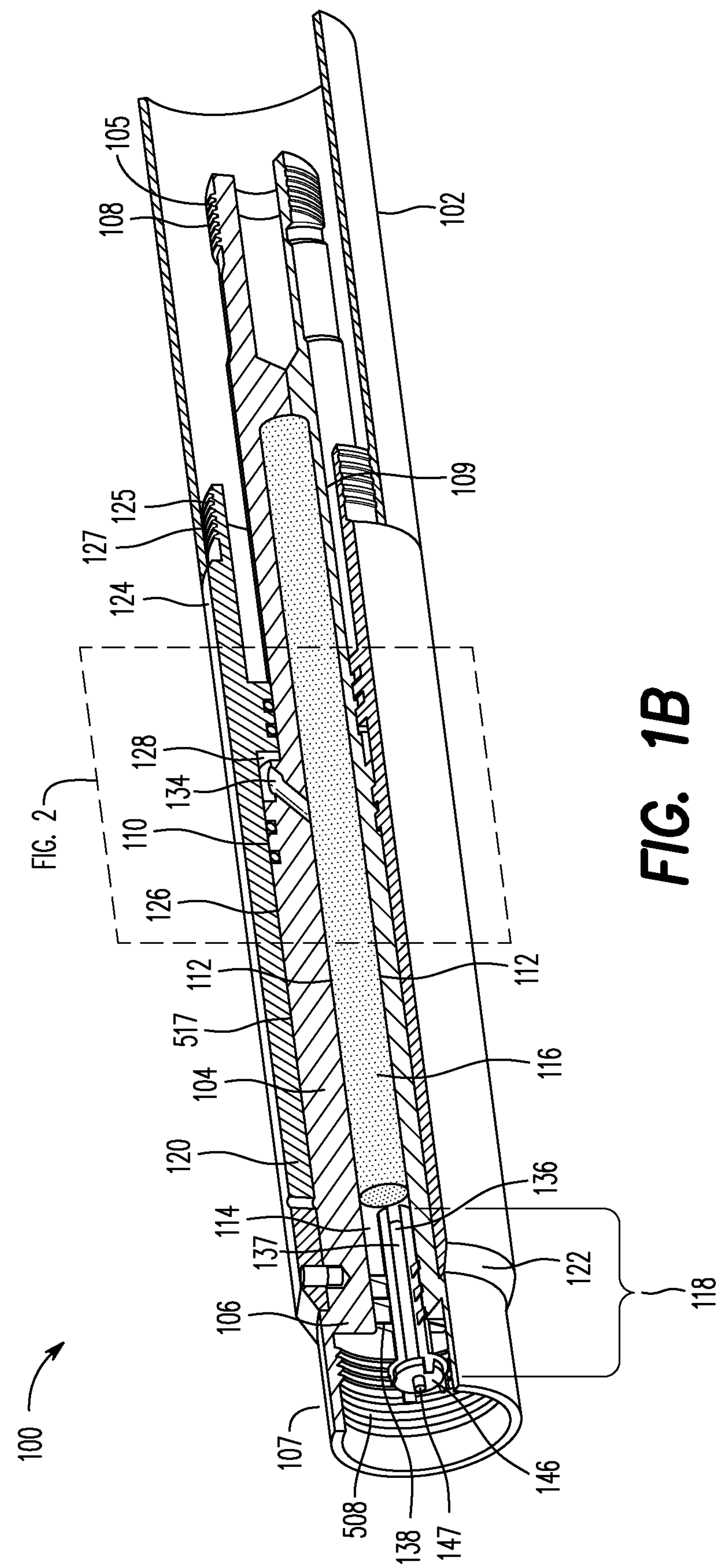
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FIG. 2
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FIG. 1B

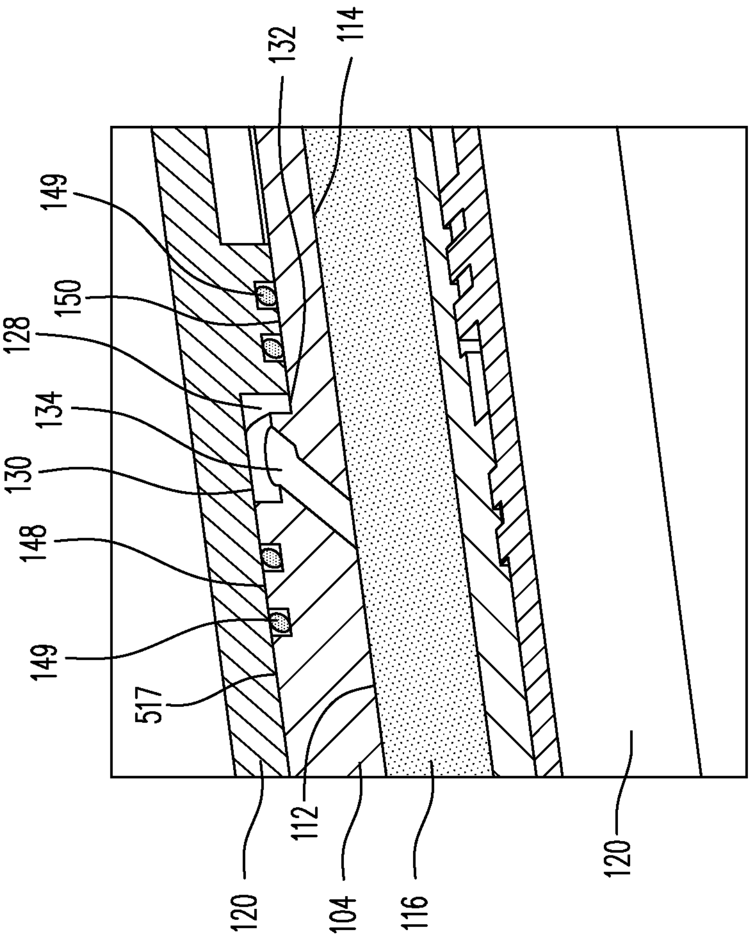
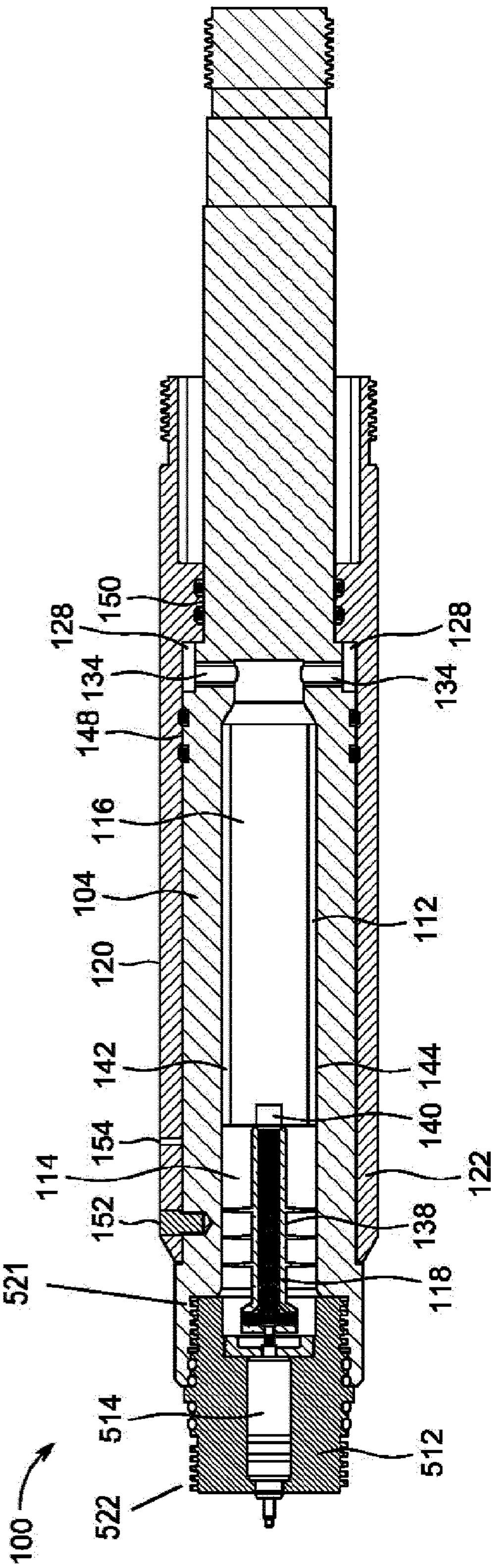


FIG. 2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134
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150
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FIG. 3A

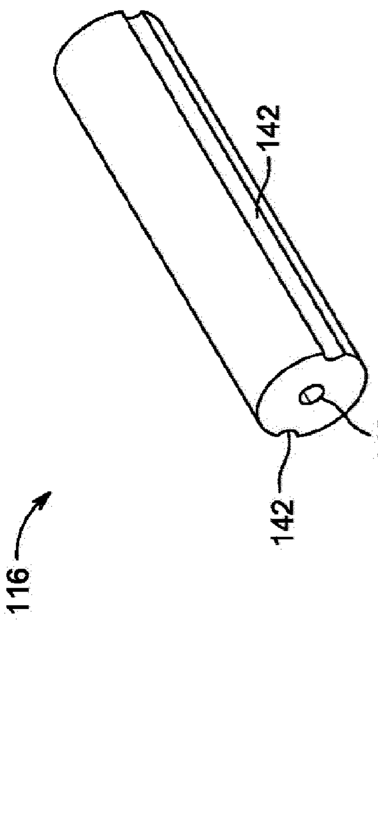
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FIG. 3B

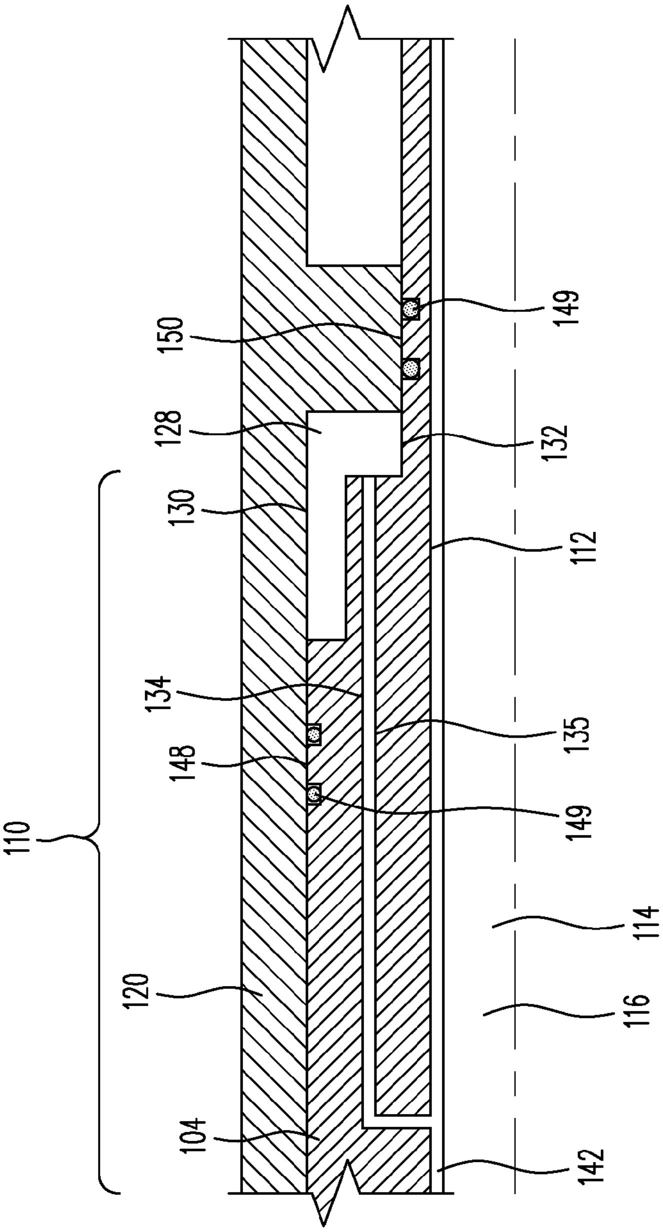

FIG. 4

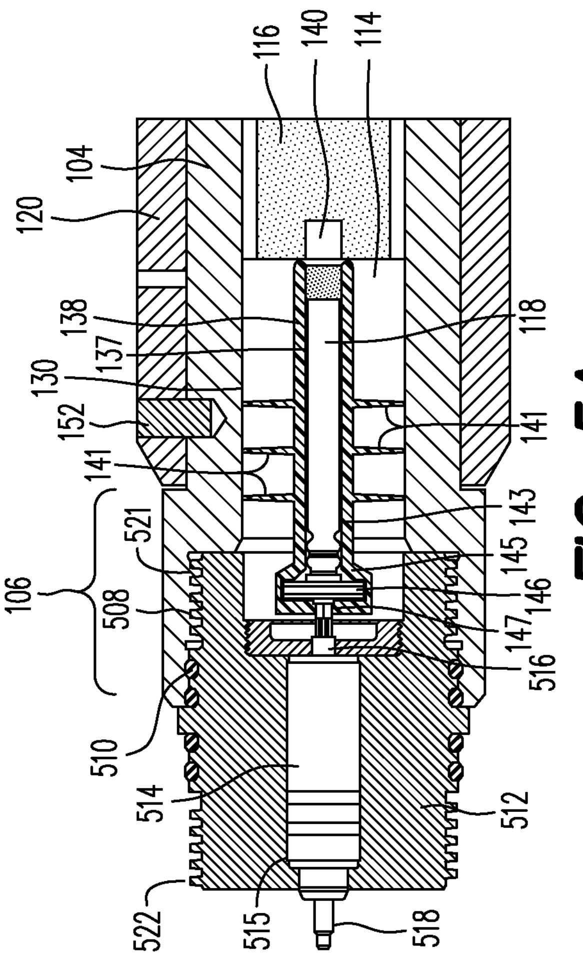
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FIG. 5A

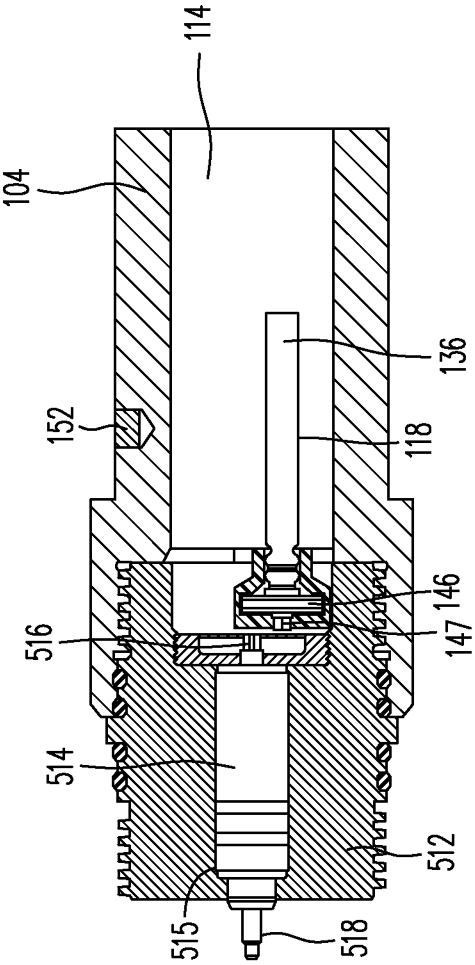
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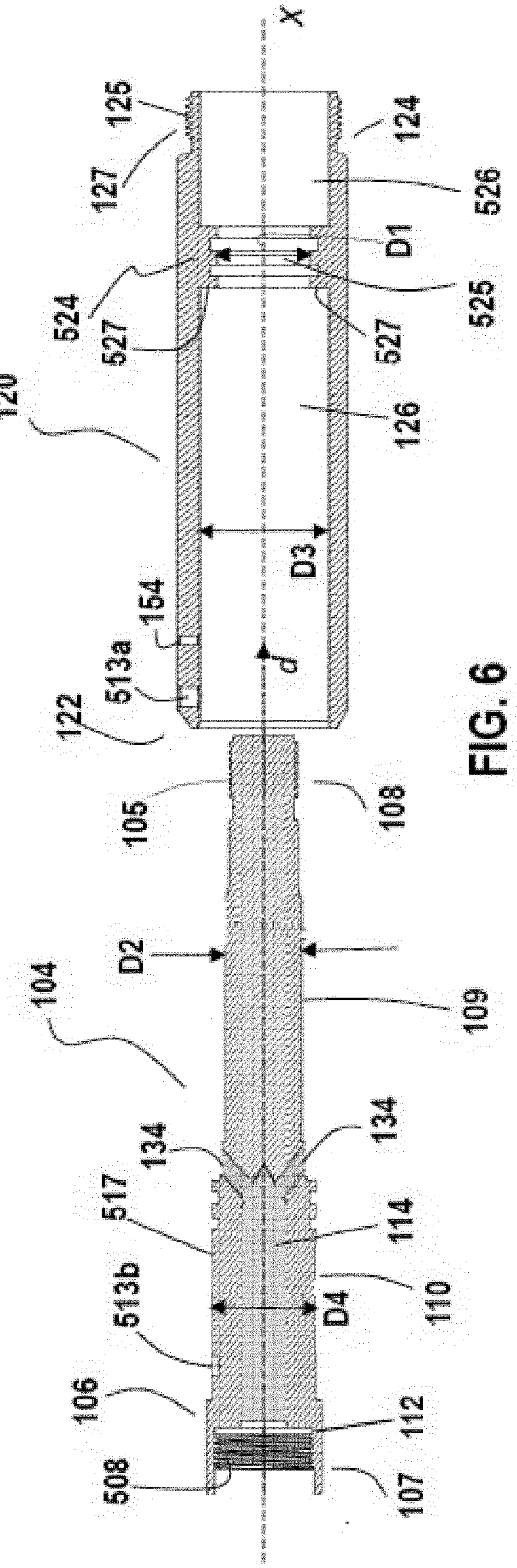
FIG. 5B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513b
D4
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FIG. 6

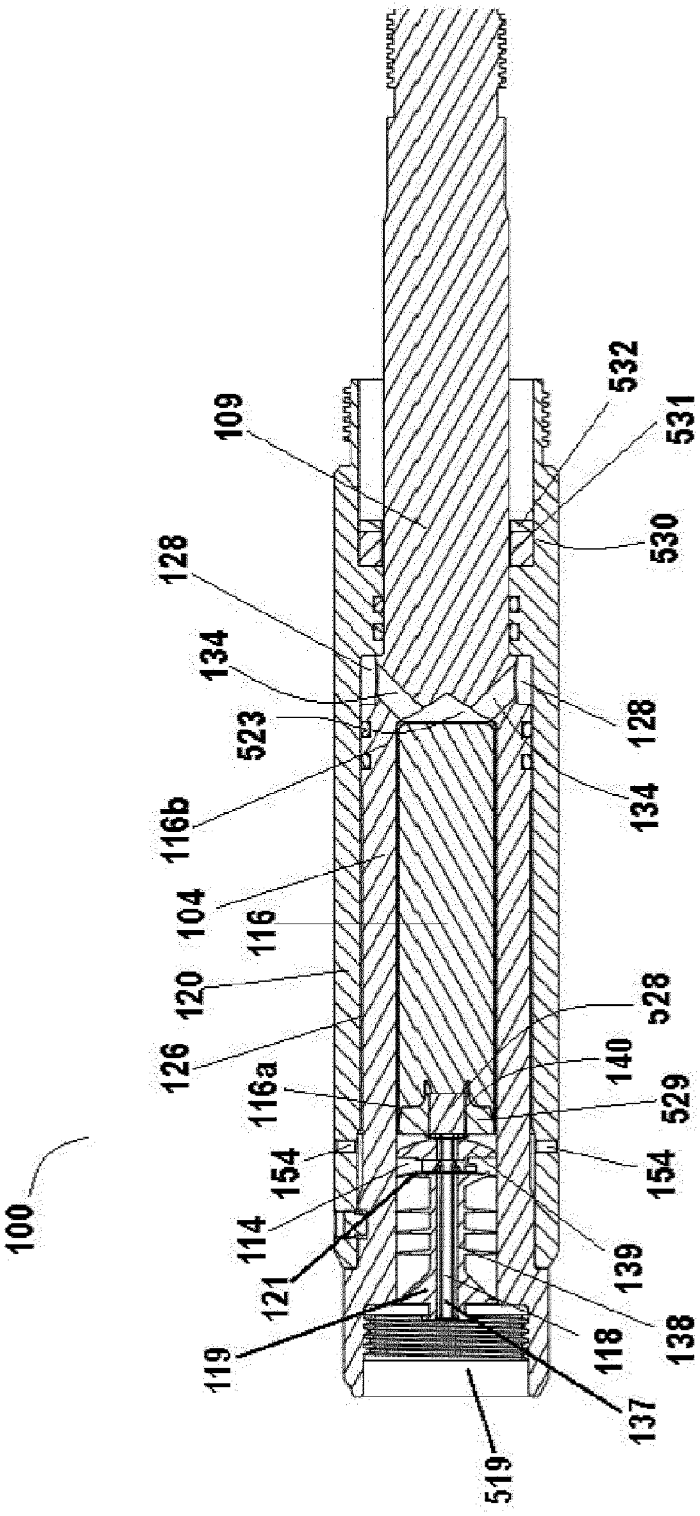
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FIG. 7

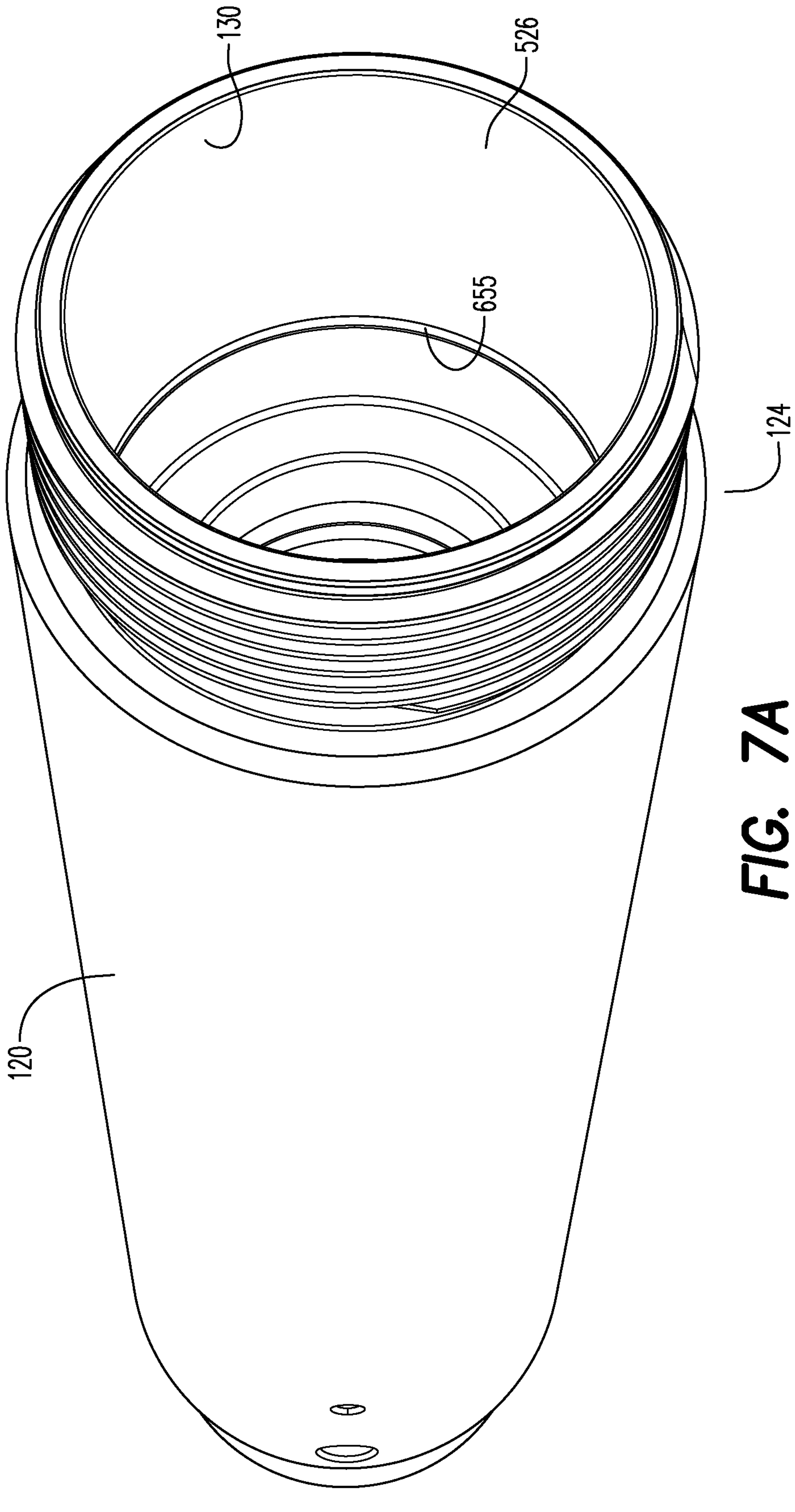

FIG. 7A

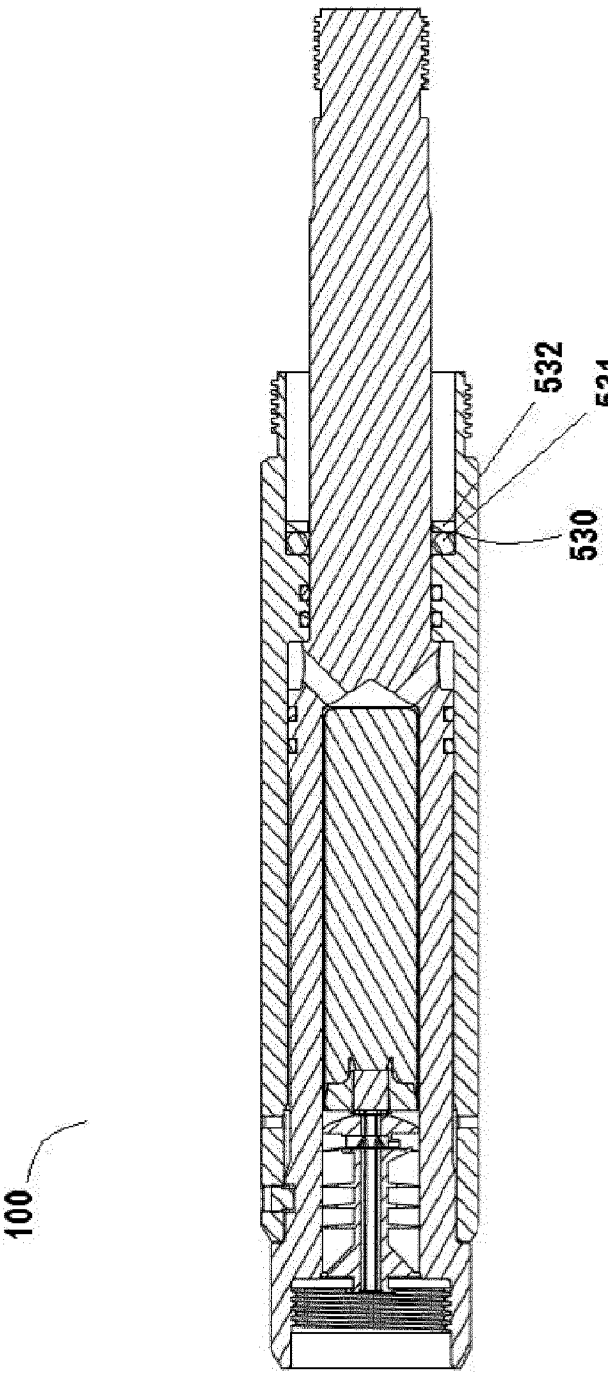

FIG. 8

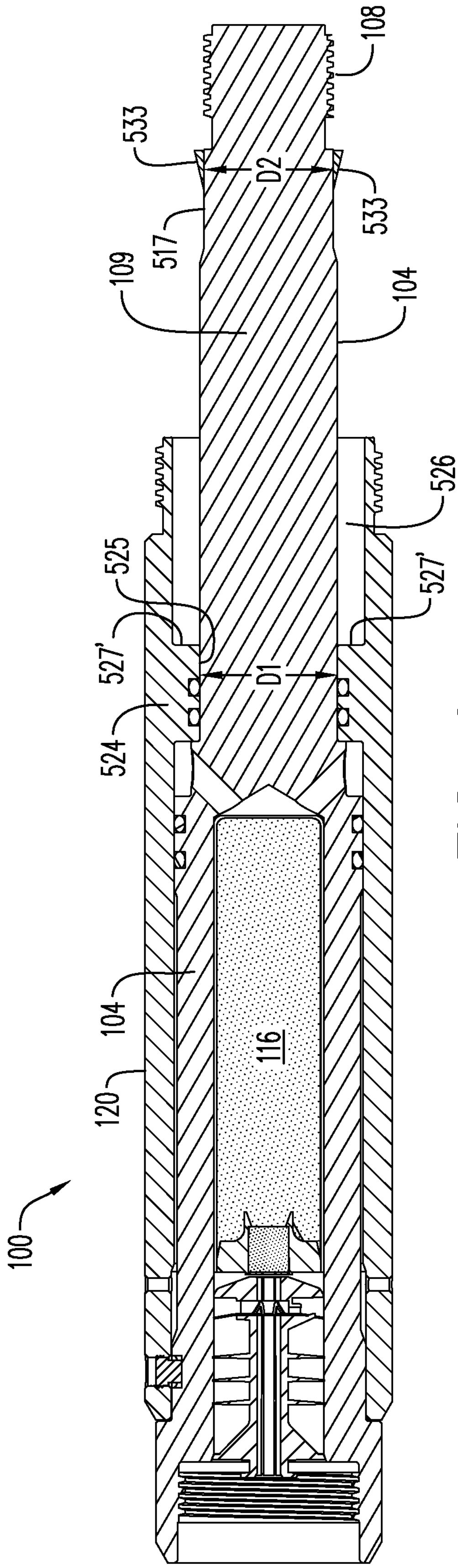

FIG. 9

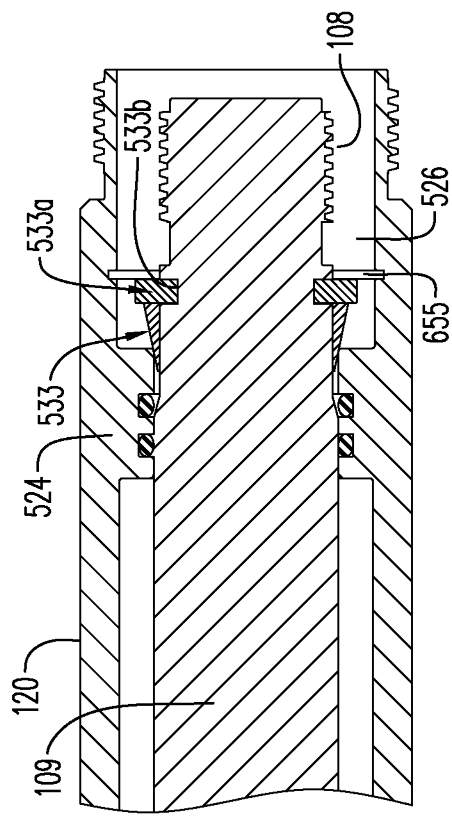

FIG. 9B

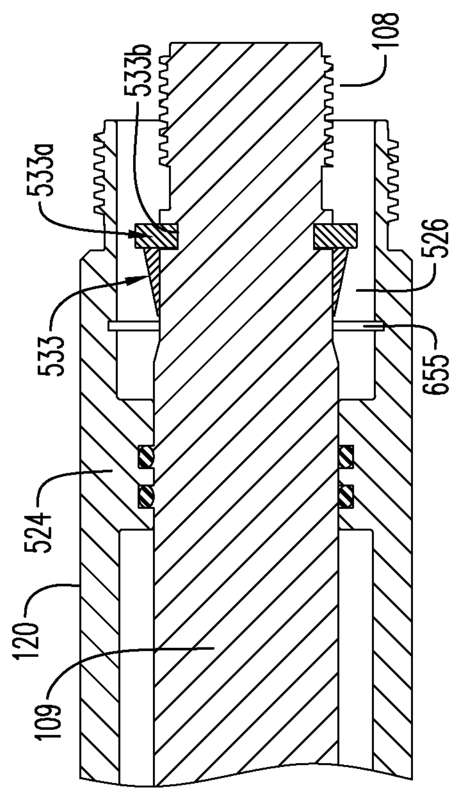

FIG. 9A

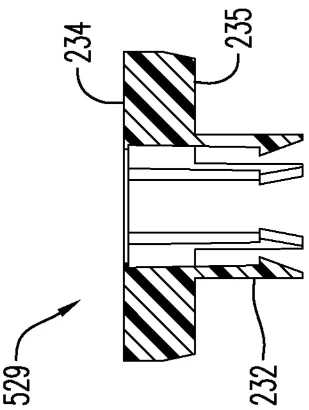

FIG. 12

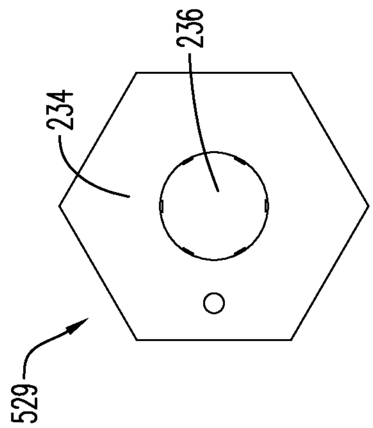

FIG. 13

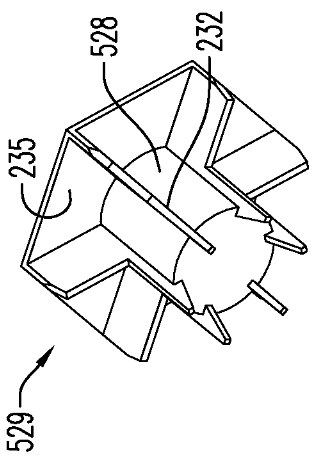

FIG. 10

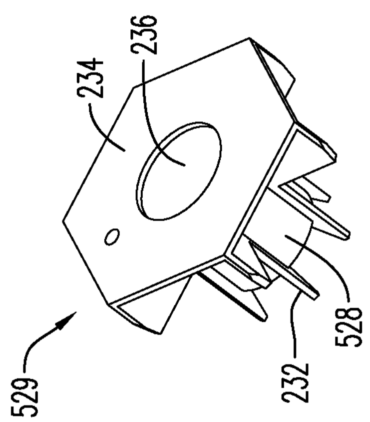

FIG. 11

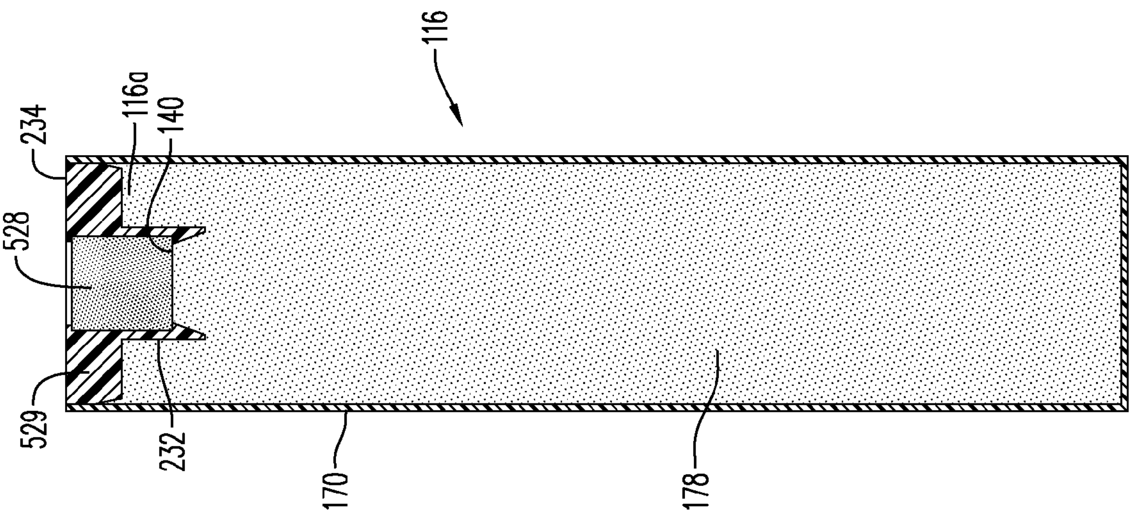

FIG. 15

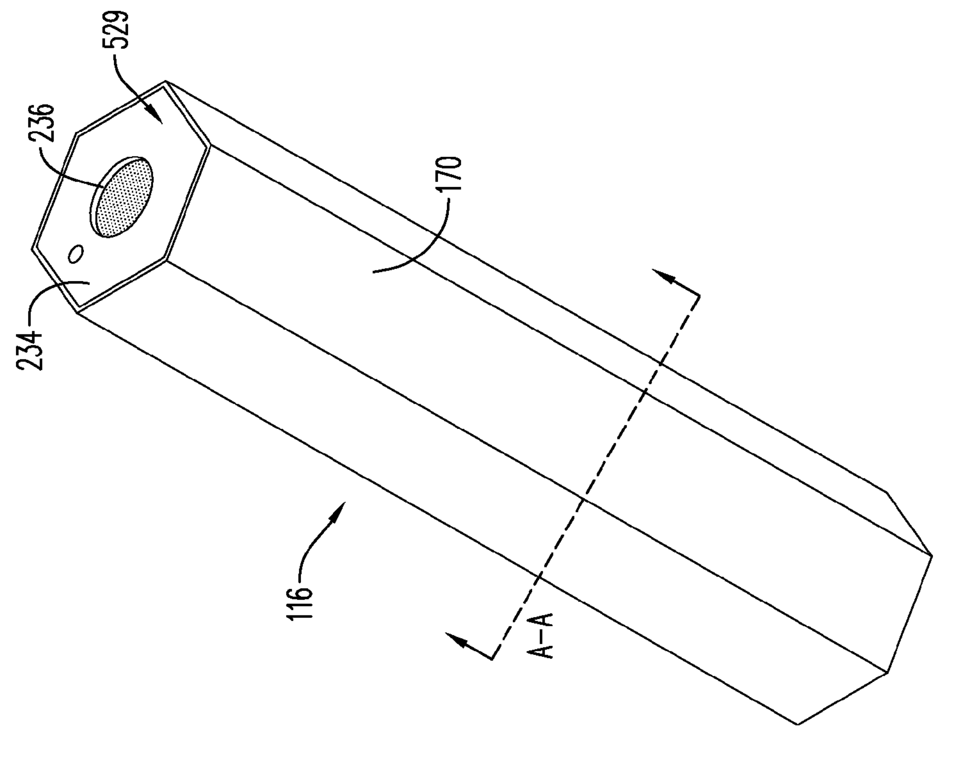

FIG. 14

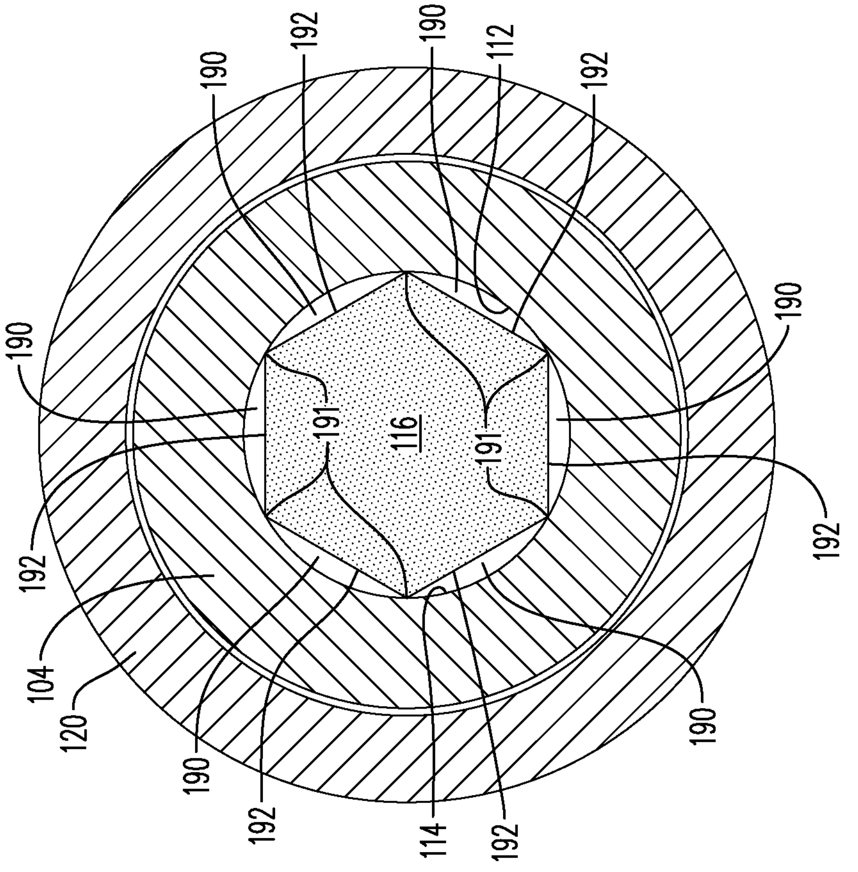
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FIG. 16

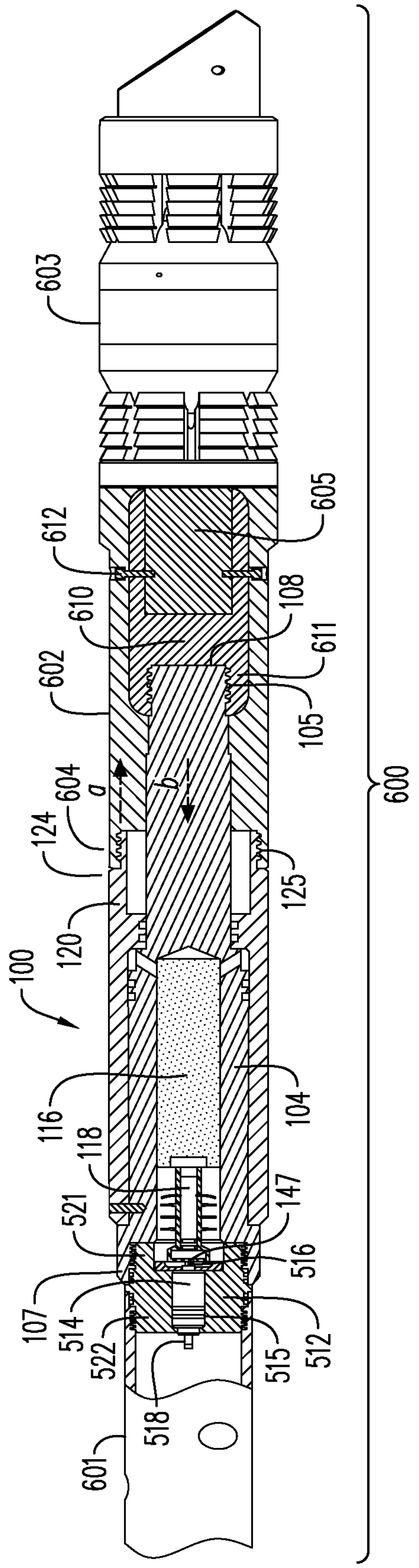
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FIG. 17

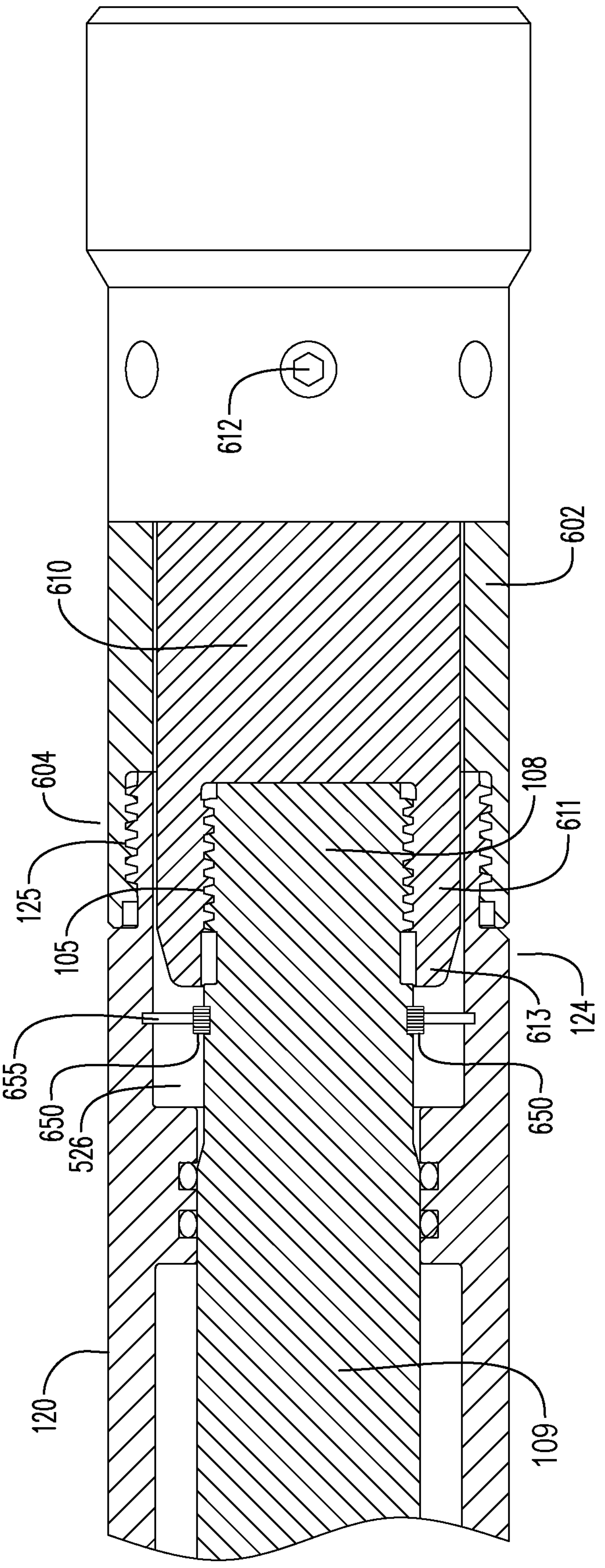

FIG. 18

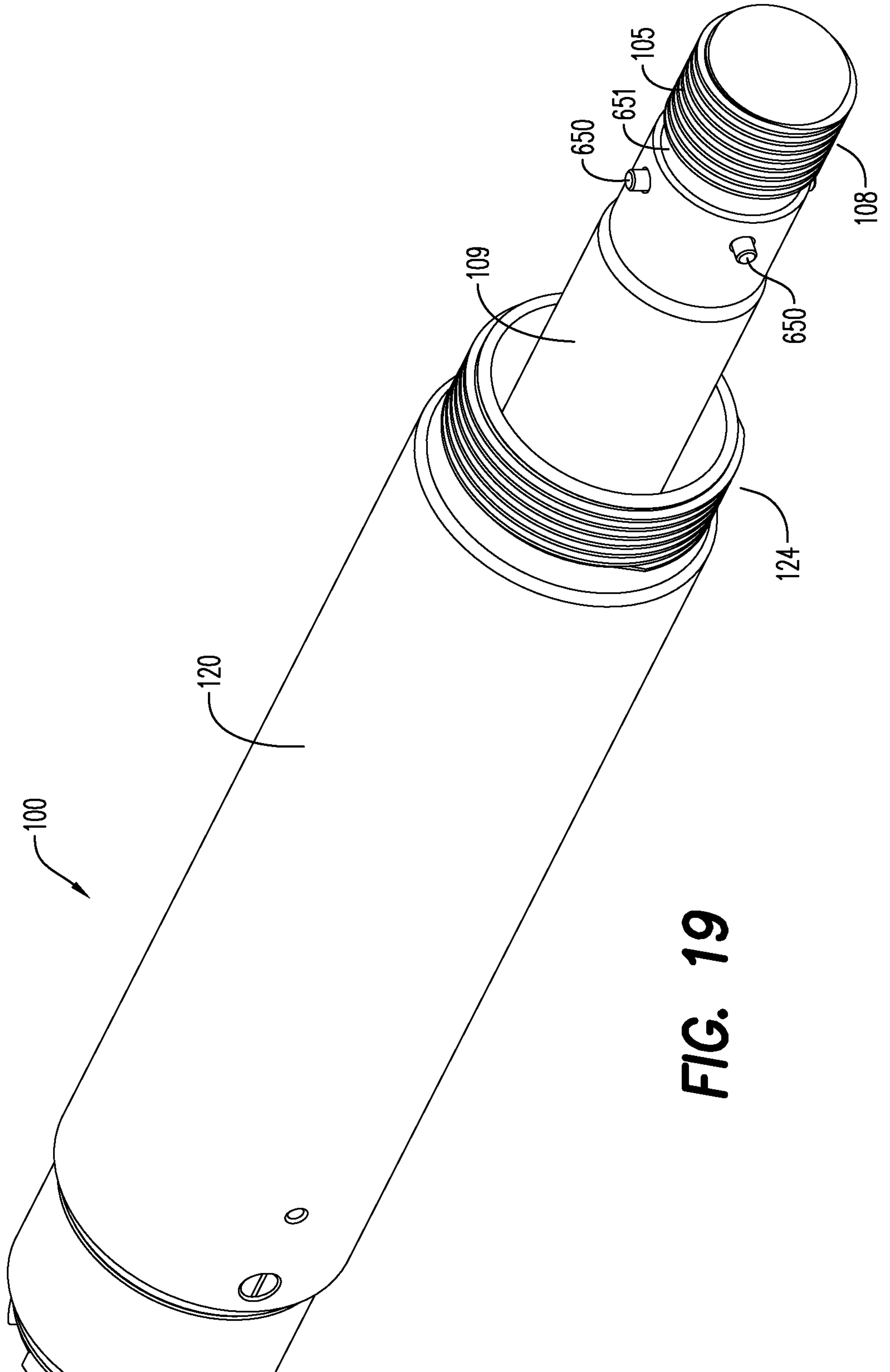

FIG. 19

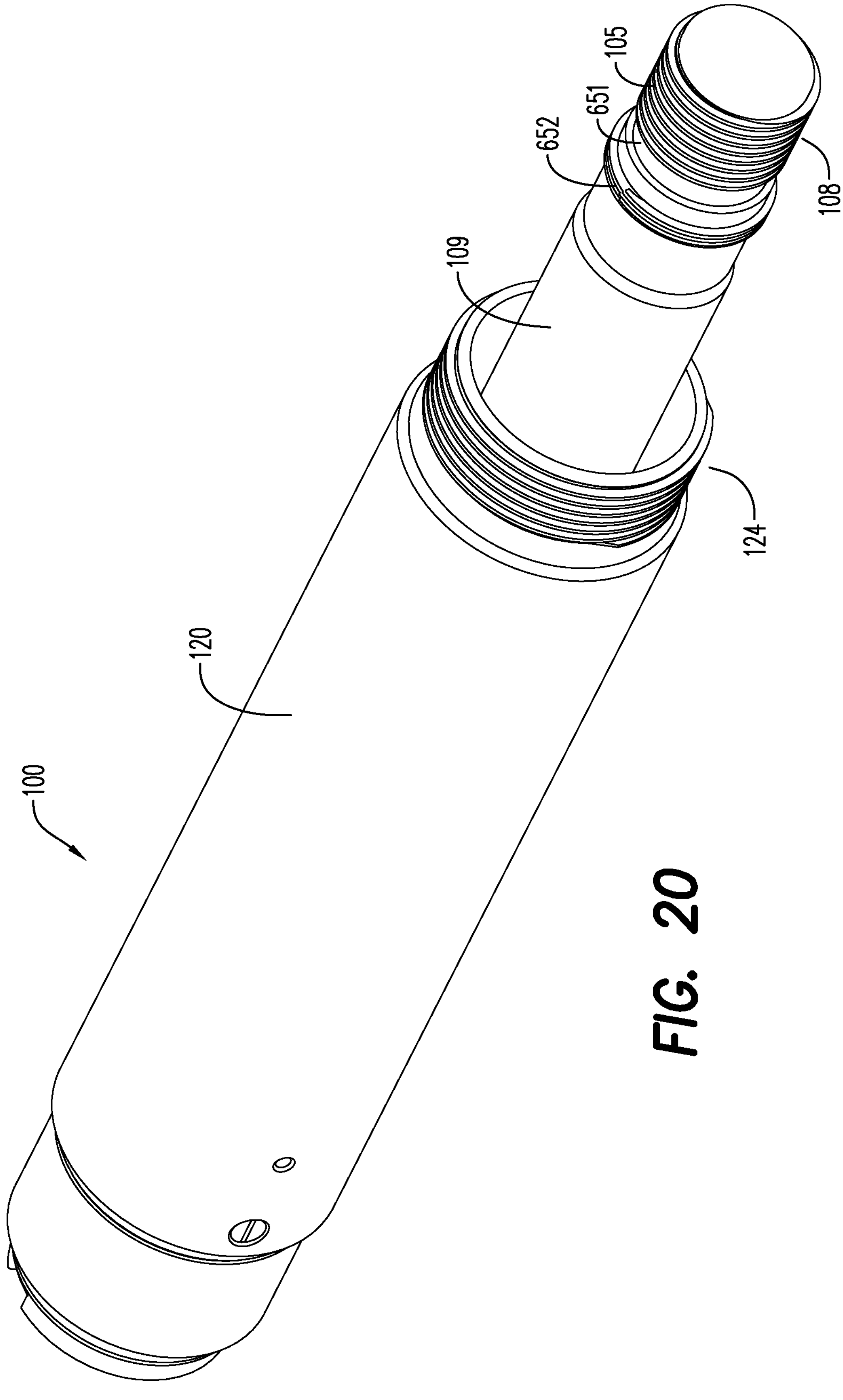

FIG. 20

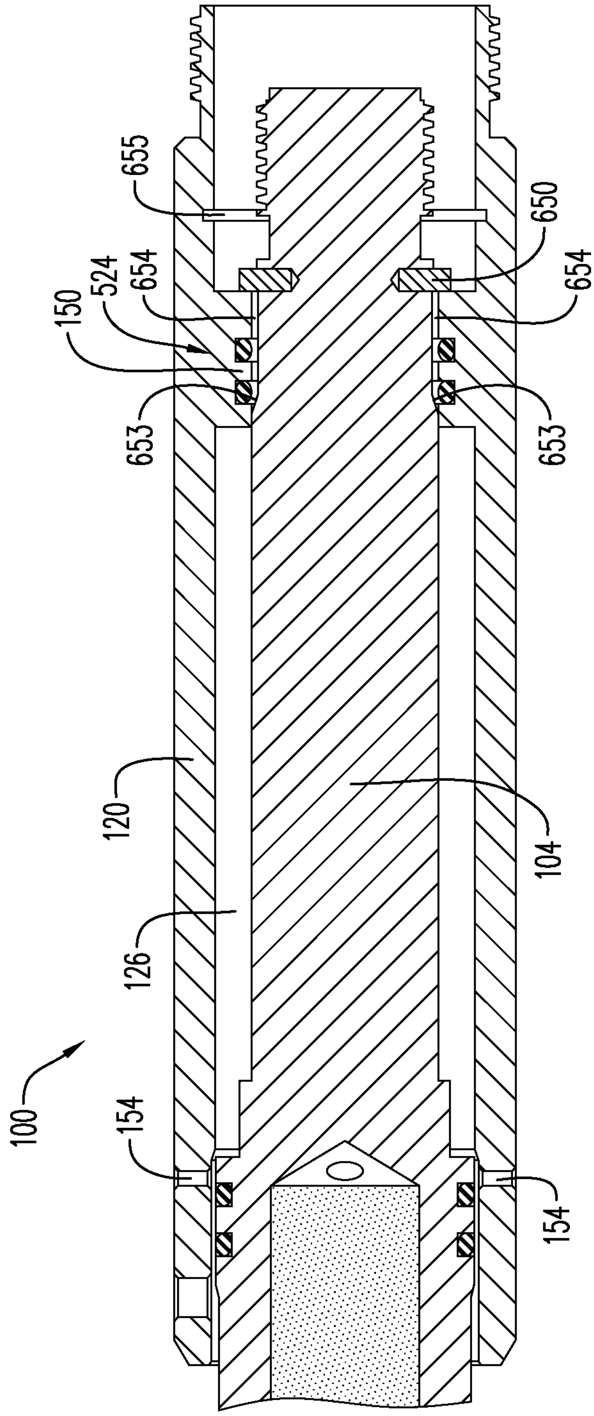

FIG. 21

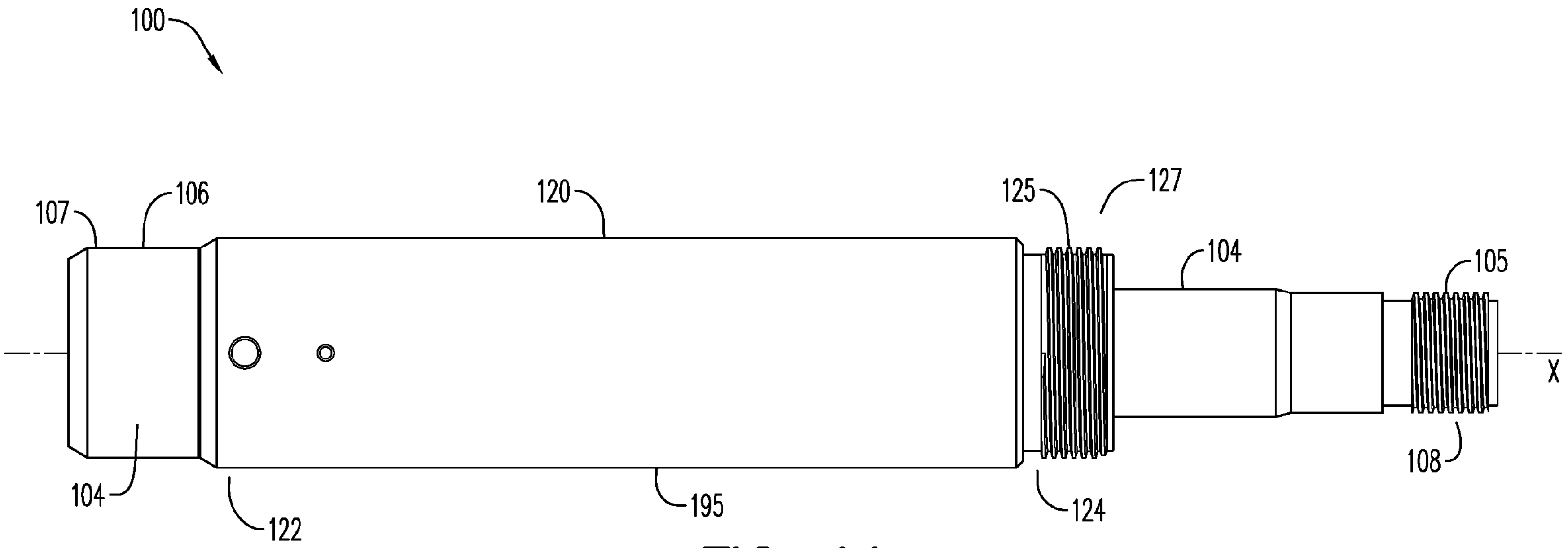

FIG. 1A