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(54) Title: VIBRATION TOOL

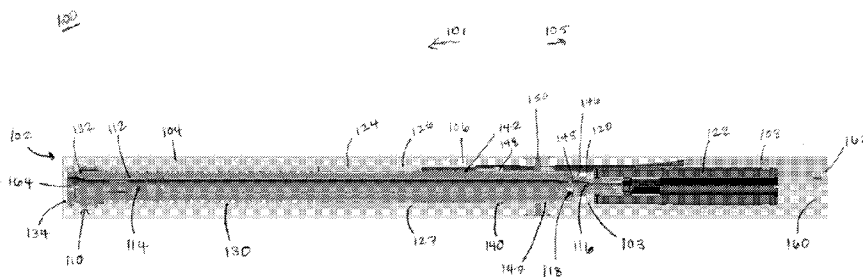


FIGURE 1

(57) **Abstract:** Various implementations described herein are directed to a vibration tool, e.g., for use in drilling. In one implementation, the vibration tool may include a housing having a bore extending therethrough. The vibration tool may also include a piston subassembly positioned inside the bore, where the piston subassembly is configured to oscillate when fluid flow inside the piston subassembly exceeds a predetermined flow rate. The vibration tool may further include a valve mechanism positioned around the piston subassembly, where the valve mechanism is configured to restrict fluid to flow inside the piston subassembly when the valve mechanism is in a closed state and configured to allow the fluid to flow from the piston subassembly to the bore when the valve mechanism is in an open state.



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VIBRATION TOOL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit to and priority of U.S. Provisional Patent Application No. 61/898,097, filed October 31, 2013, and U.S. Non Provisional Patent Application No. 14/497,413, filed September 26, 2014, both of which are hereby incorporated by reference in their entireties.

FIELD OF THE INVENTION

[0002] Aspects of the disclosure relate to drilling of geological stratum. More specifically, aspects of the disclosure relate to a vibration tool and methods of use of the vibration tool.

BACKGROUND INFORMATION

[0003] To prepare a well for production of hydrocarbons, various operations may be performed, including drilling and completion operations. In drilling a well, a drill bit may be carried on an end portion of a drill pipe. In one scenario, deviated or extended reach wells may be drilled to facilitate the recovery of hydrocarbons. Specifically, extended reach wells may be used to increase a recovery rate of hydrocarbons while limiting operational costs.

[0004] During well drilling operations, a friction of a drill string against a wellbore may be generated. In particular, horizontal sections of the wellbore may produce higher friction than vertical or directional sections of the wellbore. If a frictional force reaches a certain level, then the drill string may go into compression and ultimately buckle. Once buckling occurs, then the drill string may not be able to advance farther in the wellbore. Such a stage may be referred to as drill string lockup. The amount of drill string lockup may limit a depth at which a drilling tool or fluid can be delivered into the wellbore, thereby limiting a reach of the well drilling operations.

[0005] Furthermore, with the increase in friction, a weight transfer to a drill bit may not be immediately realized, rates of penetration may decline, the drill string and bit wear may be amplified, and productivity may be reduced. Accordingly, various drilling tools may be used to attenuate the friction, such as those which induce a vibration, hammering effect, or reciprocation in the drill string.

SUMMARY

[0006] Described herein are implementations of various technologies for a vibration tool. In one implementation, the vibration tool may include a housing having a bore extending therethrough. The vibration tool may also include a piston subassembly positioned inside the bore, where the piston subassembly is arranged to oscillate when fluid flow inside the piston subassembly exceeds a predetermined flow rate. The vibration tool may further include a valve mechanism positioned at least partially around the piston subassembly, where the valve mechanism is arranged to restrict fluid to flow inside the piston subassembly when the valve mechanism is in a closed state and to allow the fluid to flow from the piston subassembly to the bore when the valve mechanism is in an open state.

[0007] In another implementation, a latching valve subassembly for use in a tool may include a valve sleeve movably disposed at least partially over a cylindrical body, where the valve sleeve includes one or more communication ports that are aligned with one or more ports of the cylindrical body when the valve sleeve is in a first state. The latching valve subassembly may also include one or more latching mechanisms coupled to the valve sleeve. The latching mechanisms may protrude from an inner diameter of the valve sleeve. The latching mechanisms may be arranged to engage with one or more first latch stops disposed on the cylindrical body when the valve sleeve is in the first state and may also be arranged to engage with one or more second latch stops disposed on the cylindrical body when the valve sleeve is in a second state.

[0008] In yet another implementation, an impact mitigation subassembly for use in a tool may include an impact cap arranged to couple to an end portion of a moving body. The impact mitigation subassembly may also include one or more springs disposed on an inside base of the impact cap, where the springs are arranged to allow displacement of the moving body within the impact cap when movement of the impact cap is arrested.

[0009] The above referenced summary section is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description section. The summary is not intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve disadvantages noted in any part of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Implementations of various techniques will hereafter be described with reference to the accompanying drawings. It should be understood, however, that the accompanying drawings illustrate various implementations described herein and are not meant to limit the scope of various techniques described herein.

[0011] Figure 1 illustrates a cross-sectional view of a vibration tool in accordance with implementations of various techniques disclosed herein.

[0012] Figures 2 and 3 illustrate a cross-sectional view of the vibration tool in a “start” position in accordance with implementations of various techniques disclosed herein.

[0013] Figures 4-15 illustrate a cross-sectional view of the vibration tool in accordance with implementations of various techniques disclosed herein.

[0014] Figures 16 and 17 illustrate a cross-sectional view of the vibration tool in the “start” position in accordance with implementations of various techniques disclosed herein.

[0015] Figure 18 illustrates a cross-sectional view of a vibration tool in accordance with implementations of various techniques disclosed herein.

[0016] Figure 19 illustrates a side view of a sleeve of the latching valve subassembly in accordance with implementations of various techniques disclosed herein.

[0017] Figure 20 illustrates a top view of latching mechanisms of the latching valve subassembly in accordance with implementations of various techniques disclosed herein.

[0018] Figures 21 and 22 illustrate a cross-sectional view of the latching valve subassembly in accordance with implementations of various techniques disclosed herein.

[0019] Figure 23 illustrates a cross-sectional view of the vibration tool in a “start” position in accordance with implementations of various techniques disclosed herein.

[0020] Figures 24-28 illustrate a cross-sectional view of the vibration tool in accordance with implementations of various techniques disclosed herein.

[0021] Figure 29 illustrates a cross-sectional view of the vibration tool in the “start” position in accordance with implementations of various techniques disclosed herein.

[0022] Figure 30 illustrates a cross-sectional view of an impact mitigation subassembly in accordance with implementations of various techniques disclosed herein.

[0023] Figure 31 illustrates a side view of the moving body in accordance with implementations of various techniques disclosed herein.

[0024] Figure 32 illustrates a side view of an impact mitigation subassembly in accordance with implementations of various techniques disclosed herein.

DETAILED DESCRIPTION

[0025] The discussion below is directed to certain specific implementations. It is to be understood that the discussion below is for the purpose of enabling a person with ordinary skill in the art to make and use any subject matter defined now or later by the patent “claims” found in any issued patent herein.

[0026] It is specifically intended that the claims not be limited to the implementations and illustrations contained herein, but include modified forms of those implementations including portions of the implementations and combinations of elements of different implementations as come within the scope of the following claims.

[0027] Reference will now be made in detail to various implementations, examples of which are illustrated in the accompanying drawings and figures. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be apparent to one of ordinary skill in the art that the present disclosure may be practiced without these specific details. In other instances, well-known methods, procedures, components, apparatuses and systems have not been described in detail so as not to obscure aspects of the embodiments.

[0028] It will also be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are used to distinguish one element from another. For example, a first object could be termed a second object, and, similarly, a second object could be termed a first object, without departing from the scope of the claims. The first object and the second object are both objects, respectively, but they are not to be considered the same object.

[0029] The terminology used in the description of the present disclosure herein is for the purpose of describing particular implementations and is not intended to be limiting of the present disclosure. As used in the description of the present disclosure and the appended claims, the singular forms “a,” “an” and “the” are intended to include the

plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term "and/or" as used herein refers to and encompasses one or more possible combinations of one or more of the associated listed items. It will be further understood that the terms "includes" and/or "including," when used in this specification, specify the presence of stated features, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, operations, elements, components and/or groups thereof.

[0030] As used herein, the terms "up" and "down"; "upper" and "lower"; "upwardly" and "downwardly"; "below" and "above"; and other similar terms indicating relative positions above or below a given point or element may be used in connection with some implementations of various technologies described herein. However, when applied to equipment and methods for use in wells or boreholes that are deviated or horizontal, or when applied to equipment and methods that when arranged in a well or borehole are in a deviated or horizontal orientation, such terms may refer to a left to right, right to left, or other relationships as appropriate.

[0031] Various implementations will now be described in more detail with reference to Figures 1-32.

VIBRATION TOOL

Valve Mechanism with Face Seal

[0032] Figure 1 illustrates a cross-sectional view of a vibration tool 100 in accordance with implementations of various techniques described herein. One or more components of the vibration tool 100 may be composed of steel, tungsten carbide, or any other implementation known to those skilled in the art.

[0033] In one implementation, the vibration tool 100 may include a housing 102 having an upper sub 104, a central sub 106, and a lower sub 108. The upper sub 104 may be coupled to the central sub 106, and the central sub 106 may be coupled to the lower

sub 108 through the use of threads, bolts, welds, or any other attachment feature known to those skilled in the art. The housing 102 may be oriented such that the upper sub 104 may engage with uphole members of a drill string (not shown), and the lower sub 108 may engage with downhole members of the drill string.

[0034] The vibration tool 100 may also include a piston subassembly 110 disposed within a housing bore 103 of the housing 102. The piston subassembly 110 may include a piston 112 having a piston bore 114, where an uphole end portion of the piston bore 114 may receive a fluid flow from a bore of the upper sub 104. A downhole end portion of the piston bore 114 may be arranged as a nozzle 116, where the nozzle 116 may allow fluid to exit from the piston bore 114. The piston 112 may also include one or more bypass ports 118 disposed proximate to the downhole end portion of the piston bore 114, where the bypass ports may provide one or more channels for the fluid to flow from the piston bore 114 to the housing bore 103, as described in more detail below.

[0035] The piston subassembly 110 may also include a valve stopper 120, which may be coupled to and/or disposed around the piston 112. The valve stopper 120 may be coupled to the piston 112 through the use of threads, bolts, welds, or any other attachment feature known to those skilled in the art. In one implementation, the valve stopper 120 may be configured to slide onto an outer diameter of the piston 112, beginning at a downhole end portion of the piston 112, until an uphole end portion of the valve stopper 120 abuts a shoulder along the outer diameter of the piston 112.

[0036] In one implementation, the piston subassembly 110 may further include a lower impact cap 122, which may be coupled to and/or disposed around the piston 112. The lower impact cap 122 may be coupled to the piston 112 through the use of threads, bolts, welds, or any other attachment feature known to those skilled in the art. The piston subassembly 110 may be oriented such that the valve stopper 120 is positioned uphole relative to the lower impact cap 122. In particular, once coupled to the piston 112, the lower impact cap 122 may abut against the valve stopper 120 so that

movement of the valve stopper 120 relative to the piston 112 may be arrested. In one implementation, the piston 112, the valve stopper 120, and/or the lower impact cap 122 may be configured to move in conjunction with one another. In another implementation, the lower impact cap 122 may be coupled to a downhole end portion of the piston subassembly 110.

[0037] The piston subassembly 110 may be configured so that fluid may flow from the nozzle 116 to a bore of the lower impact cap 122, and then flow from the bore of the lower impact cap 122 to the bore of the lower sub 108. The lower impact cap 122 may function as a weight whose impact with the housing 102 may create vibrations throughout a drilling tool, as described in more detail below.

[0038] The vibration tool 100 may also include a retainer cap 124 within the housing bore 103, where the retainer cap 124 may be coupled to an inner diameter of the housing 102 through the use of threads, bolts, welds, or any other attachment feature known to those skilled in the art. In one implementation, the retainer cap 124 may be coupled to an inner diameter of the upper sub 104. In another implementation, the retainer cap 124 may be threaded in an uphole direction 101 until its uphole end portion abuts a shoulder of the inner diameter of the upper sub 104. The retainer cap 124 may also be disposed around the piston 112, such that the piston 112 may be allowed to move in a longitudinal direction within the retainer cap 124. In one implementation, the retainer cap 124 may include one or more static seals and/or dynamic seals to prevent fluid flow from passing axially through the housing bore 103.

[0039] The vibration tool 100 may also include a puller cover 126 within the housing bore 103, where the puller cover 126 may be disposed around the piston 112. In one implementation, the puller cover 126 may include a head section 127 having a greater outer diameter than the rest of the puller cover 126. The head section 127 may be oriented such that its uphole end portion may abut a downhole end portion of the retainer cap 124. In addition, at least a portion of the downhole end portion of the head section 127 may be seated against a shoulder formed by an uphole end portion of the

central sub 106. In such an implementation, the retainer cap 124 and the puller cover 126 may be coupled or affixed such that neither component may move with respect to the housing 102. In particular, the puller cover 126 may be coupled or affixed such that the retainer cap 124 and the puller cover 126 may be prevented from rotating.

[0040] The vibration tool 100 may also include an upper spring 130 extending in the uphole direction 101 from the retainer cap 124. The upper spring 130 may also be coupled to the piston 112. The upper spring 130 may be a coiled spring, a Belleville washer spring, or any other biasing mechanism known to those skilled in the art. In one implementation, the piston 112 may include a head section 132 having a greater outer diameter than the rest of the piston 112. In such an implementation, the upper spring 130 may be coupled to a downhole end portion of the head section 132.

[0041] The upper spring 130 may bias the piston subassembly 110 in the uphole direction 101 such that the vibration tool 100 is in a “start” position. In this position, the piston subassembly 110, and the piston 112 in particular, may be seated against an upper shoulder 134, which may be located within the bore of the upper sub 104. In particular, when the piston subassembly 110 is in the “start” position, an uphole side of the head section 132 may be seated against the upper shoulder 134. In one implementation, a preload bias may be applied to the upper spring 130 when a retainer cap 124 is coupled to the housing 102. As an example, the preload bias may be about 600 pound force (lbf).

[0042] The vibration tool 100 may also include a moving valve mechanism 140, where the moving valve mechanism 140 may be movably disposed around the piston 112. In one implementation, the moving valve mechanism 140 may be a sleeve which may be moved in a longitudinal direction with respect to the piston 112. A valve spring 142 may be coupled to an uphole end portion of the moving valve mechanism 140 and to a downhole end portion of the puller cover 127. The valve spring 142 may be a coiled spring, a Belleville washer spring, or any other biasing mechanism known to those skilled in the art.

[0043] When the vibration tool 100 is in its “start” position, the valve spring 142 may bias the moving valve mechanism 140 in a downhole direction 105. In this position, the valve spring 142 may bias the moving valve mechanism 140 into contact with the valve stopper 120, such that a face seal may be created where the downhole end portion 145 of the moving valve mechanism 140 meets the uphole end portion 146 of the valve stopper 120. In one implementation, a metal-to-metal face seal may be formed where the moving valve mechanism 140 meets the valve stopper 120. In other implementations, a rubber-to-rubber face seal or a rubber-to-metal seal may be formed where the moving valve mechanism 140 meets the valve stopper 120.

[0044] When the face seal is created, the bypass ports 118 of the piston 112 may be covered, causing fluid from the piston bore 114 to flow primarily through the nozzle 116, rather than into the housing bore 103 via the bypass ports 118. In this position, the moving valve mechanism 140 may be said to be in its “closed” state. In one implementation, the valve spring 142 may be in compression when the vibration tool 100 is in its “start” position. In this position, the valve spring 142 may apply about 80-100 lbf to the moving valve mechanism 140.

[0045] Once the face seal is broken, the moving valve mechanism 140 may be positioned such that it may not cover the bypass ports 118, allowing fluid to flow into the housing bore 103 from the piston bore 114. In such an implementation, the moving valve mechanism 140 may be said to be in its “open” state, as described in more detail below. One or more static seals and one or more dynamic seals may be disposed within the moving valve mechanism 140.

[0046] The moving valve mechanism 140 may also include a lower head section 147 and an upper head section 148, where the head sections may have a greater outer diameter than the rest of the moving valve mechanism 140. The moving valve mechanism 140 may be oriented so that the lower head section 147 may be positioned downhole with respect to the upper head section 148. When the vibration tool 100 is in its “start” position, an uphole end portion of the lower head section 147 may be seated

against one or more pins 150 protruding from the inner diameter of the housing 102. In one implementation, the pins 150 may have a flat face which may interact with the head sections of the moving valve mechanism 140, as described in more detail below. In another implementation, the vibration tool 100 may use four pins protruding from an inner diameter of the central sub 106.

[0047] The vibration tool 100 may also include a bottom impact surface 160 and/or a top impact surface 164. The bottom impact surface 160 may be coupled to a lower shoulder of the housing 102. In particular, the bottom impact surface 160 may be coupled to a lower shoulder 162 of the lower sub 108. Similarly, the top impact surface 164 may be coupled to an upper shoulder of the housing 102, such as an upper shoulder 134 of the top sub 104. The bottom impact surface 160 and/or the top impact surface 164 may be designed to receive an impact from a moving body, such as the piston subassembly 110, while limiting damage to the housing 102. In other implementations, the lower shoulder 162 and/or the upper shoulder 134 may be designed to receive an impact from the moving body without the use of the impact surfaces. The bottom impact surface 160 and/or the top impact surface 164 may be composed of a less expensive material than other components of the vibration tool 100. In one implementation, when the vibration tool 100 is at its “start” position, the lower impact cap 122 may be positioned at a specified distance away from the bottom impact surface 160.

Valve Mechanism with Face Seal in Operation

[0048] An operation of the vibration tool 100 will now be described with respect to Figures 2-17 in accordance with one or more implementations described herein.

[0049] Figures 2 and 3 illustrate a cross-sectional view of the vibration tool 100 in a “start” position in accordance with implementations of various techniques described herein. Figure 3, in particular, illustrates a close-up view of the vibration tool 100. As illustrated in Figure 2, initially, the upper spring 130 may bias the piston subassembly

110 into its “start” position, *i.e.*, into contact with the upper shoulder 134 and/or the top impact surface 164.

[0050] The upper spring 130 may be in compression when biasing the piston subassembly 110. Additionally, the valve spring 142 may bias the moving valve mechanism 140 into contact with the valve stopper 120, such that a face seal may be formed and the moving valve mechanism 140 may be in its “closed” state.

[0051] When the vibration tool 100 is in the “start” position, a fluid flow may pass from the bore of the upper sub 104 and through the piston bore 114, the nozzle 116, the bore of the lower impact cap 122, and the bore of the lower sub 108. In one implementation, the fluid flow may have a flow rate less than a predetermined threshold flow rate. The fluid flow may include a flow of drilling fluid, drilling mud, or any other implementation known to those skilled in the art. With the flow rate less than the predetermined threshold flow rate, the vibration tool 100 remains at its “start” position. In this position, the moving valve mechanism 140 may remain in its “closed” state with the face seal intact, allowing fluid to flow through to the bore of the lower sub 108 via the nozzle 116. Further, at the “start” position, the fluid flow may be forced to exit the piston bore 114 solely through the nozzle 116, causing fluid pressure to build within the vibration tool 100.

[0052] At some point, the fluid flow rate may reach an amount that is greater than or equal to the predetermined threshold flow rate. When the flow rate is greater than or equal to the predetermined threshold flow rate, a fluid pressure differential across the piston subassembly 110 may increase. Specifically, a fluid pressure may increase across the piston 112, and within the piston bore 114 in particular, which may lead to an increase in a pressure force acting on an uphole end portion of the piston 112. As a result of this pressure force, a force of the upper spring 130 may be overcome, thereby causing the piston subassembly 110 to move in a downhole direction 105.

[0053] In one implementation, the predetermined threshold flow rate may be defined as a flow rate needed to move the piston subassembly 110 in the downhole direction 105. In another implementation, the predetermined threshold flow rate may be at least partly based on the static seals and/or the dynamic seals disposed in the retainer cap 124.

[0054] Figures 4 and 5 illustrate a cross-sectional view of the vibration tool 100 in accordance with implementations of various techniques described herein. Figure 5, in particular, illustrates a close-up view of the vibration tool 100. As shown in Figure 4, as a result of the flow rate being greater than or equal to the predetermined threshold flow rate, the piston subassembly 110 may move away from the “start” position in a downhole direction 105 due to a momentum of the fluid flow and the pressure force acting on the piston subassembly 110, overcoming the upper spring 130. In one implementation, as the piston subassembly 110 moves in the downhole direction 105, the upper spring 130 may remain in compression with the piston 112. In one implementation, the piston 112, the valve stopper 120, and/or the lower impact cap 122 may move in the downhole direction 105 together. In a further implementation, once in motion, a momentum of the lower impact cap 122 may also help to move the piston subassembly 110 in the downhole direction 105.

[0055] The moving valve mechanism 140 may move with the piston subassembly 110, and maintain its face seal, due to a pressure force from the fluid flow acting on an area of the moving valve mechanism 140. Specifically, the pressure force may act on a downhole portion of the moving valve mechanism 140, proximate to where the moving valve mechanism 140 abuts against the valve stopper 120. In such an implementation, the pressure force acting on this downhole portion may cause the moving valve mechanism 140 to maintain its face seal and move in the downhole direction 105 with the valve stopper 120. In addition, this pressure force may be greater than a force of the valve spring 142. In one implementation, after movement of the moving valve mechanism 140 in the downhole direction 105, the valve spring 142 may move into tension with the moving valve mechanism 140. However, as shown in Figures 4 and 5,

despite the bias of the valve spring 142, the moving valve mechanism 140 may maintain its face seal with the valve stopper 120, moving in conjunction with the piston subassembly 110. In one implementation, the pressure force may be about 500 to about 1,500 lbf, and the force of the valve spring 142 may be about 100 lbf.

[0056] As the moving valve mechanism 140 travels in the downhole direction 105, its lower head section 147 may no longer abut the pins 150. The moving valve mechanism 140 may move a sufficient distance such that a downhole end portion of its upper head section 148 may come into contact with the pins 150, as shown in Figures 4 and 5. Upon coming into contact with the pins 150 with its upper head section 148, further downhole movement of the moving valve mechanism 140 may be arrested. In such an implementation, as illustrated from Figure 4, the piston subassembly 110 may still be positioned at a distance apart from the bottom impact surface 160 and/or the lower shoulder 162 when the pins 150 come into contact with the upper head section 148.

[0057] Figures 6 and 7 illustrate a cross-sectional view of the vibration tool 100 in accordance with implementations of various techniques described herein. Figure 7, in particular, illustrates a close-up view of the vibration tool 100. As shown in Figure 7, further downhole movement of the moving valve mechanism 140 may be arrested by the pins 150. However, the pressure force acting on the piston subassembly 110 may continue to move the piston subassembly 110 in the downhole direction 105. In turn, the piston subassembly 110 may separate from the moving valve mechanism 140, breaking the face seal where the downhole end portion 145 of the moving valve mechanism 140 meets the uphole end portion 146 of the valve stopper 120. Once the face seal has opened, the moving valve mechanism 140 may be said to be in its “open” state.

[0058] As shown in Figure 6, the piston subassembly 110 may move in the downhole direction 105 until impacting the bottom impact surface 160 and/or the lower shoulder 162, where a downhole end portion of the lower impact cap 122 may be seated against

the bottom impact surface 160 and/or the lower shoulder 162. Upon impact, vibrations may be created throughout the housing 102, which may be imparted to the vibration tool 100 and to a drill string (not shown).

[0059] Once the face seal has opened, the fluid flow may travel from the piston bore 114 and through the bypass ports 118, reaching the housing bore 103. As the fluid flow passes through the housing bore 103, the fluid pressure across the piston subassembly 110 may then decrease. In one implementation, the fluid pressure may decrease from about 500 pounds per square inch (psi) to about 40 psi. In another implementation, the initial separation between the moving valve mechanism 140 and the valve stopper 120, which causes the fluid pressure to decrease, may be about 0.1 inches.

[0060] Figures 8 and 9 illustrate a cross-sectional view of the vibration tool 100 in accordance with implementations of various techniques described herein. Figure 9, in particular, illustrates a close-up view of the vibration tool 100. As the fluid flow passes into the housing bore 103 via the bypass ports 118, the pressure force of the fluid flow acting on the moving valve mechanism 140 may decrease.

[0061] In turn, the force of the valve spring 142 may overcome this pressure force acting on the moving valve mechanism 140, thereby biasing the moving valve mechanism 140 in the uphole direction 101. In one implementation, as shown in Figure 9, the moving valve mechanism 140 may move in the uphole direction 101 while the lower impact cap 122 of the piston subassembly 110 largely maintains its position against the bottom impact surface 160 and/or the lower shoulder 162.

[0062] In another implementation, as the valve spring 142 biases the moving valve mechanism 140 in the uphole direction 101, the downhole end portion of the upper head section 148 may separate from the pins 150. In a further implementation, the valve spring 142 may bias the moving valve mechanism 140 such that the moving valve mechanism 140 is “fully open,” *i.e.*, at a maximum distance from the valve stopper 120.

When the moving valve mechanism 140 is at such a distance, the fluid may flow through the bypass ports 118 with the least obstruction.

[0063] In one implementation, the valve spring 142 may bias the moving valve mechanism 140 in the uphole direction 101 until its lower head section 147 comes into contact with a port shoulder 170 of the piston 112. In such an implementation, a downhole shoulder 172 of the lower head section 147 may be seated against the port shoulder 170, which may be located proximate to the bypass ports 118. Once seated against the port shoulder 170, movement of the moving valve mechanism 140 may be arrested until the piston subassembly 110 begins to move. In particular, the valve spring 142 may continue to bias the moving valve mechanism 140 in the uphole direction 101, but the uphole movement of the moving valve mechanism 140 may be restricted by the port shoulder 170. As such, the moving valve mechanism 140 may move in the uphole direction 101 as far as may be allowed by the positioning of the piston subassembly 110. In one implementation, uphole movement of the piston subassembly 110 may be slower than that of the moving valve mechanism 140.

[0064] With the moving valve mechanism 140 “fully open,” the fluid pressure across the piston 112 may decrease, which may lead to a decrease in the pressure force acting on the uphole end portion of the piston 112. As a result, the force of the upper spring 130 may begin to bias the piston subassembly 110 in the uphole direction 101.

[0065] Figures 10 and 11 illustrate a cross-sectional view of the vibration tool 100 in accordance with implementations of various techniques described herein. Figure 11, in particular, illustrates a close-up view of the vibration tool 100. As illustrated, the upper spring 130 may overcome the pressure force acting on the uphole end portion of the piston 112 and move the piston subassembly 110 in the uphole direction 101. As shown, the lower impact cap 122 may no longer be seated against the bottom impact surface 160 and/or the lower shoulder 162.

[0066] The moving valve mechanism 140 may remain seated against the port shoulder 170 as the moving valve mechanism 140 travels in the uphole direction 101. In one implementation, and as illustrated in Figures 10 and 11, the valve spring 142 may eventually reach a neutral state as the moving valve mechanism 140 travels in the uphole direction 101. In such a state, the valve spring 142 may be neither compressed nor in tension, and the moving valve mechanism 140 may not be biased in any direction. However, while the moving valve mechanism 140 may not be biased to move in any direction, the piston subassembly 110 may continue to travel in the uphole direction 101.

[0067] Figures 12 and 13 illustrate a cross-sectional view of the vibration tool 100 in accordance with implementations of various techniques described herein. Figure 13, in particular, illustrates a close-up view of the vibration tool 100. As illustrated, the upper spring 130 may continue to bias the piston subassembly 110 in the uphole direction 101.

[0068] As the piston subassembly 110 moves, the distance between the valve stopper 120 and the moving valve mechanism 140 may begin to decrease. As the distance decreases, pressure from the fluid flowing through the bypass ports 118 may begin to exert a force on the downhole end portion of the moving valve mechanism 140. In particular, the force may begin to bias the moving valve mechanism 140 in the downhole direction 105. In addition, the moving valve mechanism 140 may compress the valve spring 142, causing the valve spring 142 to exert a force in the downhole direction 105 towards the valve stopper 120.

[0069] Figures 14 and 15 illustrate a cross-sectional view of the vibration tool 100 in accordance with implementations of various techniques described herein. Figure 15, in particular, illustrates a close-up view of the vibration tool 100. As illustrated, the upper spring 130 may continue to bias the piston subassembly 110 in the uphole direction 101. In turn, the pressure force of the fluid flowing through the bypass ports 118 may continue to bias the moving valve mechanism 140 in the downhole direction 105, while

the valve spring 142 may continue to exert a bias on the moving valve mechanism 140 in the downhole direction 105.

[0070] As the piston subassembly 110 and the moving valve mechanism 140 travel in the uphole direction 101, the distance between the two components continues to decrease until the face seal is formed again between the valve stopper 120 and the moving valve mechanism 140. In particular, the valve spring 142 may bias the moving valve mechanism 140 into contact with the valve stopper 120, such that the face seal may be formed and the moving valve mechanism 140 may be in its “closed” state, as shown in Figures 16 and 17.

[0071] In one implementation, and as illustrated in Figures 14 and 15, the lower head section 147 of the moving valve mechanism 140 may come into contact with the pins 150 before the face seal may be re-created. In another implementation, the face seal may be re-created before the lower head section 147 may come into contact with the pins 150.

[0072] Figures 16 and 17 illustrate a cross-sectional view of the vibration tool 100 in the “start” position in accordance with implementations of various techniques described herein. Figure 17, in particular, illustrates a close-up view of the vibration tool 100. As illustrated, the upper spring 130 may bias the piston subassembly 110 back to its “start” position, *i.e.*, into contact with the upper shoulder 134 and/or the top impact surface 164. In one implementation, upon impact with the upper shoulder 134 and/or the top impact surface 164, vibrations may be created throughout the housing 102, which may be imparted to the vibration tool 100 and to a drill string (not shown). In addition, the moving valve mechanism 140 may be in its “closed” state.

[0073] With the vibration tool 100 in the “start” position, the fluid flow may again pass from the bore of the upper sub 104 and through the piston bore 114, the nozzle 116, the bore of the lower impact cap 122, and the bore of the lower sub 108. If the fluid flow rate remains greater than or equal to the predetermined threshold flow rate, then

the fluid pressure may again increase across the piston 112, leading to an increase in the pressure force acting on the uphole end portion of the piston 112. The vibration tool may then again operate as described with respect to Figures 2-17.

[0074] In operating as described above, the vibration tool 100 may cause the piston subassembly 110 to oscillate in the uphole direction 101 and the downhole direction 105, causing repeated impacts against the housing 102 and/or the impact surfaces. As a result, the vibration tool 100 may produce vibrations which may be imparted to the drill string (not shown). In one implementation, the vibration tool 100 may perform one cycle as described with respect to Figures 2-17 at a rate of about ten times per second.

Latching Valve Subassembly

[0075] Figure 18 illustrates a cross-sectional view of a vibration tool 200 in accordance with implementations of various techniques described herein. One or more components of the vibration tool 200 may be composed of steel, tungsten carbide, or any other implementation known to those skilled in the art.

[0076] In one implementation, the vibration tool 200 may include a housing 202 having a housing bore 203 and composed of an upper sub 204 and a lower sub 208. The upper sub 204 may be coupled to the lower sub 208 through the use of threads, bolts, welds, or any other attachment feature known to those skilled in the art. The housing 202 may be oriented such that the upper sub 204 may engage with uphole members of a drill string (not shown), and the lower sub 208 may engage with downhole members of the drill string.

[0077] The vibration tool 200 may include a piston subassembly 210 composed of a piston 212 having a piston bore 214, a nozzle 216, and one or more bypass ports 218. The piston subassembly 210 may further include a lower impact cap 222, where the lower impact cap 222 may be coupled to and/or disposed around the piston 212. The piston subassembly 210 may be similar to the piston subassembly 110.

[0078] The vibration tool 200 may also include a retainer cap 224, which may be coupled to an inner diameter of the housing 202 through the use of threads, bolts, welds, or any other attachment feature known to those skilled in the art. The retainer cap 224 may also include an upper spring 230 extending in the uphole direction 201 from the retainer cap 224. The upper spring 230 may also be coupled to the piston 212. The retainer cap 224 and the upper spring 230 may be similar to the retainer cap 124 and the upper spring 130, respectively.

[0079] The vibration tool 200 may also include a latching valve subassembly 240, which may be movably disposed around the piston 212. The latching valve subassembly 240 may be coupled to a valve spring 242, which may be coupled to an uphole end portion of the lower impact cap 222 and to a downhole end portion of the latching valve subassembly 240.

[0080] In one implementation, the latching valve subassembly 240 may include a sleeve 243 which may be moveable in a longitudinal direction with respect to the piston 212. One or more latching mechanisms 245 (Figures 20 to 22) may be attached or coupled to the sleeve 243, where the latching mechanisms 245 may be configured to couple to the piston 212. In one implementation, the latching valve subassembly 240 may include one or more static seals and/or dynamic seals attached to the sleeve 243, where the seals may be configured inhibit a fluid flow between the piston 212 and the housing bore 203 and/or centralize the latching valve subassembly 240.

[0081] In one implementation, the latching mechanisms 245 may engage with one or more first latch stops 280 on an outer diameter of the piston 212, such that the sleeve 243 may cover the bypass ports 218. When the sleeve 243 covers the bypass ports 218, fluid from the piston bore 214 may flow primarily through the nozzle 216 rather than into the housing bore 203 via the bypass ports 218. In such an implementation, the latching valve subassembly 240 may be said to be in its “closed” state. The latching mechanisms 245 may also engage with one or more second latch stops 282 on the outer diameter of the piston 212, such that the bypass ports 218 may be uncovered,

allowing fluid to flow into the housing bore 203 from the piston bore 214. In such an implementation, the latching valve subassembly 240 may be said to be in its “open” state. The latching valve subassembly is described in more detail with respect to Figures 19-22.

[0082] Figure 19 illustrates a side view of the sleeve 243 of the latching valve subassembly 240 in accordance with implementations of various techniques described herein. As illustrated, the sleeve 243 may be cylindrical in shape and configured to move in a longitudinal direction along an outer diameter of the piston 212. The sleeve 243 may include one or more latch holes 244 configured to engage with one or more latching mechanisms 245 shown in Figure 20.

[0083] Figure 20 illustrates a top view of the latching mechanisms 245 of the latching valve subassembly 240 in accordance with implementations of various techniques described herein. As illustrated in Figure 20, the latching mechanisms 245 may each include a bar 290 attached to a raised pocket 291, inside of which may include a ball 292. The ball 292 may be designed to roll and/or be displaced inside of the pocket 291. When coupled to the sleeve 243, each pocket 291 may be disposed through the latch hole 244, such that the ball 292 may protrude from the inner diameter of the sleeve 243. The bar 290 may be attached to the sleeve 243 via screws or any other fastening means known to those skilled in the art. In one implementation, the sleeve 243 may also include one or more balance ports for balancing pressure across the latching mechanisms 245.

[0084] The sleeve 243 may also include one or more communication ports 246, which may allow the fluid flow to pass to the housing bore 203. In particular, when the latching valve subassembly 240 is in the “open” state, the communication ports 246 may align with the bypass ports 218 to allow fluid to flow into the housing bore 203 from the piston bore 214. When the latching valve subassembly 240 is in the “closed” state, the communication ports 246 and the bypass ports 218 may be misaligned, thereby creating a seal between the piston 212 and the sleeve 243 and blocking the fluid flow

from passing through the bypass ports 218. In some implementations, the piston 212 may include bypass ports 218 circumferentially positioned at a plurality of longitudinal positions, while the sleeve 243 may also include communication ports 246 circumferentially positioned at a plurality of longitudinal positions.

[0085] In one implementation, the number of communication ports 246 may be equal to the number of bypass ports 218. In another implementation, the number of communication ports 246 may be different than the number of bypass ports 218. For example, the piston 212 may include four bypass ports 218 circumferentially spaced at each longitudinal position, while the sleeve 243 may include five communication ports 246 circumferentially spaced at each longitudinal position. In such an implementation, when the latching valve subassembly 240 is in the “open” state, the differing number of communication ports 246 and bypass ports 218 may align to create a sufficient opening area for the fluid flow to pass to the housing bore 203, regardless of a relative angular position of the sleeve 243 to the piston 212.

[0086] Figures 21 and 22 illustrate a cross-sectional view of the latching valve subassembly 240 in accordance with implementations of various techniques described herein. As shown in Figures 21 and 22, the sleeve 243 may be disposed around the piston 212, where latching mechanisms 245 of the sleeve 243 may engage an outer diameter of the piston 212. In particular, the ball 292 may protrude from the inner diameter of the sleeve 243 and interact with the piston 212.

[0087] Figure 21 illustrates the latching valve subassembly 240 in its “closed” state. In particular, the bypass ports 218 and the communication ports 246 may be misaligned. In the “closed” state, the latching mechanisms 245, *e.g.*, the ball 292, may engage with the first latch stops 280 of the outer diameter of the piston 212. The first latch stops 280 may be indentations of a specified distance in the outer diameter of the piston 212. While engaged with the first latch stops 280, the latching valve subassembly 240 may be allowed to move in a longitudinal direction for the specified distance.

[0088] In one implementation, a first latch stop 280 may be positioned downhole from a second latch stop 282. An uphole end portion of the first latch stop 280 may be bounded by a bumper 281, and a downhole end portion of the first latch stop 280 may be bounded by the outer diameter of the piston 212. The bumper 281 may be a portion of the piston 212 having an outer diameter that is less than the rest of the piston 212. In particular, the bumper 281 may be configured to allow the ball 292 to traverse the piston 212 and into the second latch stop 282, as described below.

[0089] Figure 22 illustrates the latching valve subassembly 240 in its “open” state. In particular, the bypass ports 218 and the communication ports 246 may be aligned with one another. In the “open” state, the latching mechanisms 245, *e.g.*, the ball 292, may engage with the second latch stops 282 of the outer diameter of the piston 212. The second latch stops 282 may be similar to the first latch stops 280. A downhole end portion of the second latch stop 282 may be bounded by the bumper 281, and an uphole end portion of the second latch stop 282 may be bounded by the outer diameter of the piston 212.

[0090] In one implementation, for the ball 292 to travel between a first latch stop 280 and a second latch stop 282 and to overcome the bumper 281, a minimum force may be applied to the latching valve subassembly 240. In such an implementation, the predetermined force may move the latching valve subassembly 240 between the “closed” and “open” positions. The minimum force used to overcome the bumper 281 may be based on a size of the latching mechanisms 245.

[0091] Returning to Figure 18, the upper spring 230 may bias the piston subassembly 210 in the uphole direction 201 such that the vibration tool 200 is in a “start” position. In such a “start” position, the piston subassembly 210, and the piston 212 in particular, may be seated against an upper shoulder 234 of the upper sub 204.

[0092] In addition, at the “start” position, the latching valve subassembly 240 may have its uphole end portion seated against a downhole end portion of the retainer cap 224.

The valve spring 242 may help to bias the latching valve subassembly 240 against the retainer cap 224. In such an implementation, the latching valve subassembly 240 may be in its “closed” state.

[0093] Similar to vibration tool 100, the vibration tool 200 may also include a bottom impact surface 260 and/or a top impact surface 264. In one implementation, when the vibration tool 200 is at its “start” position, the lower impact cap 222 may be positioned at a specified distance away from the bottom impact surface 260.

Latching Valve Subassembly in Operation

[0094] An operation of the vibration tool 200 will now be described with respect to Figures 23-29 in accordance with one or more implementations described herein.

[0095] Figure 23 illustrates a cross-sectional view of the vibration tool 200 in a “start” position in accordance with implementations of various techniques described herein. Initially, the upper spring 230 may bias the piston subassembly 210 into its “start” position, *i.e.*, into contact with the upper shoulder 234. The upper spring 230 may be in compression when biasing the piston subassembly 210. In one implementation, a top impact surface 264 may be coupled to the upper shoulder 234.

[0096] When the vibration tool 200 is in the “start” position, a fluid flow may pass from the bore of the upper sub 204 and through the piston bore 214, the nozzle 216, the bore of the lower impact cap 222, and the bore of the lower sub 208. In one implementation, the fluid flow may have a flow rate less than a predetermined threshold flow rate. With the flow rate less than the predetermined threshold flow rate, the vibration tool 200 remains at its “start” position. In its “start” position, the latching valve subassembly 240 may remain in its “closed” state with the seal between the piston 212 and the sleeve 243 intact, allowing fluid to flow through to the bore of the lower sub 208 via the nozzle 216.

[0097] At some point, the fluid flow rate may reach an amount that is greater than or equal to the predetermined threshold flow rate. As the vibration tool 200 is in its “start” position and the latching valve subassembly 240 is in its “closed” state, the fluid flow may be forced to exit the piston bore 214 solely through the nozzle 216, causing fluid pressure to build within the vibration tool 200. Similar to vibration tool 100, an increase in a pressure force may act on an uphole end portion of the piston 212, overcoming a force of the upper spring 230, and causing the piston subassembly 210 to move in a downhole direction 205.

[0098] Figure 24 illustrates a cross-sectional view of the vibration tool 200 in accordance with implementations of various techniques described herein. As a result of the flow rate being greater than or equal to the predetermined threshold flow rate, the piston subassembly 210 may move away from the “start” position in a downhole direction 205 due to a momentum of the fluid flow and the pressure force acting on the uphole end portion of the piston 212.

[0099] Since the latching valve subassembly 240 is engaged with the outer diameter of the piston 212 via the latching mechanisms 245, the latching valve subassembly 240 may move with the piston subassembly 210. As the latching valve subassembly 240 travels in the downhole direction 205, a portion of its sleeve 243 may come into contact with one or more pins 250. The pins 250 may be similar to the pins 150. Upon coming into contact with the pins 250, further downhole movement of the latching valve subassembly 240 may be arrested. In such an implementation, the piston subassembly 210 may still be positioned at a distance apart from the bottom impact surface 260 and/or the lower shoulder 262. In one implementation, the pins 250 may be disposed inside a pathway located in the sleeve 243, where the pins 250 may travel along the pathway as the latching valve subassembly 240 moves in the uphole direction 201 or the downhole direction 205.

[0100] Figure 25 illustrates a cross-sectional view of the vibration tool 200 in accordance with implementations of various techniques described herein. As shown in

Figure 25, further downhole movement of the latching valve subassembly 240 may be arrested by the pins 250. However, the pressure force acting on the piston subassembly 210 may continue to move the piston subassembly 210 in the downhole direction 205. In turn, the arrested latching valve subassembly 240 may begin to move from its “closed” state to its “open” state. Particularly, as the piston subassembly 210 moves in the downhole direction 205, the balls 292 may be forced to travel from the first latch stops 280 to the second latch stops 282.

[0101] As shown in Figure 25, the piston subassembly 210 may move in the downhole direction 205 until impacting the bottom impact surface 260 and/or the lower shoulder 262, where a downhole end portion of the lower impact cap 222 may be seated against the bottom impact surface 260 and/or the lower shoulder 262. Upon impact, vibrations may be created throughout the housing 202, which may be imparted to the vibration tool 200 and to a drill string (not shown).

[0102] Figure 26 illustrates a cross-sectional view of the vibration tool 200 in accordance with implementations of various techniques described herein. As illustrated, the latching valve subassembly 240 may be in its “open” state. Particularly, the balls 292 may have traversed in the uphole direction 201 along the piston 212, traveling from the first latch stops 280 to the second latch stops 282. In one implementation, a bias of the valve spring 242, acting on the latching valve subassembly 240, may help to move the balls 292 to the second latch stops 282 in the uphole direction 201.

[0103] Accordingly, the communication ports 246 and the bypass ports 218 may be aligned, allowing the fluid flow to travel from the piston bore 214 and through the bypass ports 218, reaching the housing bore 203. As the fluid flow passes into the housing bore 203, the fluid pressure across the piston subassembly 210 may then decrease. As a result, the force of the upper spring 230 may begin to bias the piston subassembly 210 in the uphole direction 201.

[0104] Figure 27 illustrates a cross-sectional view of the vibration tool 200 in accordance with implementations of various techniques described herein. As illustrated, the upper spring 230 may overcome the pressure force acting on the uphole end portion of the piston 212 and move the piston subassembly 210 in the uphole direction 201. As shown, the lower impact cap 222 may no longer be seated against the bottom impact surface 260 and/or the lower shoulder 262. In addition, due to its engagement with the second latch stops 282, the latching valve subassembly 240 may travel in the uphole direction 201 in conjunction with the piston subassembly 210 while remaining in its “open” state.

[0105] As the latching valve subassembly 240 moves in the uphole direction 201, it may eventually have its uphole end portion again seated against a downhole end portion of the retainer cap 224. The valve spring 242 may again help to bias the latching valve subassembly 240 against the retainer cap 224. Once seated against the retainer cap 224, further uphole movement by the latching valve subassembly 240 may be arrested.

[0106] Figure 28 illustrates a cross-sectional view of the vibration tool 200 in accordance with implementations of various techniques described herein. As illustrated, the upper spring 230 may continue to bias the piston subassembly 210 in the uphole direction 201.

[0107] As the piston subassembly 210 moves while the latching valve subassembly 240 may be arrested against the retainer cap 224, the latching valve subassembly 240 may be forced to move from its “open” state to its “closed” state, as illustrated in Figure 28. Particularly, since the piston subassembly 210 may continue to move in the uphole direction 201, the balls 292 may begin to traverse in the downhole direction 205 relative to the piston 212, traveling from the second latch stops 282 to the first latch stops 280.

[0108] Figure 29 illustrates a cross-sectional view of the vibration tool 200 in the “start” position in accordance with implementations of various techniques described herein.

As illustrated, the upper spring 230 may bias the piston subassembly 210 back to its “start” position, *i.e.*, into contact with the upper shoulder 234 and/or the top impact surface 264. In one implementation, upon impact with the upper shoulder 234 and/or the top impact surface 264, vibrations may be created throughout the housing 202, which may be imparted to the vibration tool 200 and to a drill string (not shown).

[0109] Additionally, the latching valve subassembly 240 may be in its “closed” state. Particularly, since the piston subassembly 210 may continue to move in the uphole direction 201, the balls 292 may have traversed in the downhole direction 205 relative to the piston 212, traveling from the second latch stops 282 to the first latch stops 280.

[0110] With the vibration tool 200 in the “start” position, the fluid flow may again pass from the bore of the upper sub 204 and through the piston bore 214, the nozzle 216, the bore of the lower impact cap 222, and the bore of the lower sub 208. If the fluid flow rate remains greater than or equal to the predetermined threshold flow rate, then the fluid pressure may again increase across the piston 212, leading to an increase in the pressure force acting on the uphole end portion of the piston 212. The vibration tool may then again operate as described with respect to Figures 23-29.

[0111] In operating as described above, the vibration tool 200 may cause the piston subassembly 210 to oscillate in the uphole direction 201 and the downhole direction 205, producing vibrations similar to those produced by the vibration tool 100.

Impact Mitigation Subassembly

[0112] Figure 30 illustrates a cross-sectional view of an impact mitigation subassembly 300 in accordance with implementations of various techniques described herein. The impact mitigation subassembly 300 may include an impact cap 302 and one or more springs 304 disposed within the impact cap 302. In one implementation, the components of the impact mitigation subassembly 300 may be composed of steel or any other implementation known to those skilled in the art.

[0113] In one implementation, the impact cap 302 may be a hollow cap configured to attach to a downhole end portion of a moving body 400, such as the pistons 112 or 212 and/or the lower impact caps 122 or 222. An uphole opening 310 of the impact cap 302 may be used for insertion of the moving body 400, as described in more detail below. Once inserted, the moving body 400 may be seated against or may compress the springs 304 within the impact cap 302.

[0114] The springs 304 may be disposed on an inside base 312 of the impact cap 302, where the springs 304 may be separated by one or more spacers 306. The springs 304 may include a coiled spring, a Belleville washer spring, or any other biasing mechanism known to those skilled in the art. An anti-erosion sleeve 308 may cover the inner diameters of the springs 304 and/or the spacers 306, and may align with a bore of the moving body 400. The anti-erosion sleeve 308 may allow for fluid to flow from the bore of the moving body 400 and through a downhole opening 314 of the impact cap 302 while protecting the spacers and/or the springs 304.

[0115] Attaching the impact mitigation subassembly 300 to the moving body 400 is described in more detail with respect to Figures 31 and 32. Figure 31 illustrates a side view of the moving body 400 in accordance with implementations of various techniques described herein. As shown in Figure 31, a downhole end portion of the moving body 400 may have one or more locking wings 402 which radially protrude from the moving body 400. In between the locking wings 402 are one or more locking slots 404, formed by the spaces between the locking wings 402. The locking wings 402 and/or the locking slots 404 may be of same size and/or shape. A locking gap 406 may be defined by a space along the moving body 400 and may be uphole relative to the locking wings 402.

[0116] Figure 32 illustrates a side view of an impact mitigation subassembly 300 in accordance with implementations of various techniques described herein. In particular, the uphole opening 310 of the impact cap 302 may include one or more key slots 352 and one or more key wings 354. The key wings 354 may radially protrude from an

inner diameter of the uphole opening 310. The key slots 352 may be formed by the spaces between the key wings 354 along the inner diameter of the uphole opening 310.

[0117] When coupling the impact mitigation subassembly 300 to the moving body 400, the key wings 354 may align with the locking slots 404 and the key slots 352 may align with the locking wings 402. In particular, the key wings 354 may be inserted into the locking slots 404 and the locking wings may be inserted into the key slots 352.

[0118] The locking gap 406 may have a longitudinal length that is approximately equal to the longitudinal length of the key wings 354. Accordingly, the moving body 400 may be inserted into the impact cap 302 until the key wings 354 occupy the space formed by the locking gap 406. The impact cap 302 may then be rotated so that the key wings 354 are aligned uphole relative to the locking wings 402. Anti-rotation screws may be fastened into screw holes 316 on the impact cap 302 to fasten the impact mitigation subassembly 300 to the moving body 400. In other implementations, other fastening means may be used to couple the impact mitigation subassembly 300 to the moving body 400.

[0119] In one implementation, the moving body 400 may compress the springs 304 when inserted into the impact cap 302. In such an implementation, the springs 304 may provide a predetermined load in the impact mitigation subassembly 300.

[0120] In operation, when the impact mitigation subassembly 300 impacts another object, the impact cap 302 may contact the other object's surface first. In particular, a bottom surface 320 may strike the other object's surface upon initial impact. The moving body 400 may continue to move within the impact cap 302, compressing the springs 304. The energy of the moving body may be stored in the springs 304, facilitating rebounding of the impact mitigation subassembly 300. In one implementation, an amount of impact produced by the impact mitigation subassembly 300 may increase with a higher predetermined load.

[0121] The impact cap 302 may be constructed of steel or any other implementation known to those skilled in the art. In one implementation, a mass of the impact cap 302 may be low enough to reduce impact force and impact-induced stress on impact surfaces, thereby mitigating deformation on the impact surfaces.

[0122] In sum, various implementations described above with respect to Figures 1-32 may allow for the cyclical increase and decrease in fluid pressure across an piston subassembly of a vibration tool. The cyclical increase and decrease in fluid pressure may cause the piston subassembly to repeatedly strike a housing of the vibration tool, producing vibrations throughout the tool. The vibrations may oscillate the drill string, or other coupled object, and reduce friction. In another implementation, the vibration tool may generate a water hammering effect, such that the vibrations may travel up and down the drill string or other coupled object. In turn, the axial vibration may oscillate the drill string, or other coupled object, and reduce friction.

[0123] While the foregoing is directed to implementations of various techniques described herein, other and further implementations may be devised without departing from the basic scope thereof. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

CLAIMS

What Is Claimed Is:

1. A vibration tool, comprising:
 - a housing having a bore extending therethrough;
 - a piston subassembly positioned inside the bore, the piston subassembly configured to oscillate when fluid flow inside the piston subassembly exceeds a predetermined flow rate; and
 - a valve mechanism positioned at least partially around the piston subassembly, wherein the valve mechanism is configured to restrict fluid to flow inside the piston subassembly when the valve mechanism is in a closed state and configured to allow the fluid to flow from the piston subassembly to the bore when the valve mechanism is in an open state.
2. The vibration tool of claim 1, further comprising an upper spring disposed outside of the piston subassembly and configured to bias the piston subassembly in an uphole direction and into a start position.
3. The vibration tool of claim 2, wherein, when the valve mechanism is in the closed state, the piston subassembly is configured to move in a downhole direction away from the start position in response to fluid pressure.
4. The vibration tool of claim 1, wherein the valve mechanism is configured to be in the closed state when the valve mechanism forms a face seal with a valve stopper of the piston subassembly.
5. The vibration tool of claim 4, further comprising a valve spring disposed inside the bore and configured to bias the valve mechanism into the valve stopper to form the face seal.

6. The vibration tool of claim 4, wherein, when the valve mechanism is in the closed state, the valve mechanism is configured to move in a downhole direction in conjunction with the piston subassembly based on fluid pressure while maintaining the face seal.
7. The vibration tool of claim 4, wherein the piston subassembly is configured to move in a downhole direction relative to the valve mechanism after downhole movement of the valve mechanism is arrested, thereby breaking the face seal and transitioning the valve mechanism to the open state.
8. The vibration tool of claim 7, wherein, once the valve mechanism is in the open state, the piston subassembly and the valve mechanism are configured to move in an uphole direction and again form the face seal.
9. The vibration tool of claim 1, further comprising one or more pins configured to arrest a downhole movement of the valve mechanism, and wherein the valve mechanism is configured to transition from the closed state to the open state once the one or more pins arrest the downhole movement.
10. The vibration tool of claim 1, wherein a pressure force acting on the piston subassembly decreases after the valve mechanism transitions to the open state.
11. The vibration tool of claim 1, wherein the piston subassembly impacts the housing while oscillating thereby creating vibrations.
12. The vibration tool of claim 1, wherein the valve mechanism comprises:
a valve sleeve movably disposed relative to the piston subassembly, wherein the valve sleeve comprises one or more communication ports that are aligned with one or more bypass ports on the piston subassembly when the valve sleeve is in the open state;

one or more latching mechanisms coupled to the valve sleeve, wherein the latching mechanisms are configured to engage with one or more first latch stops disposed on the piston subassembly when the valve sleeve is in the closed state, and wherein the latching mechanisms are configured to engage with one or more second latch stops disposed on the piston subassembly when the valve sleeve is in the open state.

13. The vibration tool of claim 12, wherein the latching mechanisms move between the first latch stops and the second latch stops after downhole movement of the valve mechanism is arrested.

14. The vibration tool of claim 12, wherein the piston subassembly comprises a bumper disposed between a respective first latch stop and a respective second latch stop.

15. A latching valve subassembly for use in a tool, comprising:

a valve sleeve movably disposed at least partially over a cylindrical body, the valve sleeve having one or more communication ports that are aligned with one or more ports of the cylindrical body when the valve sleeve is in a first state; and

one or more latching mechanisms coupled to the valve sleeve, the latching mechanisms protruding from an inner diameter of the valve sleeve, and wherein the latching mechanisms are configured to engage with one or more first latch stops disposed on the cylindrical body when the valve sleeve is in the first state, and wherein the latching mechanisms are configured to engage with one or more second latch stops disposed on the cylindrical body when the valve sleeve is in a second state.

16. The latching valve subassembly of claim 15, wherein the ports are misaligned with the communication ports when the valve sleeve is in the second state.

17. The latching valve subassembly of claim 15, wherein each latching mechanism comprises:

a bar coupled to an outer diameter of the sleeve; and

a pocket coupled to the bar and having a ball disposed within, the ball protruding from an inner diameter of the sleeve.

18. The latching valve subassembly of claim 15, wherein the valve sleeve is allowed a specified range of movement along the cylindrical body when engaged with either latch stop.

19. An impact mitigation subassembly for use in a tool, comprising:

an impact cap configured to couple to an end portion of a moving body; and

one or more springs disposed on an inside base of the impact cap, the springs being configured to allow displacement of the moving body within the impact cap when movement of the impact cap is arrested.

20. The impact mitigation subassembly of claim 19, wherein the moving body is inserted into the impact cap in a manner that produces a predetermined load in the springs.

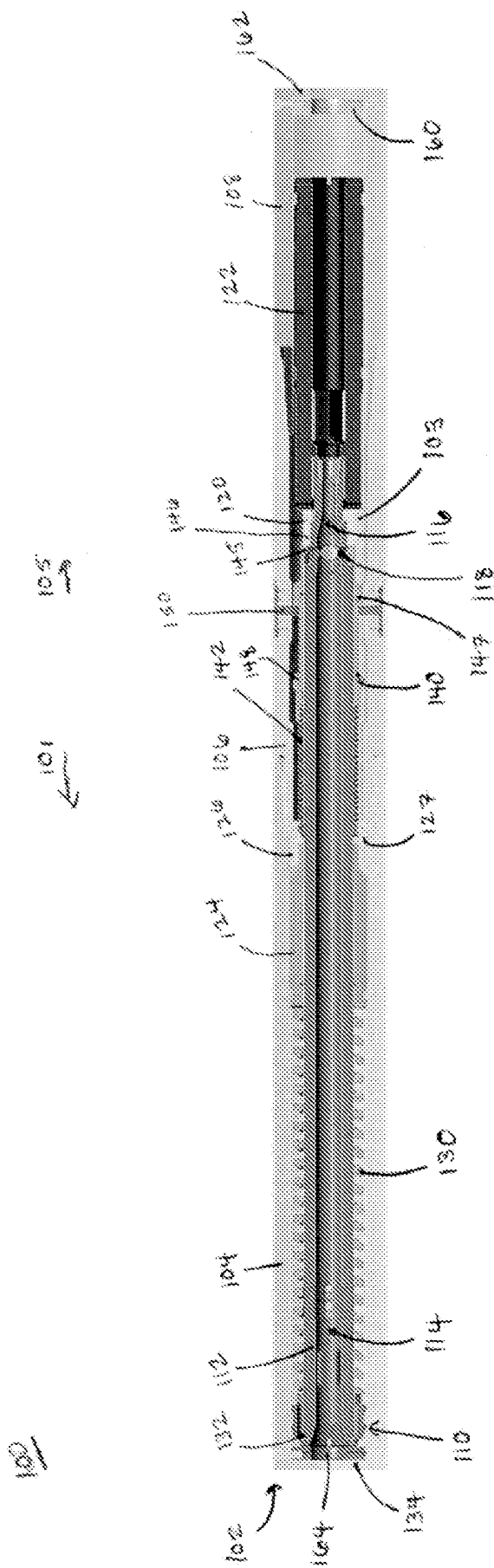


FIGURE 1

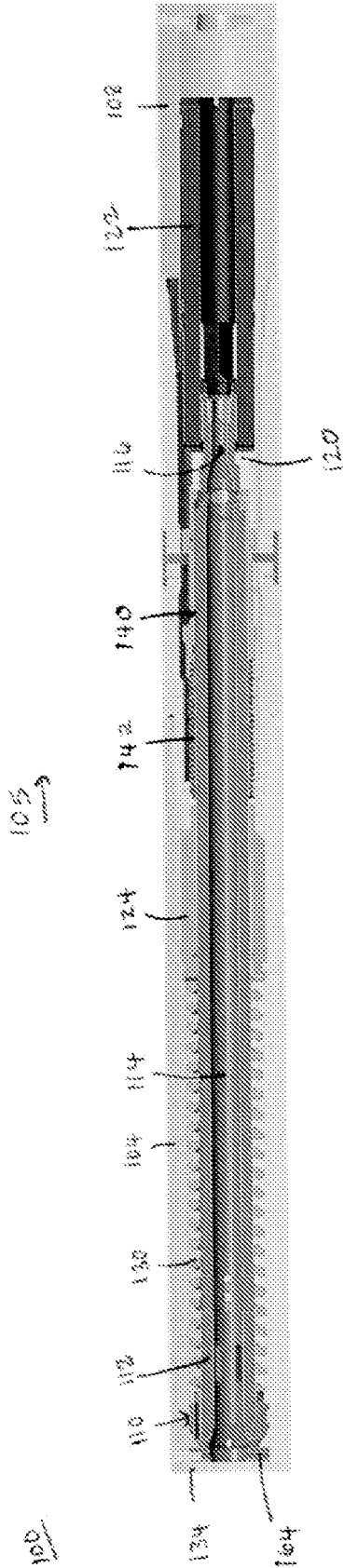


FIGURE 2

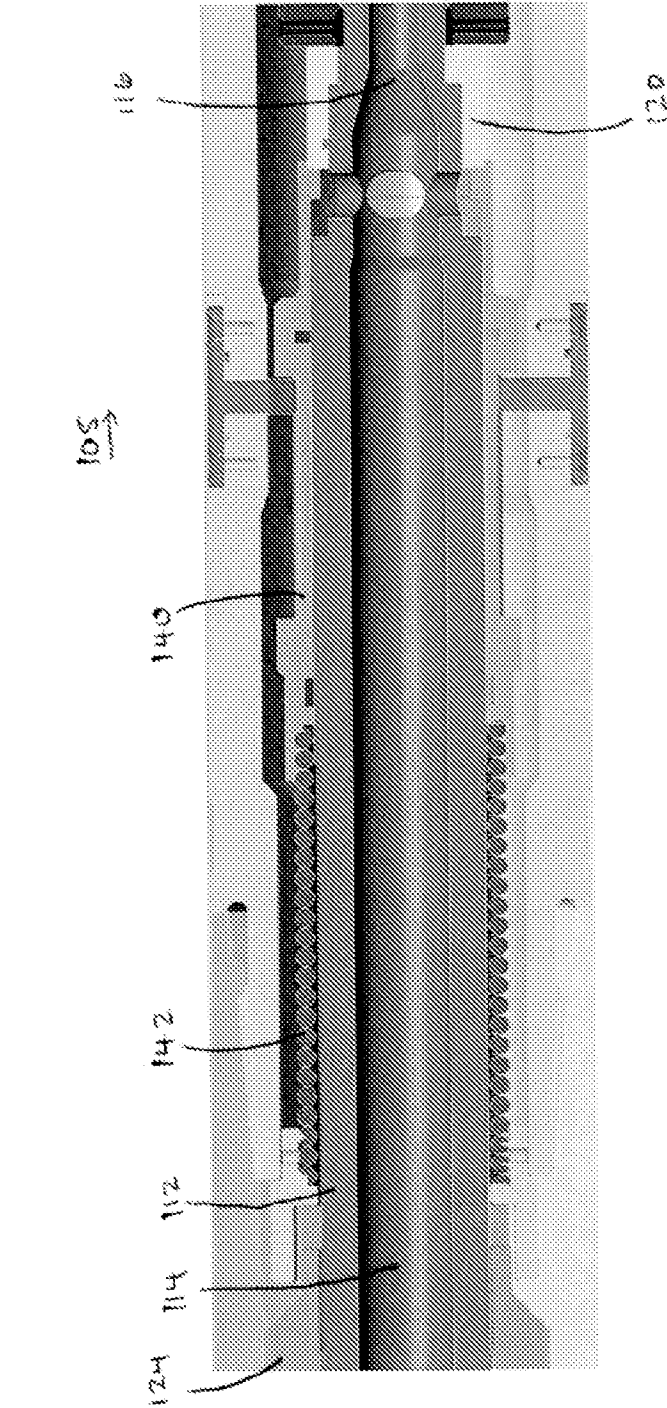


FIGURE 3

100

105

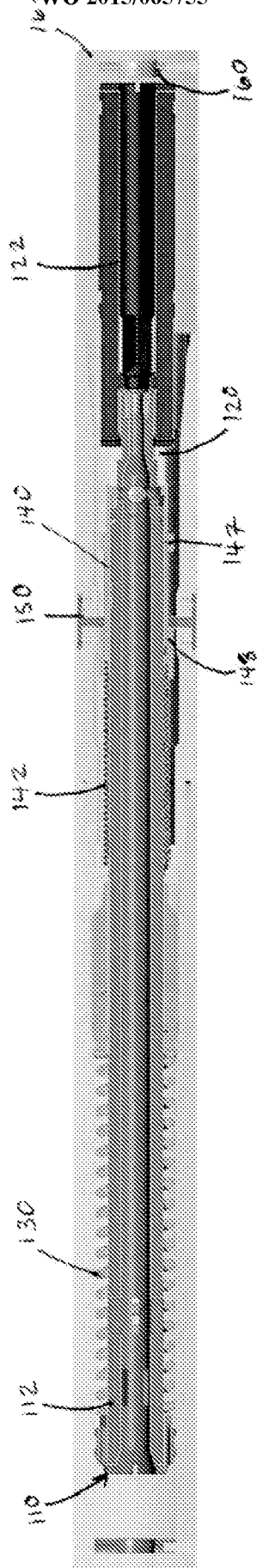


FIGURE 4

100

105

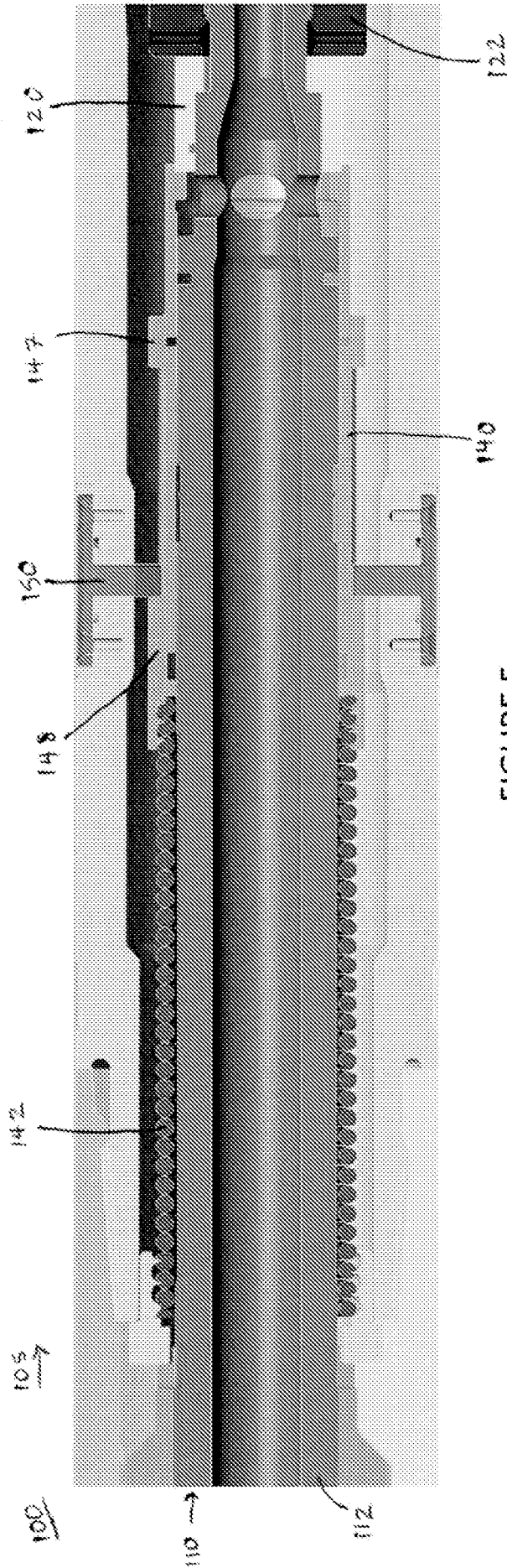


FIGURE 5

100

105

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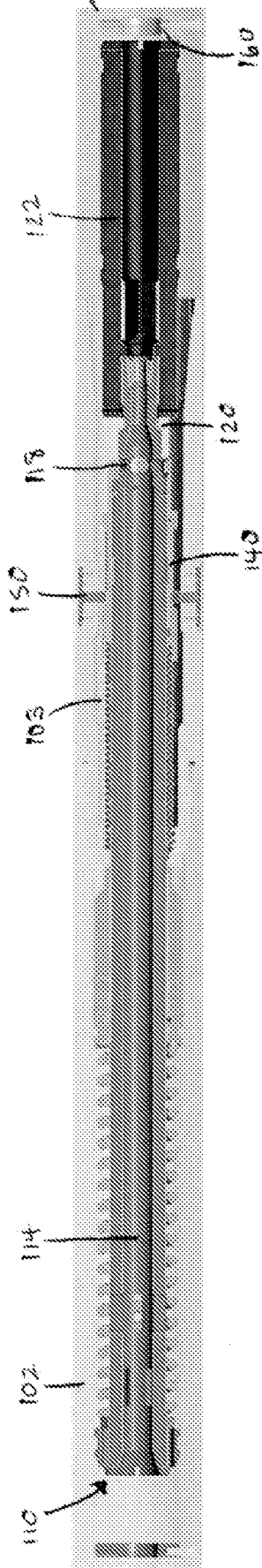


FIGURE 6

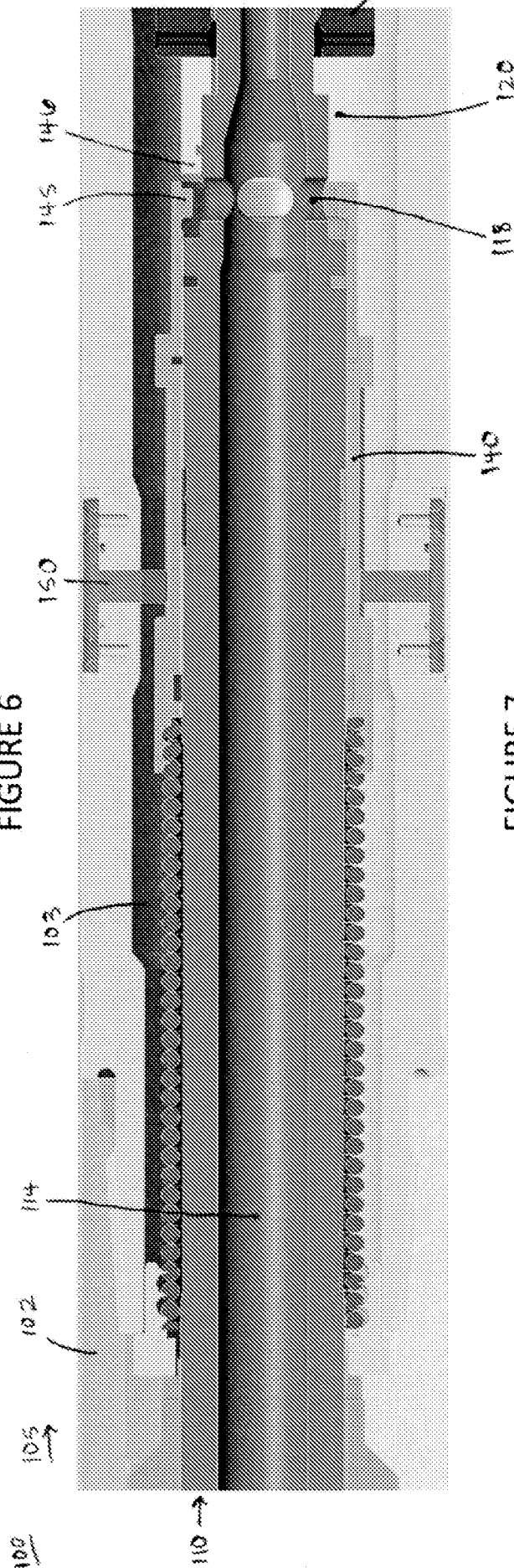
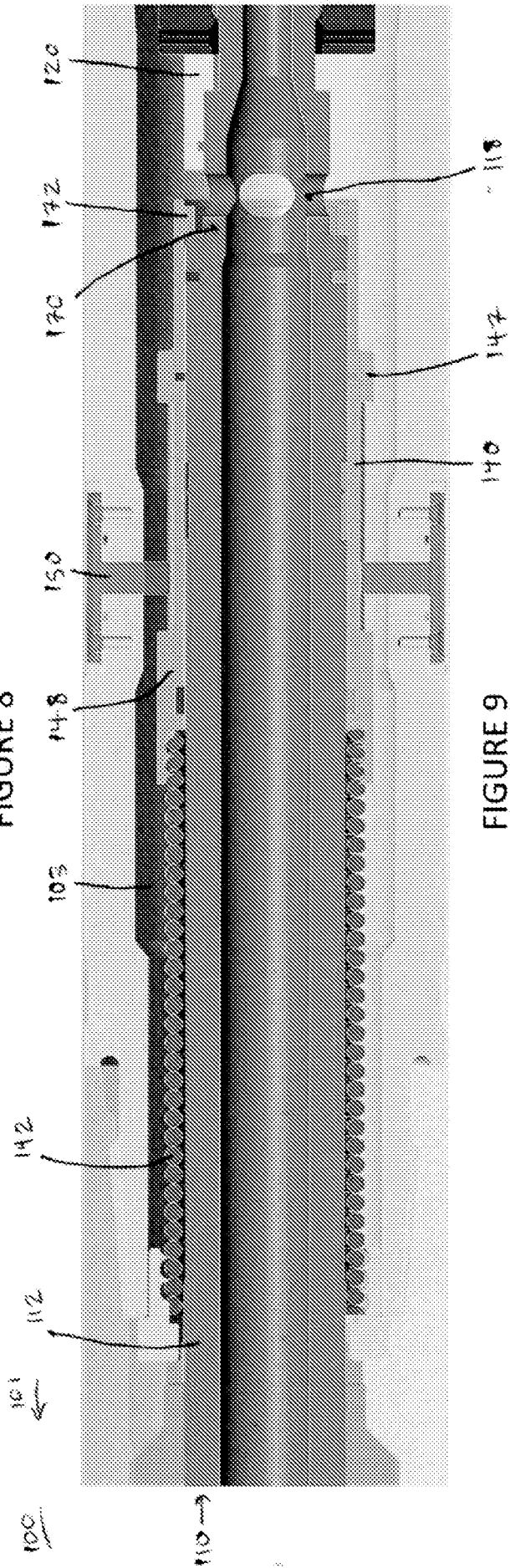
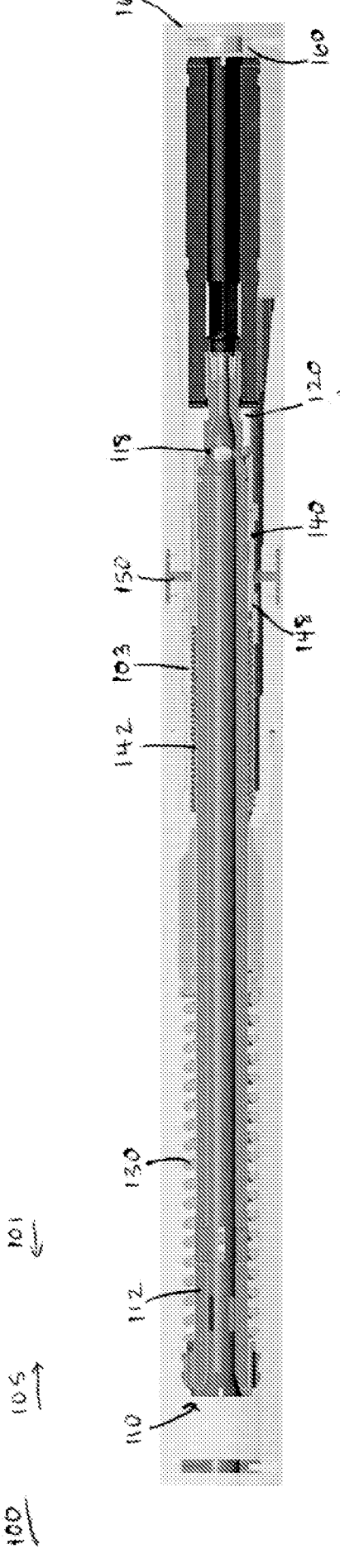


FIGURE 7



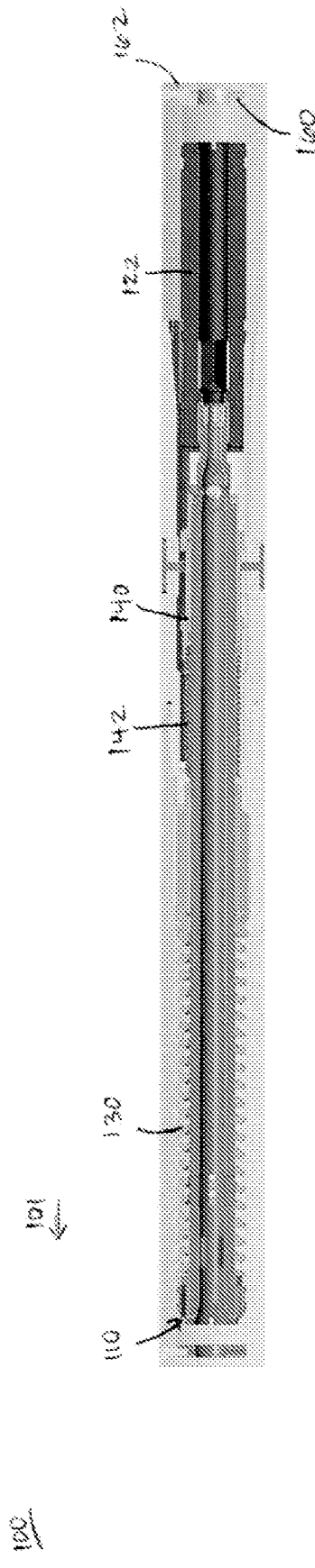


FIGURE 10

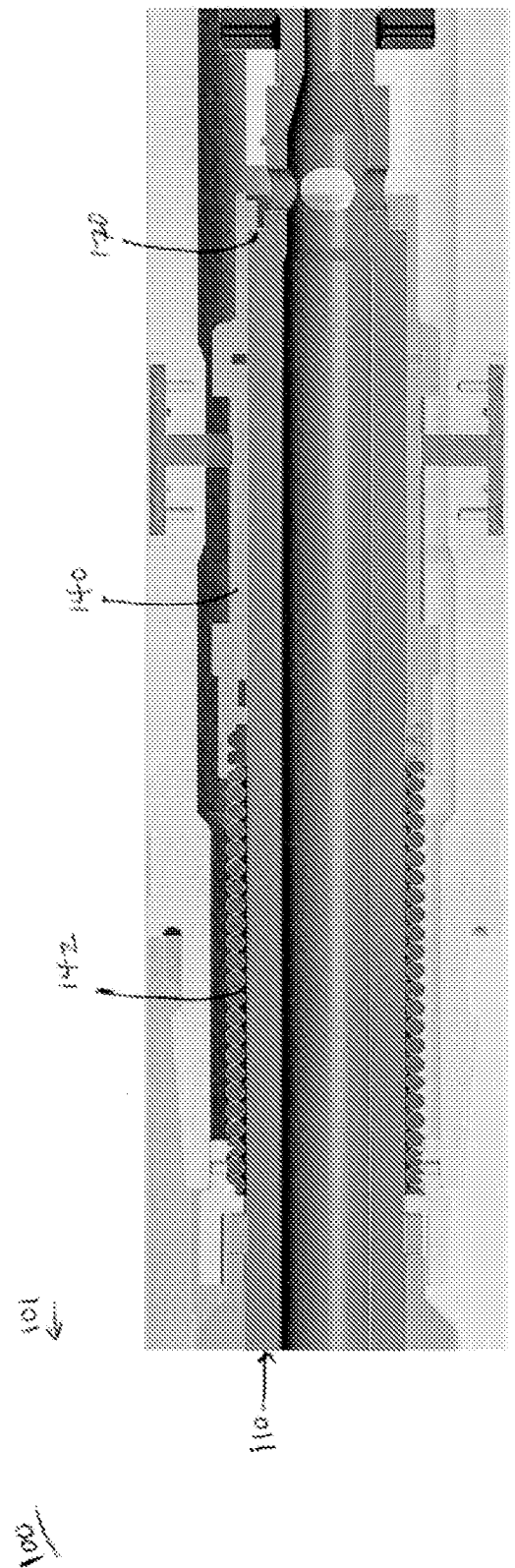
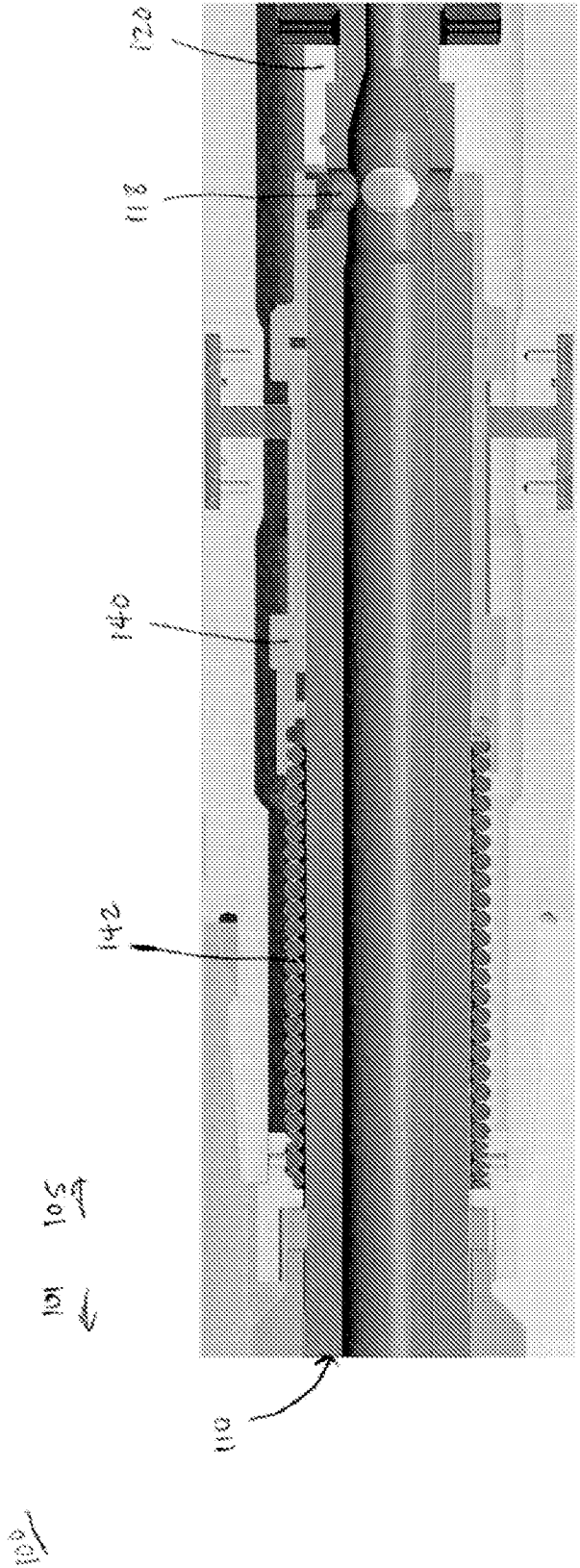
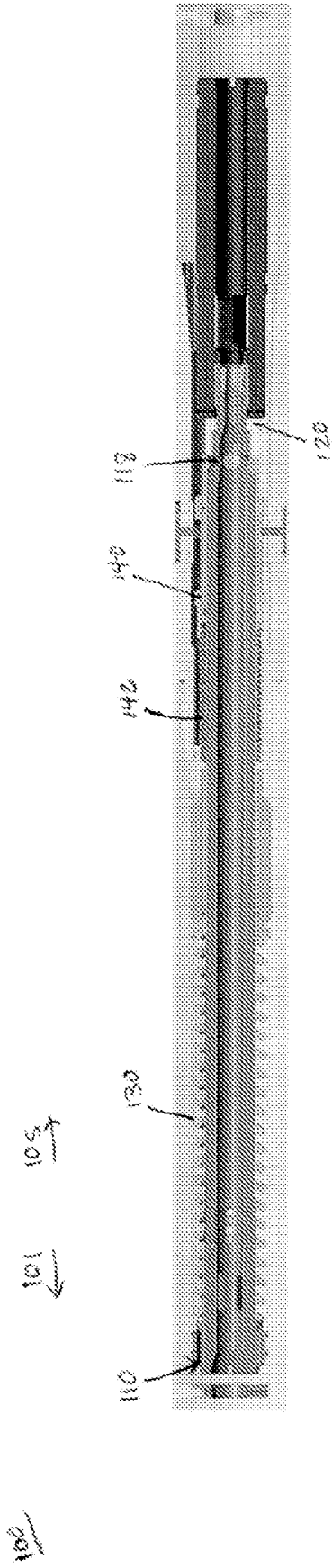
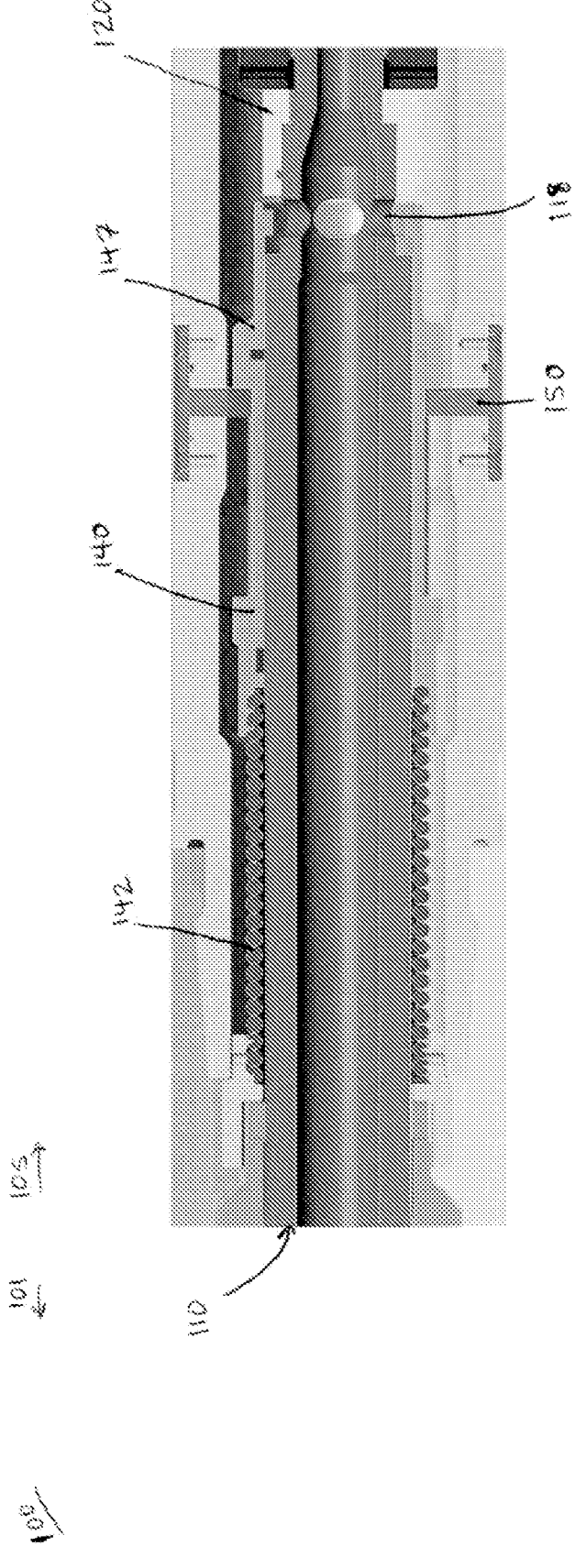
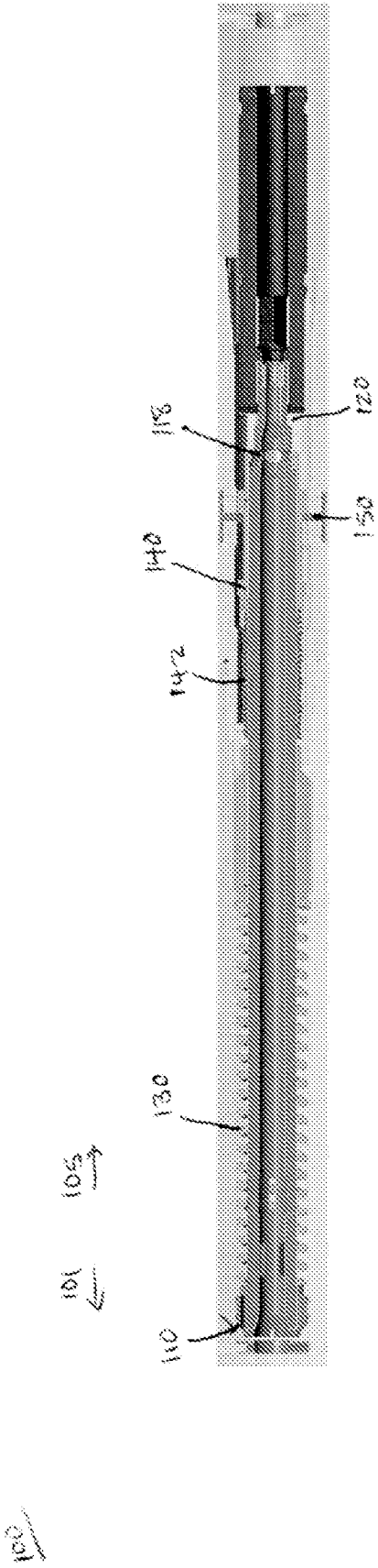


FIGURE 11





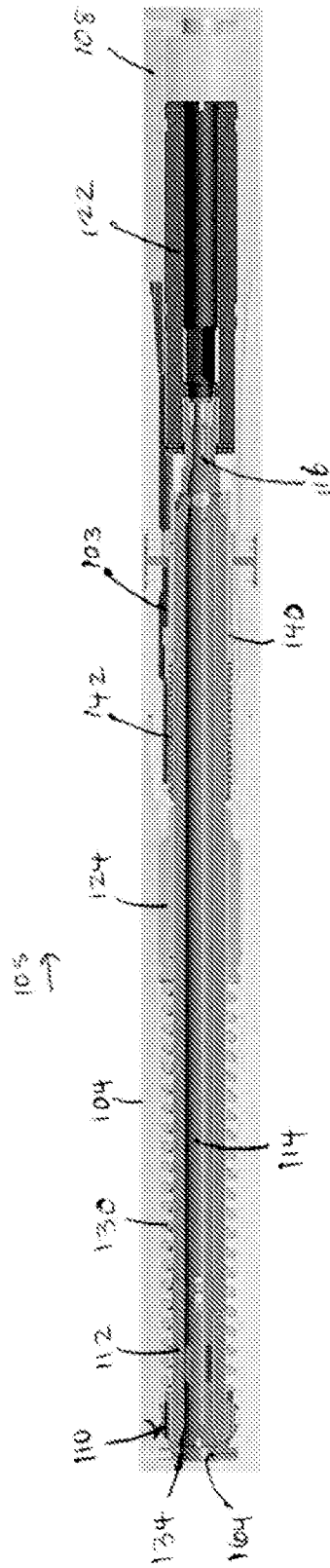


FIGURE 16

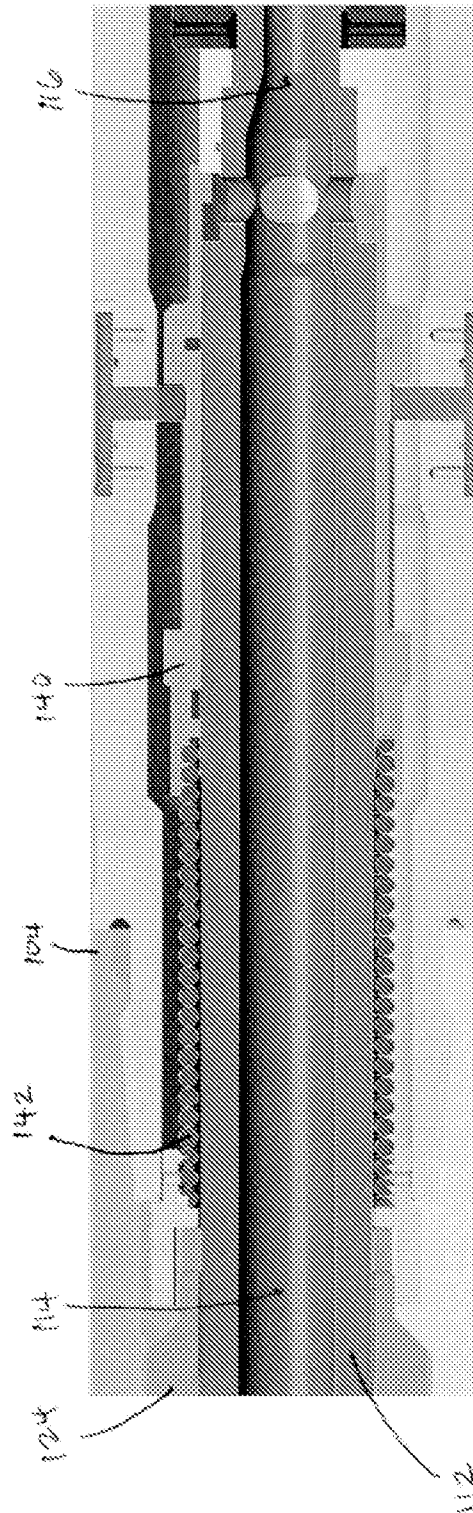


FIGURE 17

200
201
202

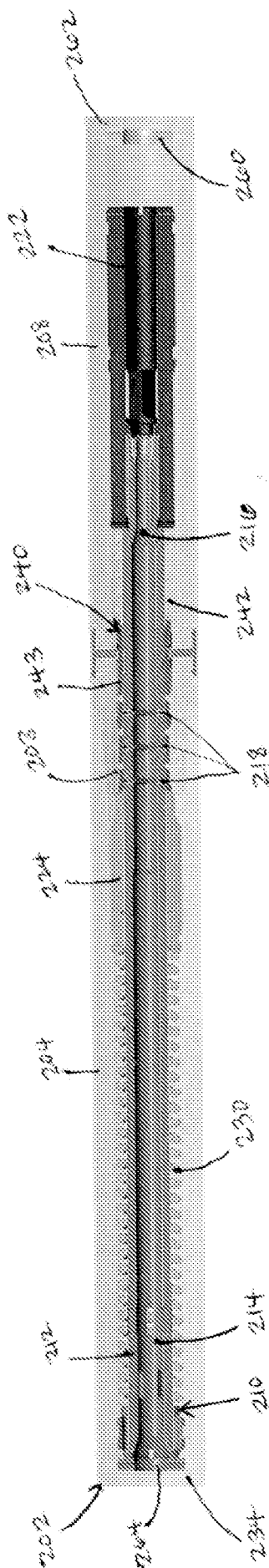


FIGURE 18

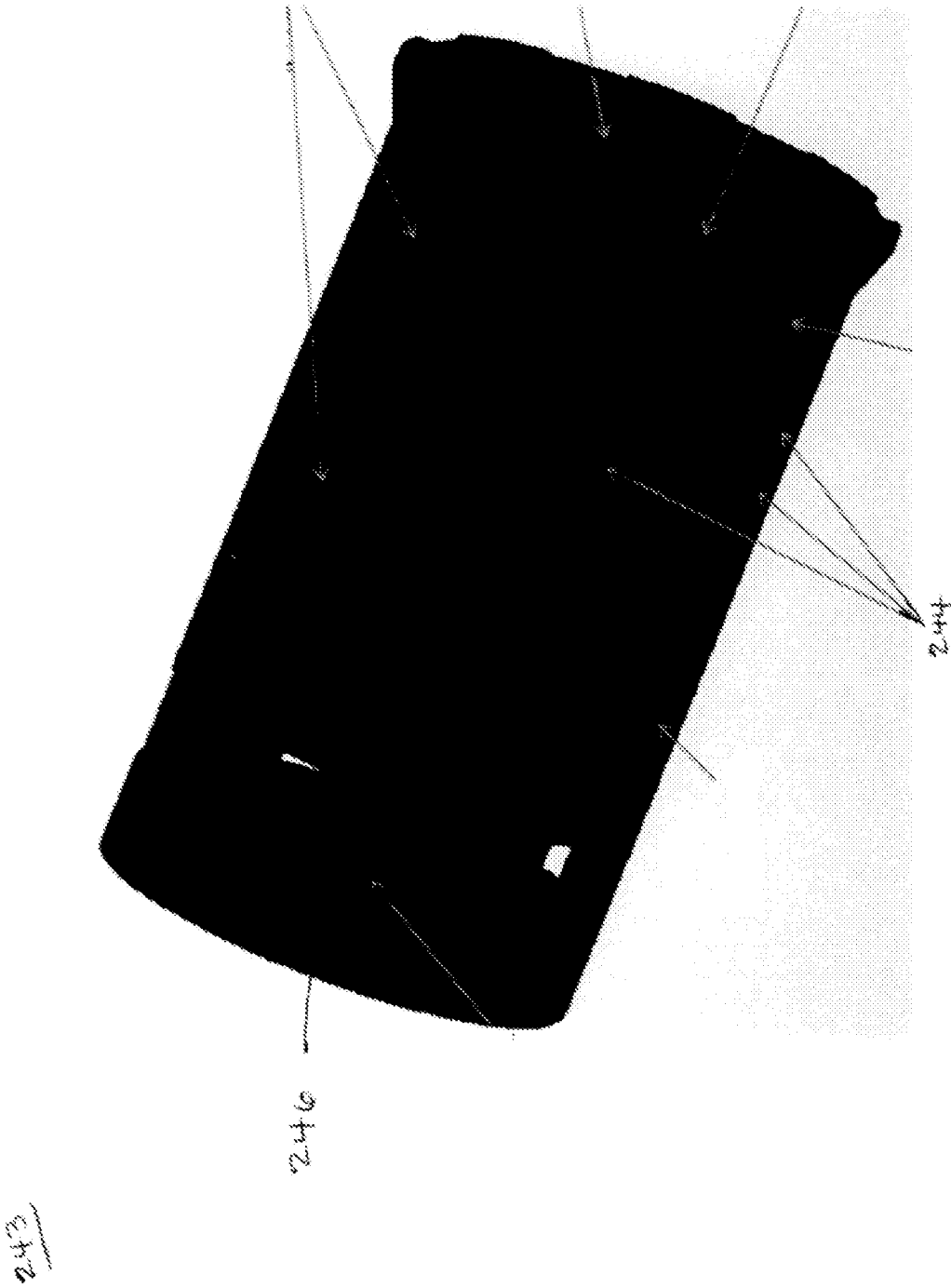


FIGURE 19

245

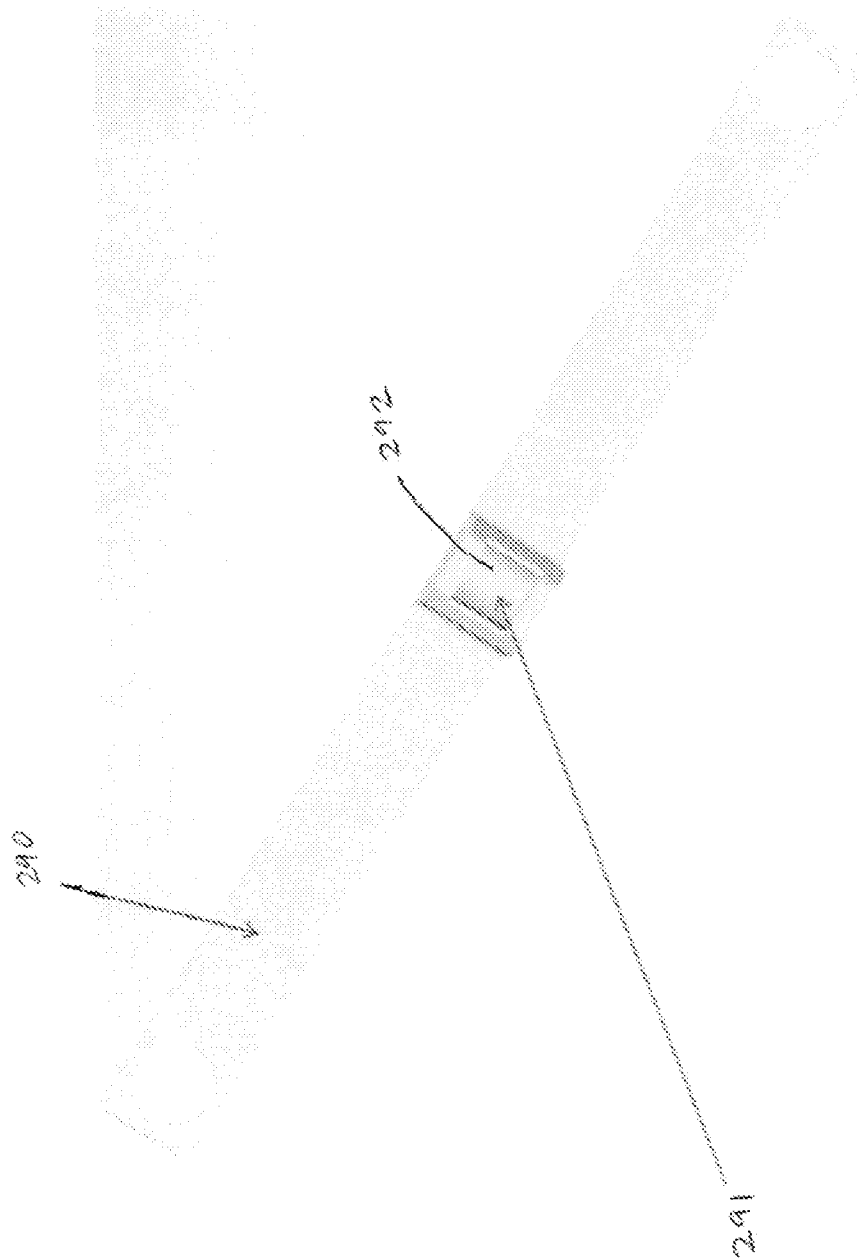


FIGURE 20

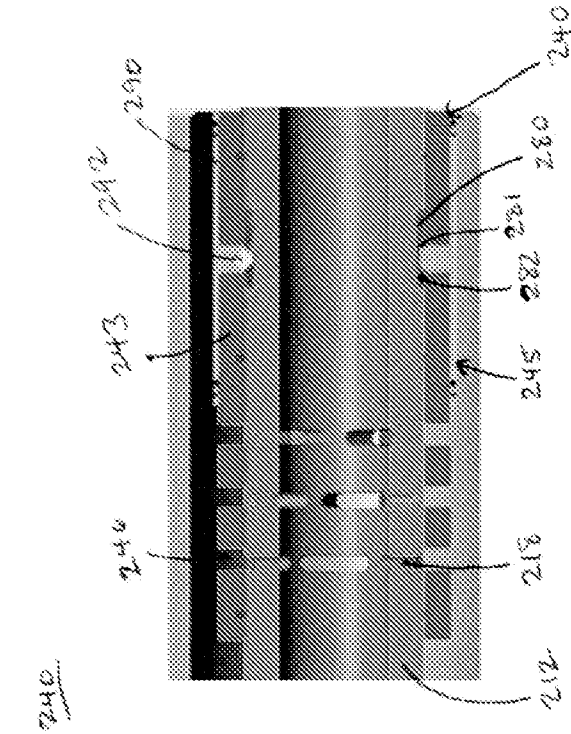


FIGURE 22

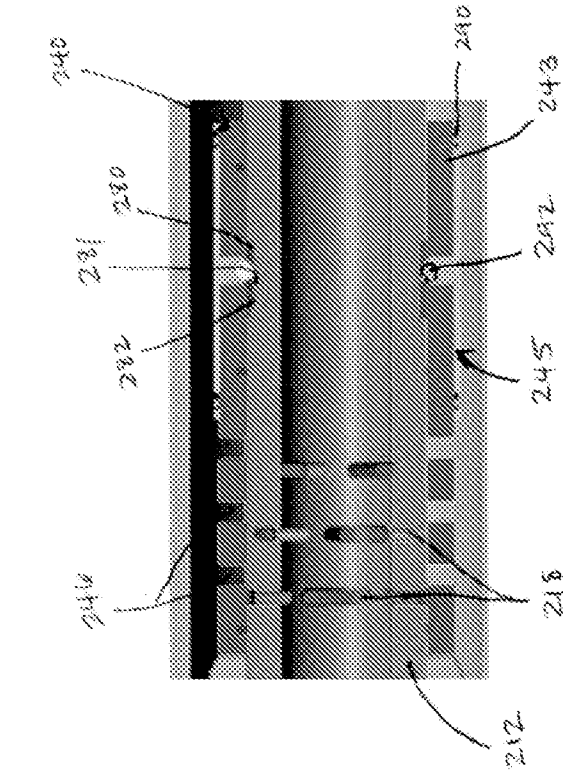


FIGURE 21

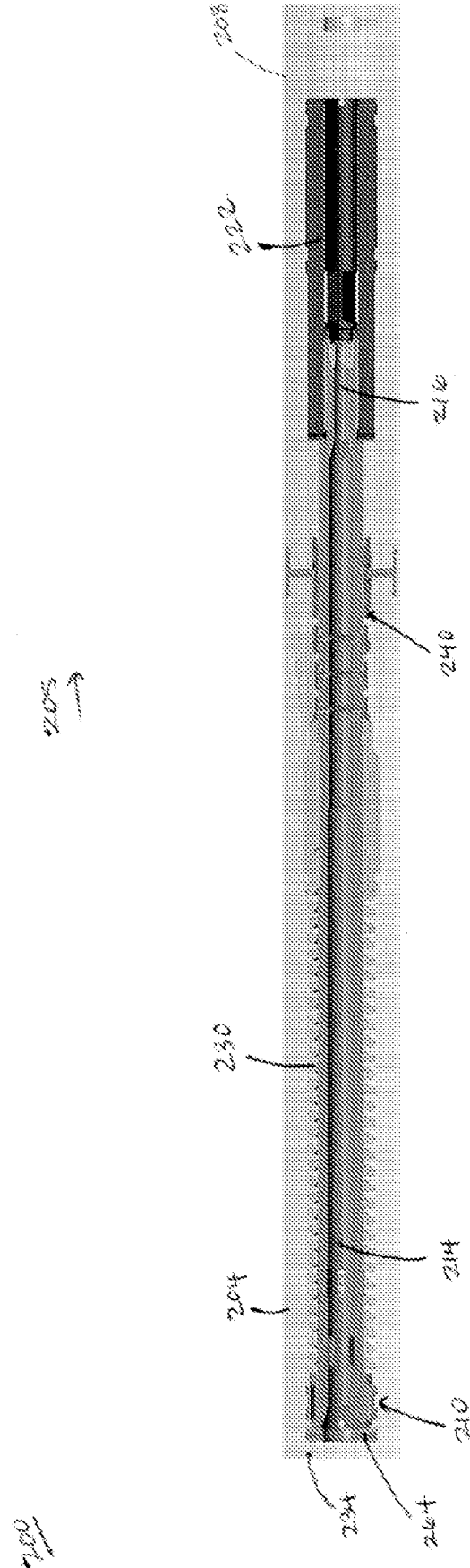


FIGURE 23

200

205 →

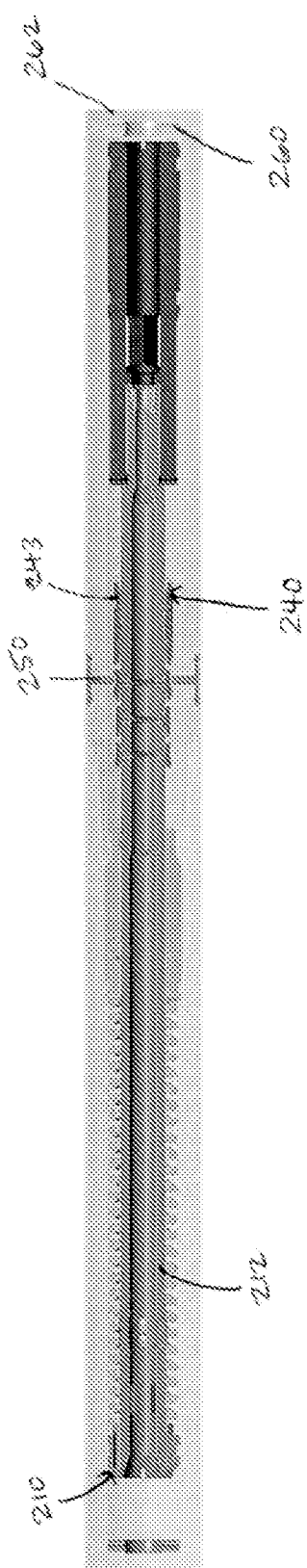


FIGURE 24

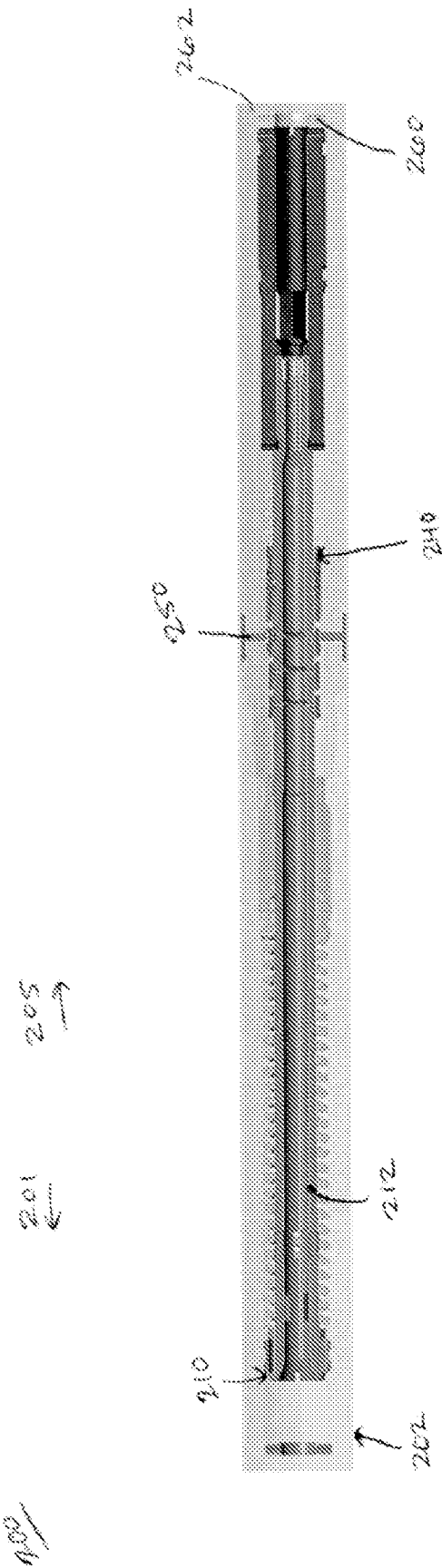


FIGURE 25

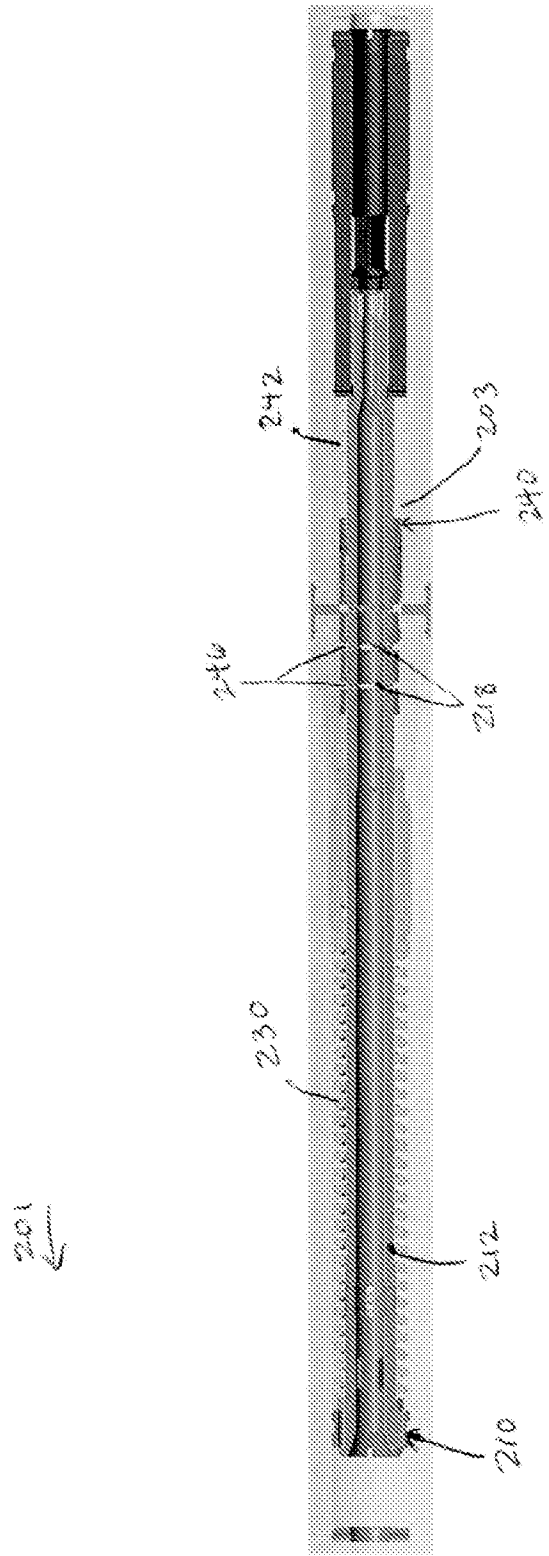


FIGURE 26

201

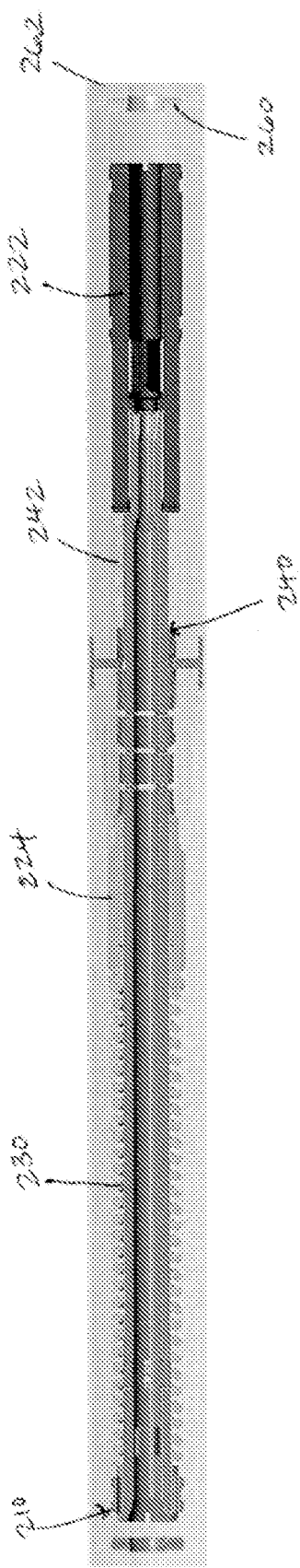
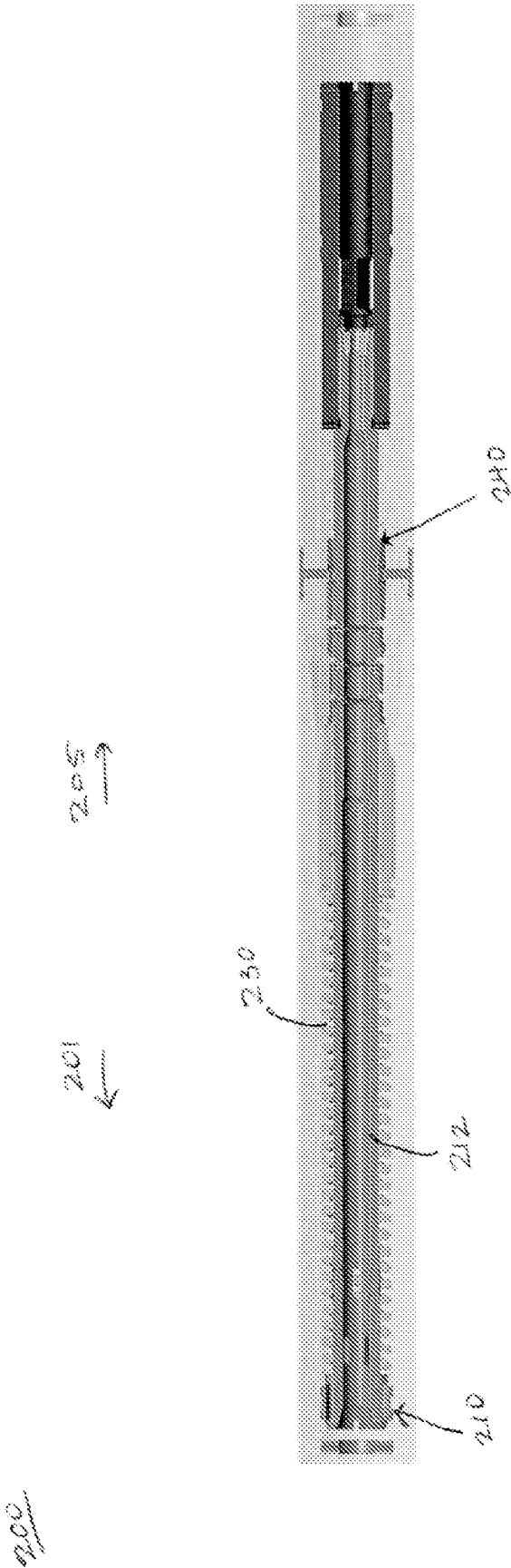


FIGURE 27



202

203

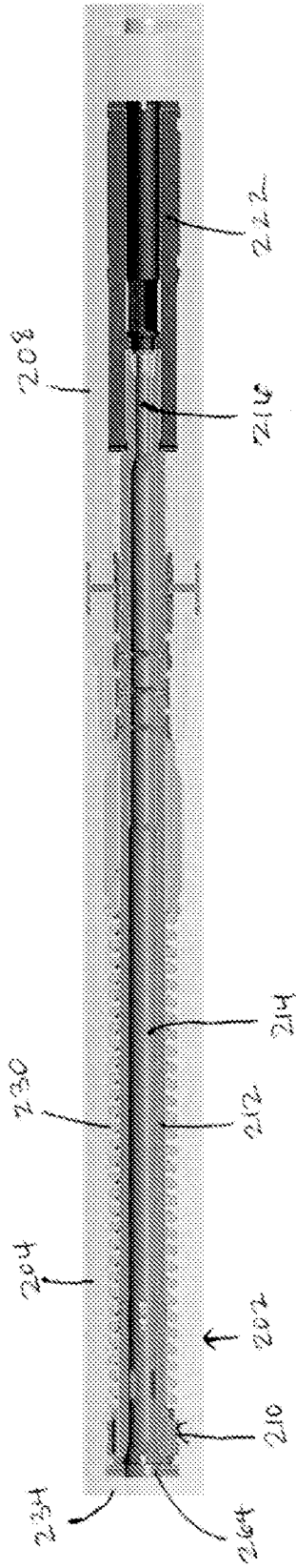


FIGURE 29

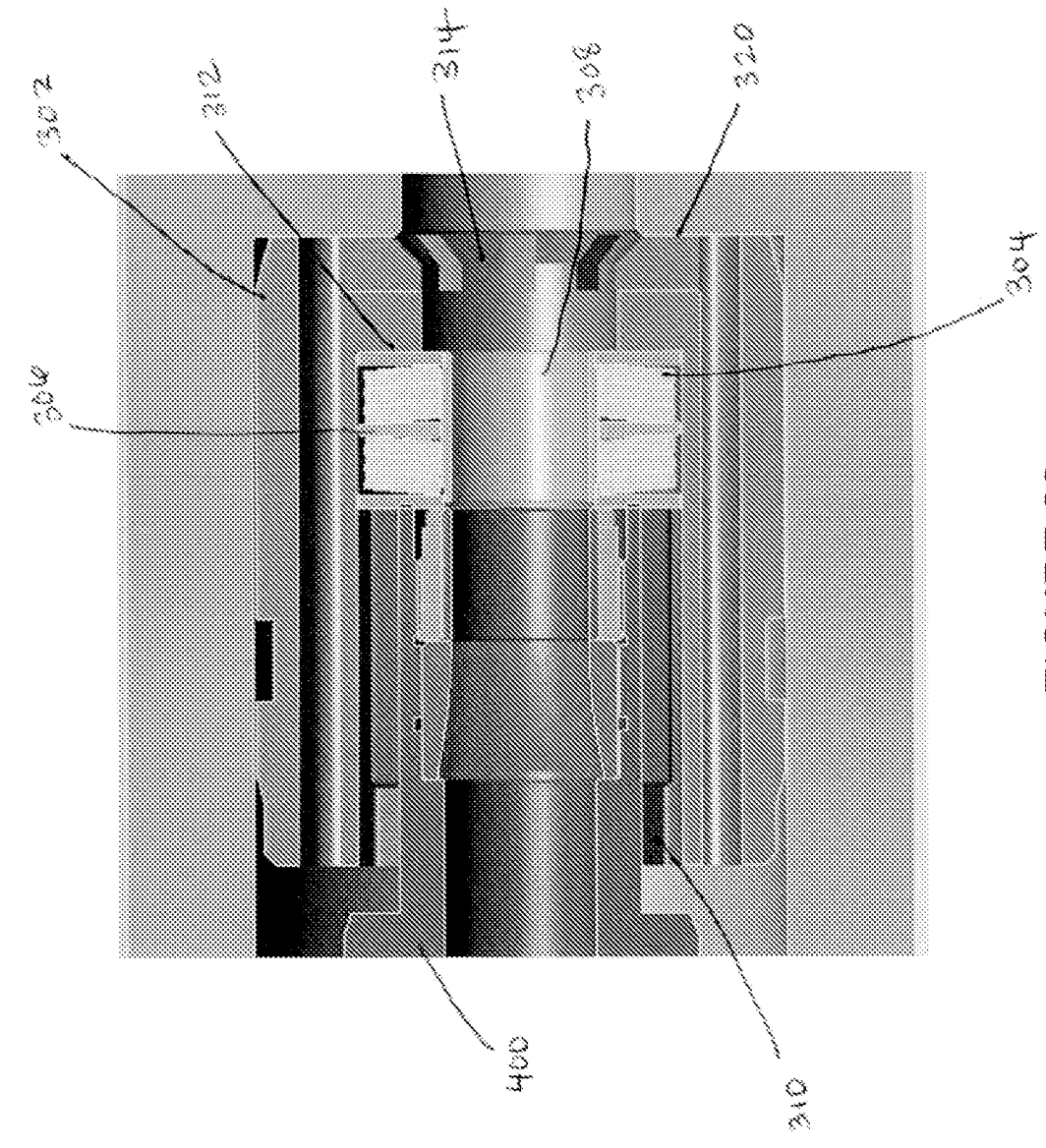


FIGURE 30

400

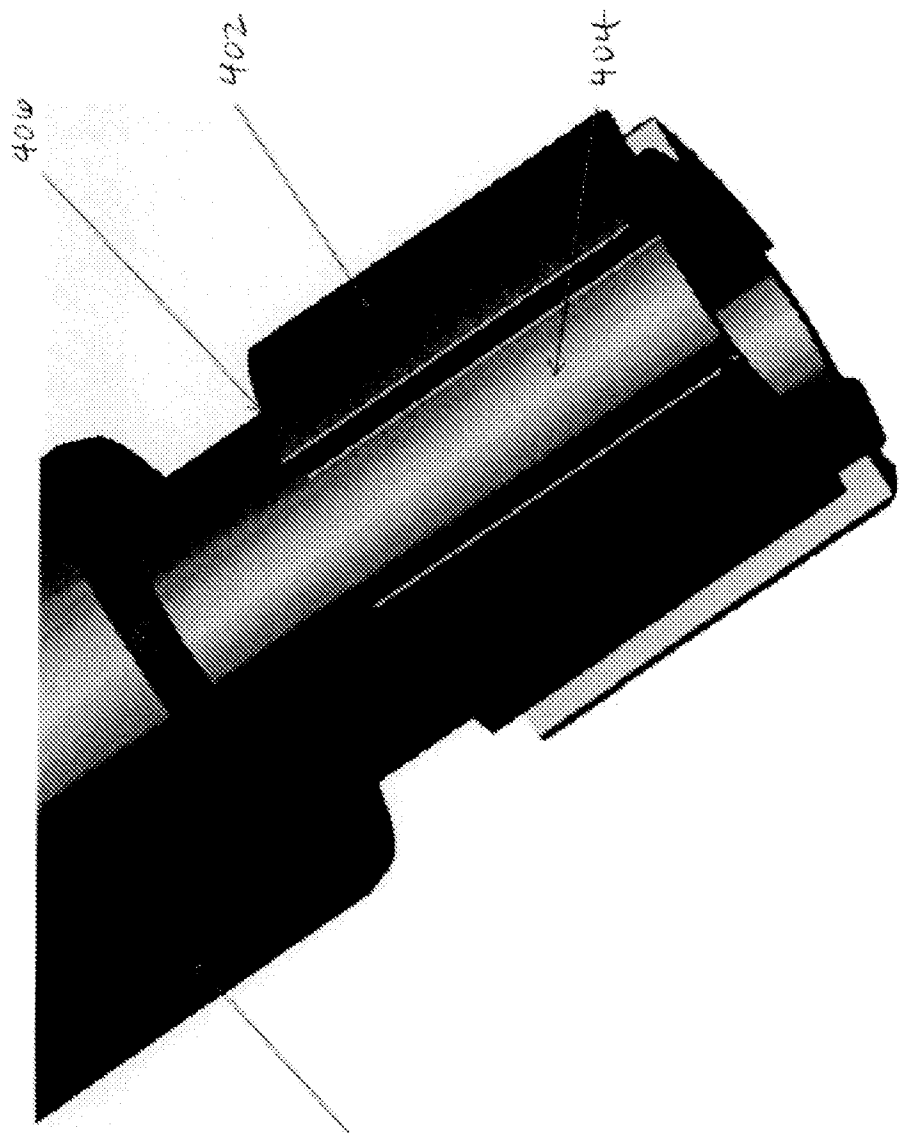


FIGURE 31

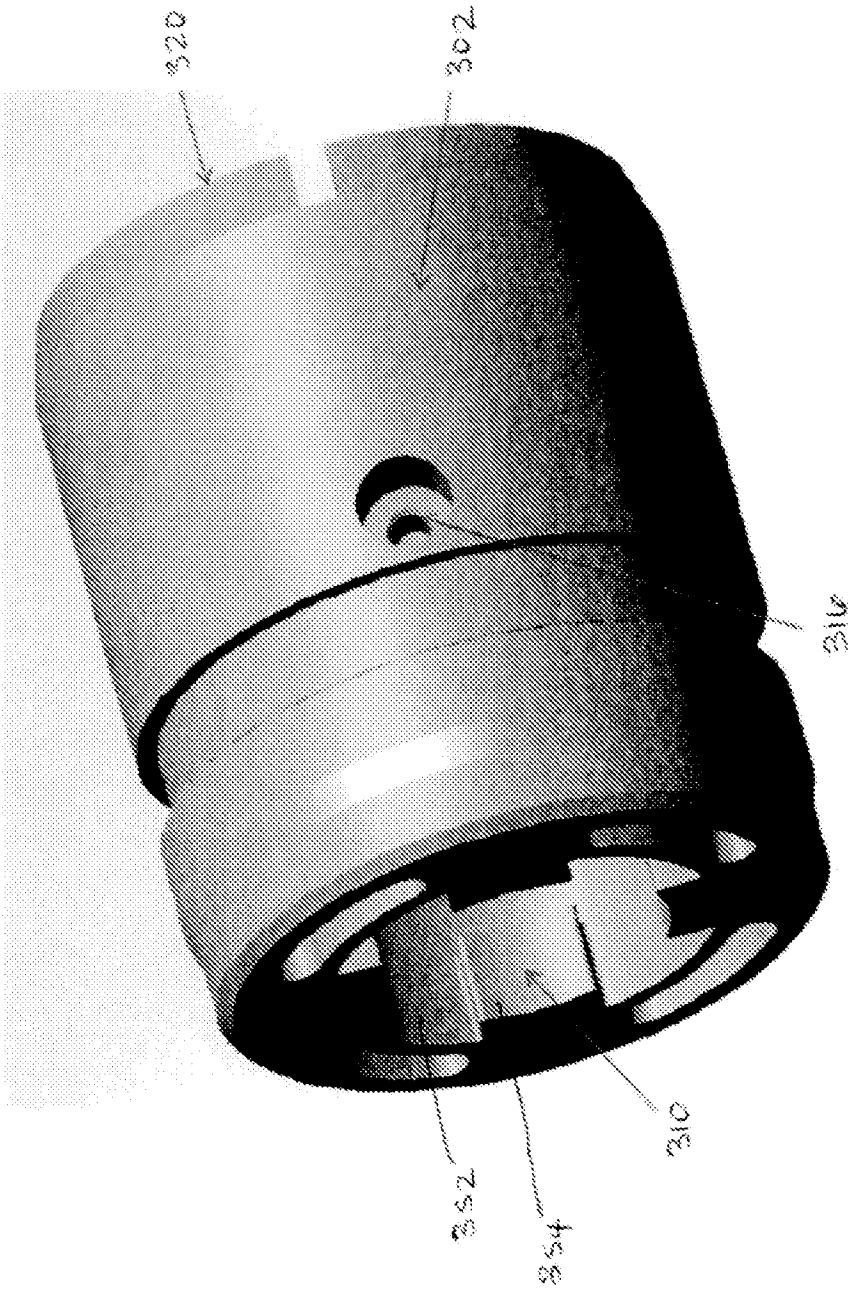


FIGURE 32

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/061475**A. CLASSIFICATION OF SUBJECT MATTER****E21B 7/24(2006.01)i, E21B 28/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 7/24; E21B 7/02; E21B 31/113; E21B 4/00; E21B 43/00; E21B 28/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: vibration, piston subassembly, valve mechanism, latching valve, impact cap, spring

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005-0241842 A1 (MARSH, BRENT) 03 November 2005	19-20
A	See paragraphs [0077],[0083],[0102]-[0110] and figures 6A-6D.	1-18
Y	US 2006-0124292 A1 (VICTOR, BRUCE M.) 15 June 2006	19-20
	See paragraphs [0064]-[0065] and figure 7.	
A	US 2005-0230101 A1 (ZHENG et al.) 20 October 2005	1-20
	See paragraphs [0040]-[0053], claim 1, and figures 4A-4B.	
A	US 2010-0276204 A1 (CONNELL et al.) 04 November 2010	1-20
	See paragraphs [0023]-[0025] and figures 3-7.	
A	US 6152222 A (KYLINGSTAD, AGE) 28 November 2000	1-20
	See column 2, lines 22-64 and figures 1-3.	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

28 January 2015 (28.01.2015)

Date of mailing of the international search report

28 January 2015 (28.01.2015)

Name and mailing address of the ISA/KR

International Application Division
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Republic of Korea

Facsimile No. ++82 42 472 3473

Authorized officer

PARK, Tae Wook

Telephone No. +82-42-481-3405



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/061475

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005-0241842 A1	03/11/2005	AT 453036 T CA 2564935 A1 DE 602004024832 D1 EP 1756389 A1 EP 1756389 B1 MX PA06012478 A NO 20065513 A US 6986394 B2 WO 2005-111366 A1	15/01/2010 24/11/2005 04/02/2010 28/02/2007 23/12/2009 17/08/2007 29/01/2007 17/01/2006 24/11/2005
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